MILTON KEYNES HEAT NETWORK PROJECT

Phase 3 Final Report

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Table of Contents

Executive Summary

This Report summarises the third phase of work completed by Ameresco on the Milton Keynes Heat Network Project outlining our approach, findings and recommendations.

Thameswey Central Milton Keynes (TCMK) owns and operates an Energy Centre in Central Milton Keynes, originally energised in 2006 and currently have 17 main connections on the network. This energy centre, located on Avebury Boulevard, is comprised of two natural gas CHP units and an additional 10MWth boiler for top up capacity with a total electrical output of 6.1 MWe (restricted to maximum of 5.0 MWe) and a total heat output of 16.3MWth. The additional 10 MWth boiler is also to cover output in periods of CHP maintenance.

The existing equipment is currently under-utilised, with average and maximum demands significantly lower than the installed capacity of the system. This indicates that there is significant room for expansion in the currently installed network, which has been considered for usage prior to requiring additional thermal or electrical generation equipment. See below for an outline of the energy network as it is currently installed.

The previously issued second phase of the project analysed possible areas to extend the existing Thameswey operated District Heat Network, and identified the most favourable building loads to connect, and network routing. The option of connecting the Milton Keynes Hospital to the town centre scheme was discounted based on piping cost, and a separate local scheme was recommended for both areas.

Modelling found high returns on investment for the expansion of the heat network, particularly since there is significant unused capacity in the existing energy centre, and identified the most favourable areas for expansion of the scheme.

Phase three approach

This phase considers a business case around the lead option, a specific pipe routing to 29 new loads in the town centre, which include some yet to be constructed developments. Further stakeholder engagement has been used to update the heat and power loadings and profiles. Techno-economic modelling has been carried out in EnergyPro for each of these connections, with the findings further analysed including cashflow, IRR and NPV in a separate spreadsheet model.

The scheme development is modelled to imitate a ‘real world’ development, with different piping spines and building connections being added in a progressive manner. A new energy centre is required, of similar size to the existing energy centre, midway through the expansion. A detailed design and capital costing has been carried out for these elements of the scheme, including an implementation plan.

We have included a range of tariffs to attract additional connections, and considered the effect of rolling the scheme out more rapidly than currently planned. We have analysed the effect of adverse scenarios such as reduced load connections, increased capital cost, varying energy rates, among others, and prepared a risk register.

The review included options for governance structures and Heads of Terms associated with the development of the scheme.

Proposed scheme summary

The analysis identified that the expansion of the heating network would take approximately 10 years until the spare capacity of the existing energy centre is used, based on the current build out business case.

Hence, developing the scheme in two stages is recommended, with potentially different governance structures. The first stage is the expansion of the heating distribution network, using the spare capacity of the existing energy centre, but making provision in the piping for a future additional energy centre. The second stage is the construction of the second energy centre, and further expansion of the scheme.

The modelled scheme encompasses the addition of 29 buildings, indicated above, with the red line and shaded buildings indicating the current pipework infrastructure and connected buildings. The blue, green, and purple lines indicate the proposed new spine pipework, with the green square indicating the current energy centre location. The location of the new energy centre is flexible from an engineering perspective, with the possibly of locating adjacent to the existing, or anywhere along the blue spine. Installed pipework should be large enough to allow this flexibility.

Economic summary

The economic analysis has considered both stages separately and combined, over a 25 and 40 year period.

The table below shows the NPV for the two distinct stages of the project, over a 40 year period, for a given Discount Rate. The Discount Rate will be affected by the choice of governance structure, as each commercial structure has access to funding at different rates.

Discount Rate	**Extension to Existing** *40 Year NPV*	**New EC & further connections** *40 Year NPV*
Baseline (3%)	£30,234,764	£29,273,653
3%	£42,522,943	£46,310,152
4%	£33,788,077	£34,138,028

5%	£30,234,764	£29,273,653
5%	£27,122,540	£25,060,982
6%	£21,983,799	£18,216,046
7%	£17,981,571	£12,994,594
8%	£14,832,922	£8,963,976
9%	£12,331,141	£5,814,153
10%	£10,324,004	£3,321,131
11%	£8,698,523	£1,321,732

40 Year NPV of separate stages

The above table shows the NPV for the two distinct stages of the project, over a 40 year period, for a given discount rate. The discount rate will be affected by the choice of governance structure, as each commercial structure has access to funding at different rates.

The extension to existing, is considering the value of only the addition of addition load including spine pipework and building integration, until spare capacity in the current thermal network is exhausted. The second column above is considering the additional value on top of this including building a new energy centre to operate thermally in parallel and any remaining pipework. A cash transfer from the second stage has been allocated to the current energy centre cash flow to acknowledge the value of the shared infrastructure built out under the first stage.

IRR	**Entire Additional Scheme**	**Extension Only**	**New Energy Centre & Further Connections Only**
25 Year	19%	27%	11%
40 Year	20%	27%	12%

IRR for entire additional scheme and separate stages individually

See above for the 25 year and 40 year project Internal Rates of Return for the whole scheme as well as being broken down into the extension only and new Energy Centre and further connections. The IRRs for the extension to existing are significantly higher due to the already sunk capital of the currently installed energy centre, giving small additional CAPEX only for installing additional pipework, as well as limited additional energy centre maintenance requirements to service additional buildings.

Tariff Structures

The business model proposed in this study aims to widen the customer base by offering a range of tariffs suited to the customer's needs. Three tariff structures have been set up and allocated to each customer, such that there is an equal weighting of each tariff, to provide a realistic rollout scenario.

Tariff 1 is a loose representation of the existing Thameswey model which incentivises customers joining the scheme by replacing their ageing boiler infrastructure completely. This incentive mechanism is that the district network will be the sole heat supply for the building which means that on-site boilers are not required to be replaced at end of life, offsetting a large capital expense.

This tariff rate is also suitable for new builds which are obliged by local regulations to connect to the network unless technically or economically unfeasible. Thameswey uses a high connection charge to recover the cost of integrating the individual buildings into the network, however this study has not considered the use of this revenue stream as varying tariffs was considered a better option from a rollout perspective.

Tariff 2 provides a reduced rate incentive for those customers that don't require boiler replacements immediately at the time of connection, and therefore require other incentives to join prior to this timeframe. They will still receive the benefit of not being required to replace boilers at their end-of-life, however will also receive reduced rates for Heat, Electricity and Standing Charges.

Tariff 3 uses heavily discounted heat rates and is useful for expanding reach of the network to those customers that would not otherwise join.

Resulting tariffs for heat and electricity are shown below. These are weighted based on connection size to give a more balanced view of rates from the customer's perspective.

	Heat	**Electricity**
	*pence/kWh gas equiv**	*pence/kWhe*
Tariff 1	4.3	10.6
Tariff 2	2.4	10.9
Tariff 3	2.2	11.1

Environmental impact summary

Carbon benefit has been modelled over a 40-year period using the natural gas CHP solution. Given a de-carbonising electricity grid in line with 2015 projections by the Department of Energy and Climate Change (DECC), natural gas CHP is unlikely to maintain an overall carbon benefit past 2027.

A faster (relatively immediate) rollout speed, represented as 1000% in the shows a markedly better savings initially from higher output earlier, while the carbon intensity of the grid remains high. The sharp decline in both is due to the build of the new energy centre and bringing on new electrical loads, where full waste heat usage is not possible. Overall efficiency decreases during this time, and under the standard rollout schedule scenario, the project fails to return to a positive carbon benefit after this time due to the falling emissions factor. This suggests that from a carbon reduction perspective, that unless the scheme can be rolled out quickly and the new energy centre built almost immediately, a new natural gas CHP-based energy centre will not be an efficient solution.

	Year of neutral benefit *(zero point)*	**Carbon savings up to that year** *tCO2e*
50%	2034	6,660
100%	2027	8,059
1000%	2028	18,898

At the time where natural gas fired CHP can no longer deliver low enough carbon intensity energy to compete with the grid, lower carbon intensity sources of heat and electricity can be fed into the existing infrastructure to bolster the carbon reduction potential of the system.

Possible options that could be considered at the point of future investment are discussed in the body of the report and include:

- Heat pumps (industrial waste heat, ground, water source)
- Biomass/Gasification
- Carbon capture and storage

Social impact summary

This scheme aligns effectively with the following social criteria relevant to the local authority's objectives and drivers.

Supportive business environment
An expanded energy network will provide a larger number of local businesses the opportunity to access green, reliable, low maintenance heat for reasonable prices, lowering operating costs and therefore promoting the development of local business.

Energy poverty
Delivering reliable low-cost heat to residential properties lowers energy costs for consumers and can potentially support energy poverty reduction goals. Possible application of specifically discounted rates for low-income consumers.

Local employment
Major construction projects such as this will engage local businesses and simulate the local economy, providing jobs for local residents throughout the lengthy project period.

Green and resilient infrastructure
Developing sustainable infrastructure that is adaptable to suit future changes ensures that the financial and carbon viability of the network continues long into the future.

Carbon reduction
Delivering low-carbon heat supports not only the reduction targets of council facilities, but also promotes the up-take of low carbon energy sources throughout the community. It provides a platform for heat distribution that is flexible enough to allow for integration of future technologies.

Recommendations and next steps

Based on the findings from all phases, the following recommendations can be made.

1. **Provide incentives for uptake of district energy quickly.** There are still a vast number of significant heat and energy loads located in central Milton Keynes that are not yet connected to a thermal network, presenting a strong business case for significantly expanding the Milton Keynes heat network. The current operator's planned connection schedule is relatively slow and the requirement for an expansion of generation capacity would not be reached until approximately 2026. Any council incentives provided to local businesses to connect to a low-carbon energy network would reduce the rollout timeframes, benefiting all parties.
2. **Oversize all new heat network infrastructure.** Any new spine pipework infrastructure investments by the current operator should be oversized to cater for additional loads of a second energy centre as well as an allowance for further extension of the Milton Keynes heat network. The increase in capital associated with a larger pipe size is minimal in context of the overall works

of an energy network. Rather than tapering the spine pipework towards the end of the network, spine pipework should be of a large size throughout to allow increased flexibility for energy centre location. This is especially important considering the opportunity for biomass generation which due to factors discussed in this report would likely be positioned just outside of the central city.

3. **Compensate current operator to provide increased capacity in network.** As the current network reaches its installed capacity after approximately 12 additional connections, an increase in total installed pipe size would not support the business case of the current operator, so a financial incentive would be required to ensure the rollout of a network that will cater to future opportunities. Methods of this transfer are discussed in the report body.
4. **Switch to low-carbon heat sources if not building new energy centre soon.** Based on current forecasts for grid de-carbonisation, on the current rollout schedule, the additional energy centre to be installed in 2026/2027 would be unlikely to provide a significant or even positive carbon impact with standard natural gas CHP. An investment in high-carbon infrastructure would be unlikely to be supported from a public-sector perspective, so at this time a report into the most effective low-carbon heat and power generation should be commissioned. This will ensure the long-term future of the network.
5. **Roll out connections as quickly as possible by offering incentive tariffs.** It would be of significant benefit to long-term project value both from an economic and environmental perspective for rollout speed to be significantly increased. Uses of incentive techniques through zero or low connection fees, as well as discounted tariffs will encourage earlier uptake from potential customers. Offers for tariff rates will need to be carefully considered through discussions and surveys of these potential customers.
6. **Choose a commercial structure which caters for a low cost of finance.** Financing rate presents the greatest effect on the value of the project, so funding options at the time of capital expenditure will partly determine the most effective commercial structure for the venture.
7. **Explore farther afield energy-dense thermal network opportunities.** Phase two report concluded that there is the possibility of setting up the Hospital and Woughton area as a separate energy network as it is uneconomic to connect this area to the central Milton Keynes network. This could be constructed in parallel and could provide economic and environmental benefits.

Listing of Tables

Listing of Figures

1. Introduction

This report has been commissioned by Milton Keynes Council to investigate opportunities to expand the district heating network in the Milton Keynes area.

1.1. District Heating

There are significant benefits of providing heat and power via distributed networks, generated locally in an efficient, reliable energy centre. A network of pipes supplies heat to individual buildings, eliminating the need for local boilers, and providing low-carbon electricity at the same time.

Benefits of district heating:

- Reduced cost energy for end users
- Reliable heating and power supply, centrally backed up with boilers and thermal storage
- Reduced end-user boiler room space requirements
- Carbon savings compared with grid supplied energy
- Investment opportunity, and local employment

1.2. Existing Milton Keynes Heat network

Thameswey Central Milton Keynes (TCMK) owns and operates an Energy Centre in Central Milton Keynes, originally energised in 2006 and currently have 17 main connections on the network, see Figure 1 for map of the network and Table 3 for further details of each connection. This energy centre, located on Avebury Boulevard, is comprised of two natural gas CHP units and an additional 10MWth boiler for top up capacity with a total electrical output of 6.1 MWe (restricted to maximum of 5.0 MWe) and a total heat output of 16.3MWth. The additional 10 MWth boiler is also to cover output in periods of CHP maintenance.

Figure 1 – Existing Thameswey heat network

Thameswey's Energy Centre, located on Avebury Boulevard, is comprised of two natural gas CHP units and an additional 10MWth boiler for top up capacity with a total electrical output of 6.4 MWe (restricted to maximum of 5.0 MWe) and a total heat output of 16.3MWth. The additional 10 MWth boiler is also to cover output in periods of CHP maintenance.

The existing equipment is currently underutilised, with average and maximum demands significantly lower than the installed capacity of the system. This indicates that there is significant room for expansion in the currently installed network before requiring additional thermal or electrical generation equipment.

1.3. Aims and objectives

Milton Keynes Council has a requirement for a detailed feasibility and project delivery study into the extension of the existing district heat network to supply areas in and around Central Milton Keynes. The project includes appraising a multi-partner model for heat transfer and supply.

This report sets out the findings of phase 3 of the study and covers more detailed analysis of buildings, a more robust round of techno economic modelling, continuing stakeholder engagement and the development of potential business models.

The overall objectives of the study are to:

Carry out a detailed engineering feasibility study appraising the options for extensions to the existing Milton Keynes City Centre heat and power networks.

Prepare an outline business case for the extension of the existing Milton Keynes City Centre CHP scheme.

These overall objectives will be achieved through the following sub-aims, to

- Select the most favourable solution(s) and carry out modelling to more accurately size the CHP plant and pipework
- Develop a measure of likelihood to connect and base future modelling on this
- Develop more detailed pipework routes to connect to existing heating plant rooms
- Develop a clear business model/structure around the lead option
- Develop a range of value propositions to offer to customers in order to attract connection
- Carry out sensitivity analysis around costs, prices and energy demands
- Carry out sensitivity around new buildings that may come online over the medium term
- Contact with potential customers to understand energy demands and ease of connection
- Develop detailed design and costing
- Develop an implementation plan and risk register
- Legal planning around setting up necessary company structures

2. Heat and Energy Mapping

Three phases of work have been undertaken, each becoming more detailed and increasingly focused leading to a single proposed scheme.

- **Phase 1** – developed a red line boundary for the project followed by a wide area analysis of building heat and power demands across the whole area
- **Phase 2** – included a more detailed analysis covering 150 buildings across a series of more focused clusters
- **Phase 3** – determined the major anchor buildings and a set of DH spines between these, followed by a detailed analysis of 29 key existing buildings and proposed developments

GIS techniques have been used to map heat and power loads for around 150 buildings across the wider Milton Keynes area. Techno economic analysis in each phase has been carried out using EnergyPro software. A detailed half hourly EnergyPro model of the existing DH scheme was developed to act as a base case throughout the project, including complex whole sales electricity market arrangements. Phases 1 and 2 modelled buildings in clusters to reach OPEX, NPV and CO_2 savings to compare cluster economics.

Phase 3 modelled 29 buildings/developments individually in a cumulative way based on a build-out timescale agreed with MKC and Thameswey. The project has therefore reached a single clear DH solution to extend and supplement the existing DH scheme. A range of possible business models have then been analysed to identify a way forward for the main stakeholders.

2.1. Phase 1 - Wide Area Heat and Power Analysis

Work began by establishing a red-line boundary for the study and identified seven building clusters as potential heat demand for the existing energy centre. An early conclusion was that the demand from only a few of the clusters would be sufficient to utilise all the available spare energy centre capacity.

Scope (Red Line boundary)

A red line boundary was determined at the beginning of the project as shown in Figure 2. The study includes the already built heat network and is bordered by key geographical barriers with the railway line on the West and the Grand Union Canal on the East. Central Milton Keynes is a relatively high density area but the redline includes Milton Keynes General Hospital, the Xscape ski slope and Milton Keynes Shopping Centres, all of which were key buildings investigated. The dotted line highlights two additional areas that were considered for any outlying heat load opportunities.

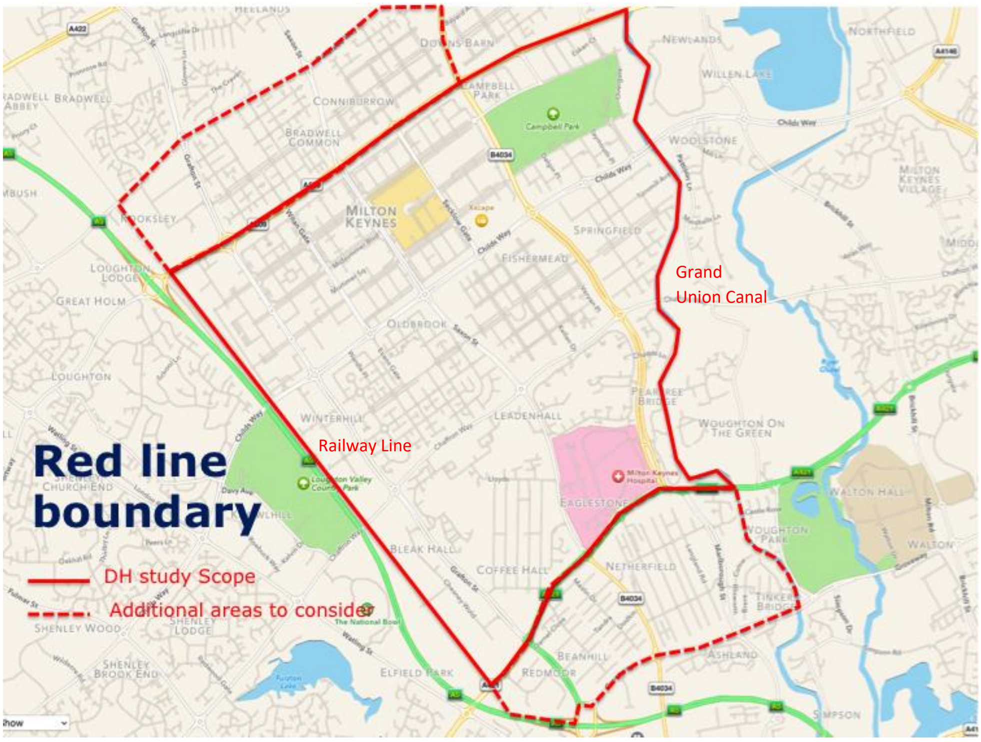


Figure 2 - Project Red-line scope and Further Potential areas

Initial cluster analysis

Central Milton Keynes has a numbered grid system and this was used to develop some initial clusters around major heat load areas. Earlier rounds of high level clustering indicated seven main potential heat network clusters that warrant further investigation as shown in the Phase 1 report. We have therefore carried out more detailed modelling on the seven most likely approaches.

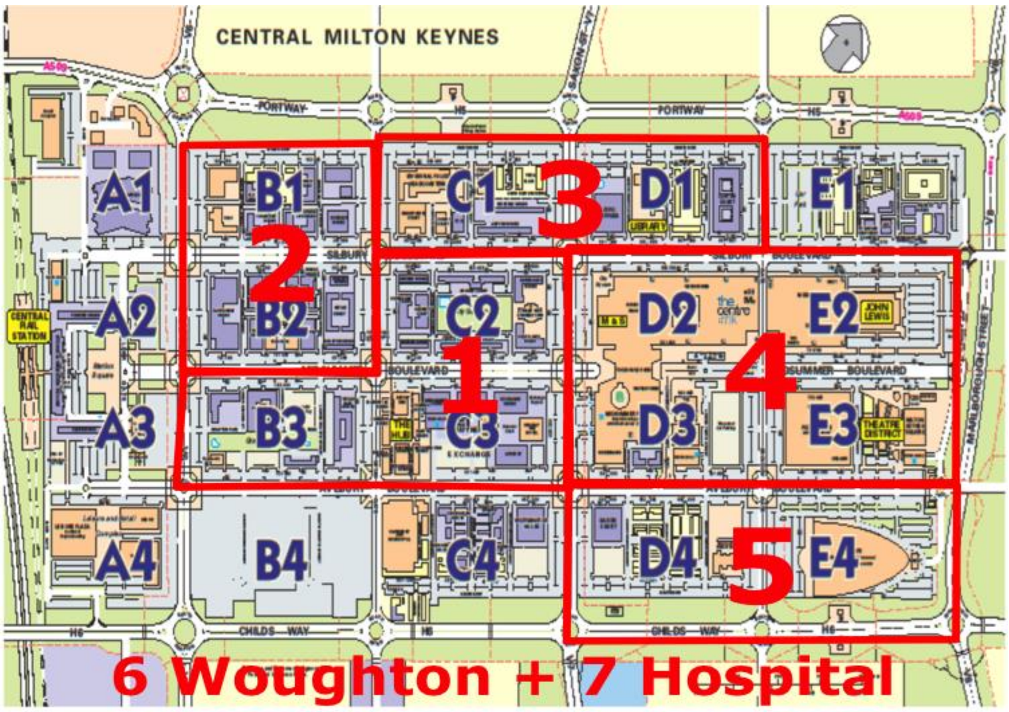


Figure 3 - Initial building clusters

Base case models the current business as usual case including the current Thameswey energy centre and the 17 buildings currently connected. This base case model mimics the way Thameswey buy and sell energy including their use of the STOR, TRIADs and the wholesale electricity market. This scenario involves direct sale of heat to customers, direct sale of electricity to customers via private wire, the operation of the thermal stores and the sale of electricity at variable export and import prices based on wholesale market prices.

- Cluster 1 (Central close to Energy Centre) [C2, C3, B3] – a heat network supplying buildings close to the existing energy centre. These are mainly hotels, offices and retail.
- Cluster 2 (West central) [B1, B2] – to supply mainly offices and some retail buildings.
- Cluster 3 (Public sector quarter) [C1, D1] – two law courts, police headquarters and MK Council office plus a large library.
- Cluster 4 (Shopping Centres) [D2, E2, D3, E3] – two large shopping centres and a range of department store including a large John Lewis.
- Cluster 5 (Xscape) [D4, E4] – Xscape ski slope and a range of entrainment and leisure venues inside the same building
- Cluster 6 – (Woughton) a more extensive heat network supplying two large schools a college and a leisure centre. Although this is some distance from the main energy centre the cluster has a significant heat load.
- Cluster 6 plus 7 – (Woughton plus Hospital) an even more extensive heat network to supply both the Woughton campus and the hospital.

Clusters 1-6 were modelled as entirely separate clusters to see if they were economic in their own right. Cluster 7 (the hospital) was modelled with cluster 7 in a cumulative way as the distances of both 6 and 7 are much greater than other clusters. i.e. highly unlikely to build cluster 7 from the current energy centre without building cluster 6.

Conclusions

The existing scheme is large but under-utilised with only 17 buildings currently connected. Heat mapping has highlighted there are several opportunities in central Milton Keynes and there is also potential for additional growth by including the Woughton Campus area as well as Milton Keynes General Hospital.

Each of the clusters highlighted has shown positive signs from both an economic and emissions reduction perspective. Cluster 4, which includes the two large shopping centres, is the most attractive on NPV at this stage. The figures for pipework costs assume each cluster has separate branches, linking clusters together will allow fewer branches but this will only increase the economic value of the project.

The 5MWe electrical supply licence limit that could significantly affect the project economics. A new energy centre will almost certainly be required to connect if more than two clusters come on-stream.

2.2. Phase two – detailed heat & power analysis

A further round of more detailed GIS mapping was then undertaken to include some additional buildings and delete others based on site work and stakeholder engagement. The data has been thoroughly reviewed/updated and some actual energy and building data obtained from stakeholder has been incorporated. This exercise significantly improved the reliability of the data set mapped across Milton Keynes of almost 150 buildings.

A major review of the business as usual model took place to revise the model mimicking the existing Thameswey scheme in more detail. This included some very significant updates to the tariffs and charging regimes in order to fully represent Thameswey's operations.

Based on the above and the previous round of modelling, a more detailed clustering exercise was carried out to reach nine clusters in central Milton Keynes. These clusters have been developed by identifying all the major buildings in central MK above 1 GWh/yr gas demand and then plotting spine pipework from the existing energy centre to serve these. Buildings were then clustered around the spine pipework. Two further clusters were considered around the hospital and Woughton and these were treated as an entirely separate heat network with a new energy centre located at the hospital. Two new-build and two housing opportunities were also modelled.

Techno-economic modelling was then carried out to determine the whole life economic return on investment for each cluster in a progressive way along each spine pipe route. A more detailed capital cost model based on improved cost assumptions was developed to underpin the modelling. This included more accurate pipework routes and measurements to make the modelling more robust.

Stakeholder engagement has continued via email/phone to obtain more robust building/energy data to feed into the modelling. Further site visits have also been carried out to identify building heating systems, boiler plant locations etc. to determine connectability.

Strategic issues

The phase 1 analysis clearly indicated that the Hospital and Woughton clusters should be treated as an entirely separate scheme to central Milton Keynes. The remainder of the study assumed this to be the case.

1. The Hospital is a very large load but a long way from the current energy centre in central MK Just running pipework from the existing energy centre to the hospital would cost around £2.5M.
2. The existing CHP/DH scheme in central Milton Keynes has spare capacity but adding just a few of the local buildings could take up this spare capacity. The existing energy centre is therefore highly unlikely to supply the hospital or Woughton clusters.
3. If the existing energy centre goes above a peak 5MWe electricity supply to customers, then it will require Thameswey to become a licensed electricity generator or the generation business would need a different legal status/arrangement. Crossing 5MWe is not seen as a hard barrier but would bring additional costs and require different commercial arrangements.

For the above reasons we now consider central Milton Keynes and the Hospital/Woughton as two entirely separate schemes with a proposed new energy centre located at the hospital.

Detailed clusters analysis

Central Milton Keynes

Figure 4 shows the clusters of buildings based on the strategic pipework legs 1, 2 and 3.

- Cluster 1a (Ramada)
- Cluster 1a + 1b (Ramada + Xscape)
- Cluster 2a (Santander)
- Cluster 2a + 2b (Santander + Station)
- Cluster 2a + 2b + 2c (Santander + Station + Planet Ice)
- Cluster 3a (Police HQ)
- Cluster 3a + 3b (Police HQ + MK Council)

- Cluster 3a + 3b + 3c (Police HQ + MK Council + Centre:MK)
- Cluster 3a + 3b + 3c + 3d (Police HQ + MK Council + Centre:MK + Silbury East)

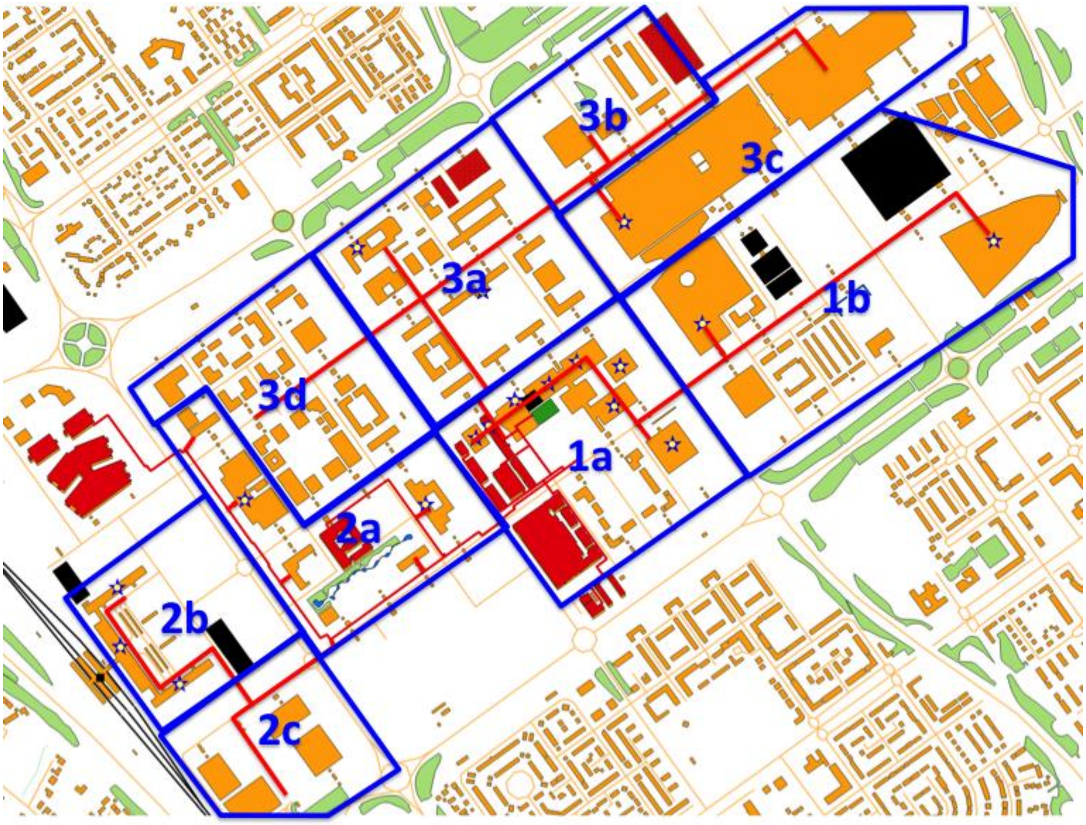


Figure 4 - Clusters in relation to strategic pipework in central Milton Keynes

- Cluster 1a (Ramada) – a heat network supplying large buildings close to the existing energy centre. These are mainly hotels and offices including Ramada Encore, Holiday Inn, Jury's Inn, Westminster House (Allianz Insurance), Midsummer court and Home Retail Group.
- Cluster 1a + 1b (Ramada + Xscape) – an extended scheme to include the Xscape ski slope, Debenhams, the INTU shopping Centre, Premier Inn and Saxon Court.
- Cluster 2a (Santander) - a heat network supplying large buildings already close to the existing network to the west including Santander House, Witan Gate House, 401 Grafton Gate and a Travelodge.
- Cluster 2a + 2b (Santander + Station) - an extended scheme to include three large offices around the railway station including Station House, Elder House and Phoenix House.
- Cluster 2a + 2b + 2c (Santander + Station + Planet Ice) – a further extension to include Morrison's supermarket, Toys R Us and the Planet Ice Leisure Plaza
- Cluster 3a (Police HQ) - a heat network supplying large public and commercial buildings to the north including a large Police Headquarters, two law courts and a range of commercial offices.
- Cluster 3a + 3b (Police HQ + MK Council) - an extended scheme to include MK Council civic offices and a central large library but also including connections to council managed flats around North 9th and 10th street.
- Cluster 3a + 3b + 3c (Police HQ + MK Council + Centre:MK) – a further extension to include two large shopping centres and a range of department store including a large John Lewis.
- Cluster 3a + 3b + 3c + 3d (Police HQ + MK Council + Centre:MK + Silbury East) - a further extension to include John Lewis and the Centre:MK shopping centre plus some larger stores in the centre i.e. M&S, House of Fraser, Boots and Bhs.

Hospital and Woughton

Figure 5 shows the buildings mapped around Milton Keynes Hospital including Redway School to the south and some care homes to the west with the buildings mapped around the Woughton area including Woughton Leisure Centre, MK College and St Pauls School.

Figure 5 - Strategic pipework for Milton Keynes Hospital and Woughton

Cluster 4a – (Hospital) a separate heat network supplying MK University Hospital buildings and some surrounding care homes plus a school. A new energy centre would be located at the hospital.

Cluster 4a + 4b (Hospital plus Woughton) an extension to the hospital heat network to supply both the Woughton campus including Woughton Leisure Centre, St Paul's RC School, MK Academy and MK College.

Further details on the analysis and conclusions for the hospital cluster can be found in Appendix G: Summary of Phase 2: Hospital.

Potential new-build opportunities

There are a range of possible new-build/refurbishment opportunities across central Milton Keynes. Many of these are vacant sites awaiting developer interest and have not been submitted for planning consent. However, the most likely opportunities that are closest to going ahead are:

- **YMCA** – a new-build development of a hostel block providing 200 apartments and a residential block providing 230 apartments
- **Lloyds Court** – refurbishment of a 13,800m2 office block

Potential housing opportunities

There are a range of possible new-build/refurbishment housing opportunities across the Milton Keynes area. We understand that none of the possible sites have any well-developed plans at this stage. However, the most likely opportunities that sit close to the proposed DH spine pipework are:

- **Coffee Hall** – a possible new-build development to replace MKC and Housing Association social rented housing with some private housing. Estimated to be around 659 new build properties.

- **Netherfield** – a possible new-build development to replace MKC and Housing Association social rented housing with some private housing. Estimated to be around 889 new build properties.

These sites are shown in Figure 6 and have been modelled as additions to the Hospital cluster 4a.

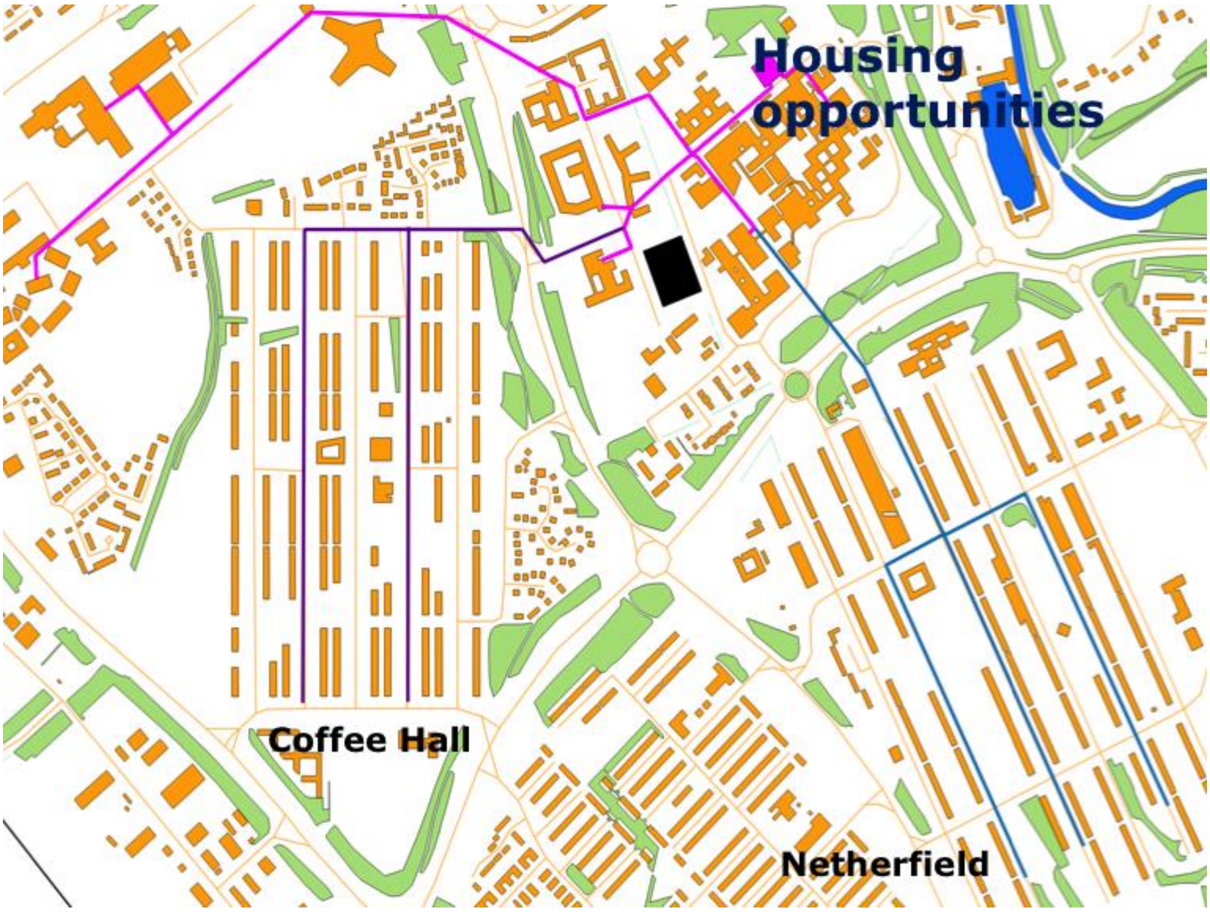


Figure 6 - Potential housing opportunities

Conclusions

Modelling shows that all of the scenarios in central Milton Keynes show high returns on investment. However, this is largely due to the fact that there is an existing heat network scheme that has already had a very large investment made by Thameswey. There is also very significant spare capacity in the current energy centre to supply some future clusters although it should be noted that there is insufficient capacity to supply all of the clusters modelled.

Cluster 2a around Santander has the highest Internal Rate of Return (IRR) as the pipework length is very small. Cluster 1a+1b (Ramada + XScape) shows the greatest NPV as the energy demands are very large and close to the existing energy centre. Cluster 3a+3b+3c+3d (Police HQ + MK Council + Centre:MK + Silbury East) has the highest operating surplus and the highest CO2 savings in central Milton Keynes because this cluster has the highest energy demands but also relatively long pipework and high capital costs. All the clusters modelled included private wire sale of electricity.

Cluster 4a (Hospital) has been modelled as a separate scheme with a new energy centre that would ultimately supply 4b as well. Although the energy demands are high in the hospital and Woughton clusters, the additional capex for the new energy centre plant and the long pipework required provides a lower return on investment than opportunities in central Milton Keynes. Further details on the analysis and conclusions for the hospital cluster can be found in Appendix G: Summary of Phase 2: Hospital.

Adding the YMCA/Lloyds Court new-build opportunities does increase the NPV somewhat but is probably not a deciding factor in taking the 3a or the 3a+3b clusters forward.

Adding the housing opportunities in Coffee Hall and Netherfield reduces the NPV and IRR of the hospital option 4a. Neither housing scheme provides an economic option, mainly due to the very large capital costs involved. However, MKC may have other reasons to consider these options in the future e.g. improvements in affordable warmth and carbon emissions. Both housing options provide the largest CO2 savings but this simply represents the size of the schemes.

2.3. Phase three - development of final scheme

Phase 3 focussed on the major anchor load buildings across the central Milton Keynes area and analysing spine pipework that connected these. Initially the top 50 buildings (based on heat and power demand) were ranked based on linear heat density and likelihood of connection. Linear heat density was based on total electricity equivalent MWh divided by distance from the energy centre. Linear heat density is a proxy for heat losses and economics. Some smaller and less likely buildings were then dropped from the ranking and some longer-term developments were added based on updated advice from Thameswey about likelihood. This left 29 major buildings/developments.

Discussions were then held with Thameswey to rank the 29 remaining anchor buildings/developments based on Thameswey's business pan and likely build-out. This resulted in an agreed build-out shown in figure 6.

The 29 buildings were modelled in one cluster but each building was added in the order shown. This resulted in 29 EnergyPro models forming a progressive approach across 29 buildings.

Following Thameswey's advice, the top four potential new build sites were added that are closest to submitting planning applications. Thameswey also felt Lloyds Court refurbishment should be seen as low likelihood for connection. Following extensive discussions with Thameswey, the likelihood ratings were updated to an even more extreme range between public and commercial and re-ranked. Other key buildings were then ranked by Thameswey based on their view of commercial likelihood and their existing business plan. This resulted in the build-out order shown in Figure 6 and Table 1.

Initial build-out up to around building 8 was based on heat/power supply taking up spare capacity in the existing energy centre. Once this reached the 5 MWe electricity supply licence limit then a transitional heat only model was introduced. Following this, a second energy centre was introduced into the model. It was assumed that this new energy centre would be operated as a separate entity allowing a further 5 MWe electricity to be supplied without a supply licence. Modelling did reach a stage where even two energy centres had both reached the 5MWe limit and further customers were then connected as 'heat-only', avoiding the need for a supply licence or third energy centre.

Phase 3 therefore modelled 29 buildings/developments as 29 separate EnergyPro runs based on a build-out timescale agreed with MKC and Thameswey. As a result, the project has reached a single clear DH solution to extend and supplement the existing DH scheme with a second energy centre. A range of possible business models have then been analysed to identify a way forward for the main stakeholders.

Further analysis of the hospital cluster has been excluded from phase three of the study as phase two concluded that the area is uneconomic to consider connecting to a centralized Milton Keynes energy centre, however could be considered for a separate thermal network, so is outside of the scope of this study. See Appendix G: Summary of Phase 2: Hospital for a summary of the corresponding phase two results.

3. Stakeholder engagement

Methodology including review of responses of previous studies

Obtaining accurate estimates or data for heat and electrical consumption is of critical importance to the efficiency sizing and modelling of district energy schemes.

There are several sources of information of for understanding energy consumption. These include:

- Half-hourly gas and electrical consumption data
- Monthly energy bills
- Department of Energy data (government buildings)
- Benchmark data

Best practice as per Heat Networks Code of Practice is to obtain half-hourly data from potential sites for accurate energy usage profiles, and the general approach to gathering this data is to send out a questionnaire requesting information.

After reviewing previous studies, response rates to this approach are generally quite low, so a different approach was taken in this instance.

For previous phases of this report enquiries were sent out to all Milton Keynes sites, however due to the limited responses, it was decided that it would be more beneficial to focus the stakeholder engagement on the 25 previously identified sites.

A staged approached was adopted as outlined below.

Stage 1

A general letter was sent out to potential clients in the first instance, capturing information from those sites with readily available information. Response rates to this letter, as expected were low. See Appendix F: Letter to stakeholders for letter template.

Stage 2

Sites were contacted individually with the intention of capturing required contact details and assessing the response to confirming whether the site has a centralised heating system.

Stage 3

Where details for the site manager or other knowledgeable contact were obtained, data was requested in the form of monthly bills and ideally half-hourly data if available.

This approached maximized the amount of information recovered, and made the requests more approachable by staging the questions and not overwhelming the recipient with an extensive survey.

Stakeholder engagement response and data.

See Table 1 below for response rates to contact and data requests.

	Public		**Private**	
	Number	*Percentage Total*	*Number*	*Percentage Total*
Buildings Contacted	6	NA	19	NA
Confirmation of Heating System	6	100%	15	79%
Monthly Data	6	100%	6	32%
HH Data	1	17%	4	21%

Table 1 - Stakeholder engagement response

Response rates were high, with over 80% of contacted sites confirming that wet centralised heating plant is used, providing a preliminary confirmation of connection capacity. In addition to this all of the publicly owned sites provided monthly data, and approximately one-third of private sites contacted. The rate of sites providing half hourly data was roughly comparable between the public and private sector, at approximately 20%.

All forms of information gained can be input into the energy modelling process. Following best practice guidelines, where half-hourly data is not available, monthly or benchmark data is used to calculate usage curves based on building type and usage. See table below for a summary of energy modelling input data with the final data source indicated.

It is expected that planning conditions would be placed upon all new builds to assess the economic viability of connection to the heat network.

	Public / Private	ELEC (MWh)	GAS (MWh)	Confirmation of heating system	Data received
YMCA (Hostel & Resid)	Private	661	2189	Y	-
Police Headquarters	Public	985	2161	Y	Monthly
Civic Offices	Public	1326	907	Y	Monthly/HH
Central Library	Public	238	573	Y	Monthly
B3.3N Pre-Planning office	Private	1608	733	NA	NA
B3.3N Pre-Planning Res	Private		975	NA	NA
1-199 North 9th Street Flats	Public	308	847	Y	Monthly
CBXIII – Pre-Planning 1200 site	Private	750	1000	NA	NA
C3.1/2 Pre-Planning	Private	842	384	NA	NA
C3.1/2 Pre-Planning Res	Private		510	NA	NA
B4.1-B4.3 Pre-Planning	Private	7722	2851	NA	NA
B4.1-B4.3 Pre-Planning Res	Private		7152	NA	NA
Magistrates Court	Public	289	680	Y	Monthly
County Court	Public	151	214	Y	Monthly
Santander House	Private	7922	5113	Y	-
Witan Gate House	Private	2709	486	Y	Monthly
Central Business exchange	Private	6247	4032	Y	-
Midsummer court	Private	5119	3304	Y	-
Exchange House	Private	6143	3965	Y	-
401 Grafton Gate	Private	2090	1349	Y	-
Jurys Inn	Private	1390	894	Y	Monthly/HH
Avebury House	Private	1229	793	Y	-
Home Retail Group	Private	5053	3261	-	Monthly/HH
Ramada Encore	Private	675	434	Y	Monthly/HH
Holiday INN	Private	1397	3591	-	-
Westminster House (Allianz	Private	3063	1977	Y	-
Travelodge	Private	230	168	Y	Monthly/HH
Sovereign Court	Private	2728	1761	Y	-
Silbury Court	Private	2843	1835	-	-
Ashton House	Private	1905	1230	-	-
Norfolk House	Private	1905	1230	Y	-
Lloyds Court (Refurbishment)	Private	1629	1009	Y	Monthly

Table 2 - Energy Data

4. Network Strategy

4.1. Existing Capacity

Current capacity of network/energy centre.

The existing heat network is shown in and is based around an energy centre (shown in green) comprising two 3.2MWe CHP engines a 10MWth gas fired boiler and 560m3 of thermal storage. Thameswey provide both heat and electricity via private wire to most of their customers and this includes both residential and commercial buildings. It is expected that operation and maintenance activities will continue as currently scheduled and the addition of extra load will not significantly affect this. They currently have 17 main connections shown in Table 3.

Connection	Map Reference Number
Carnegie House	1
Manhattan House	2
Chelsea House	3
Staten House & Brooklyn House	4
Metropolitan House	5
Dakota House	6
The Pinnacle	7
The Pinnacle	8
The Quadrant:MK (Network Rail)	9
The Quadrant:MK (Network Rail)	10
The Quadrant:MK (Network Rail)	11
Sainsbury's & Amethyst House, Topaz House, Jade	12
Opal House	13
Ruby House	14
Luminous House	15
Moonstone House	16
Petersfield Green	17

Table 3 - Current Thameswey Connections

Figure 1 shows the existing thermal network location with the green building representing the energy centre, red buildings indicating those clients who are thermally connected, and the red line showing pipework routing.

It is notable that there are high heat demand buildings very close to the energy centre and along the existing pipework route e.g. Santander, that have not connected. This is due to the Thameswey high connection cost business model of rolling out connections based on the individual buildings boiler replacement timeframes.

Remaining capacity for possible usage with the new network.

The existing equipment is currently under-utilised, with average and maximum demands significantly lower than the installed capacity of the system.

This indicates that there is significant room for expansion in the currently installed network before requiring additional thermal or electrical generation equipment. Average utilisation of the equipment is especially low, with only 31% of the available capacity being generated, compared to 73% at the peak. This shows that methods of peak shaving could create additional electrical capacity within the network once it has been expanded to reach electrical limits. Energy storage mitigates this time-of-use problem on the thermal supply.

	Thermal	Electrical
Total Installed capacity (MW)	16.294	6.09
Max demand (MW)	11.04	4.45
Average Demand (MW)	1.76	1.86
Current Utilisation % (Max)	68%	73%
Current Utilisation % (Ave)	11%	31%
Annual MWh spare (assuming 100% availability on installed capacity)	127,000 MWhth	37,000 MWhe

Table 4 - Existing Scheme Capacity Analysis

4.2. Network routing

Visual representation. Comparison to earlier clustering study.

For the phase three study, as can be seen from the figure below, all sites are in the immediate vicinity of Milton Keynes centre.

Figure 7 - Proposed Routing and Connections

The feasibility of the proposed route has been assessed by thermal network contractors and compared with the routing of the current Thameswey scheme, and consideration has been given to:

- Minimise pipework lengths to reduce heat losses and costs.
- Minimise trenching requirements for connecting building loads.
- Reduce the number of road crossings to minimize road closures and traffic management.
- Contact with the DNO to identify connection issues with the electrical network.
- Pipe and insulation sizing and impact on civils costs.

Best practice from Heat Networks Code of Practice has been followed for this feasibility stage by obtaining and reviewing drawings from the DNO to determine locations of existing services and any impacts these may have on the proposed routing. These are included in a separate electronic format.

4.3. Rollout/Phasing

The preliminary connection schedule has been determined in conjunction with Thameswey, based upon their investigations and experience with the currently operating scheme, with projections made for future connections. This schedule is formed around the Thameswey business plan, which facilitates connections in accordance with sites requirements for boilers replacements. For further information see Section 2.3.

It is likely that this program could be speeded up significantly with the introduction of incentive tariffs for those customers who don't need to replace their boilers. The effect of rollout speed on the investment economics is analysed in section 7.1.

The rollout is schedule in a deliberately unsynchronised manner, to simulate a 'true to reality' future scenario, rather than a bias towards connections nearer to the proposed energy centre location being prioritised. This creates a more robust and realistic scenario that isn't relying on the specifics of individual connections to make the business case work. In this way, each of the sites are quite interchangeable, so if one doesn't happen to connect another site is likely to take its place. This reduces the overall financial risks associated with certain connections coming on board at particular times, due to the ultimate feasibility of the system not being reliant on optimal rollout of sites.

Order	Building Name	Connection	Connection Type
1	YMCA (Hostel & Resid)	2018	Heat/Electricity
2	Police Headquarters	2019	Heat/Electricity
3	Civic Offices	2020	Heat/Electricity
4	Central Library	2020	Heat/Electricity
5	B3.3N Pre-Planning	2020	Heat/Electricity
6	1-199 North 9th Street Flats	2021	Heat Only
7	CBXIII – Pre-Planning 1200 site	2021	Heat/Electricity
8	C3.1/2 Pre-Planning	2022	Heat/Electricity
9	B4.1-B4.3 Pre-Planning	2023	Heat/Electricity
10	Magistrates Court	2024	Heat/Electricity
11	County Court	2024	Heat/Electricity
12	Santander House	2025	Heat/Electricity
13	Witan Gate House	2026	Heat/Electricity
14	Central Business exchange	2027	Heat/Electricity
15	Midsummer court	2028	Heat/Electricity
16	Exchange House	2029	Heat Only
17	401 Grafton Gate	2030	Heat Only
18	Jurys Inn	2031	Heat Only
19	Avebury House	2032	Heat Only
20	Home Retail Group	2033	Heat Only
21	Ramada Encore	2034	Heat Only
22	Holiday INN	2035	Heat Only
23	Westminster House (Allianz	2036	Heat Only
24	Travelodge	2037	Heat Only
25	Sovereign Court	2038	Heat Only
26	Silbury Court	2039	Heat Only
27	Ashton House	2040	Heat Only
28	Norfolk House	2041	Heat Only
29	Lloyds Court (Refurbishment)	2042	Heat Only

Table 5 - Site Connection List

The table above shows that 14 sites are predicted to be able to connect electrically before the 5 MWe electricity supply licence limit is reached for both the existing and new energy centres. All 29 sites are to connect thermally to the network on shared pipework infrastructure.

4.4. New energy centre

Initial build-out up to around building 8 was based on heat/power supply taking up spare capacity in the existing energy centre. Once this reached the 5 MWe electricity supply licence limit then a transitional heat only model was introduced using spare boiler capacity. Following this, a second energy centre was introduced into the model. It was assumed that this new energy centre would be operated as a separate entity allowing a further 5 MWe electricity to be supplied without a supply licence. Additional connections for both heat and power were added until the peak electrical capacity of new energy centre was reached. All further customers were then connected as 'heat-only', avoiding the need for a supply licence or third energy centre. See outline below for further details.

1. Connections and spine pipework will be built according to the rollout schedule, connecting to only the existing energy centre until the capacity is exceeded.
2. At this point, the existing network is fully saturated, which includes electrical connection for buildings 1-8 (7 excluded) and thermal connections for 1-13.
   The existing private wire network becomes fully saturated at peak after connection 8, at which stage wiring will continue to be rolled out in connection trenches in anticipation of the new energy centre coming online in the future. This will allow a simple process of finalizing connections and bringing them all on as connected loads once the new energy centre has been built, as of connection 14.
3. New energy centre is built in readiness for connection 14, and once operational, previously installed yet unconnected private wire loads will be brought onto the new energy centre.
4. Subsequent connections to the network are to be installed up to peak 5MWe capacity of the new energy centre, with all further connection heat only.

The benefit of this approach is the ability to bring loads on earlier rather than waiting for several more years for subsequent connection to happen once the new energy centre is built. In the two-operator scenario, this means that connection 9-13 will be supplied with heat from a different supplier to their electricity, and this electrical connection cost has been attributed to the new scheme – therefore minimizing the impact on the current operator. Given that in any scenario energy production would need to be coordinated between the existing and new energy centres, having varied billing methods should not pose any issues.

5. EnergyPRO modelling

5.1. Heat and electricity load profiles

Half-hourly heat and electricity load profiles were developed for existing connected loads and each of the 29 potential new connections. This process is described below.

Existing connected loads

An extensive data file was provided by Thameswey for the year 2014. This gave five minute readings for fuel input, heat output and electricity output for both CHP engines, and the boiler separately. The data also included flow and return temperatures as well as change in the thermal store content. The year 2014 was selected because this was the most recent year that a complete year of data was available at the time the modelling. Heat demands were derived by summing the generation half-hourly heat from the two existing CHP engines and the boiler, subtracting any heat rejected and taking into account the change in the thermal store. Total annual energy sold for residential and commercial customers was then used to split the total demand into residential and commercial. The difference between the generated amount and the supplied amount was used to derive losses/parasitic loads. Some manual adjustment was required for spurious readings during the year.

Real data provided by the organisation

In some cases the actual half hourly data provided by the connections was loaded directly into energyPRO. An example of one half-hourly electricity profiles over a year is shown below. In this case (the Civic Offices) this includes the operation of 165kWpk of solar PV.

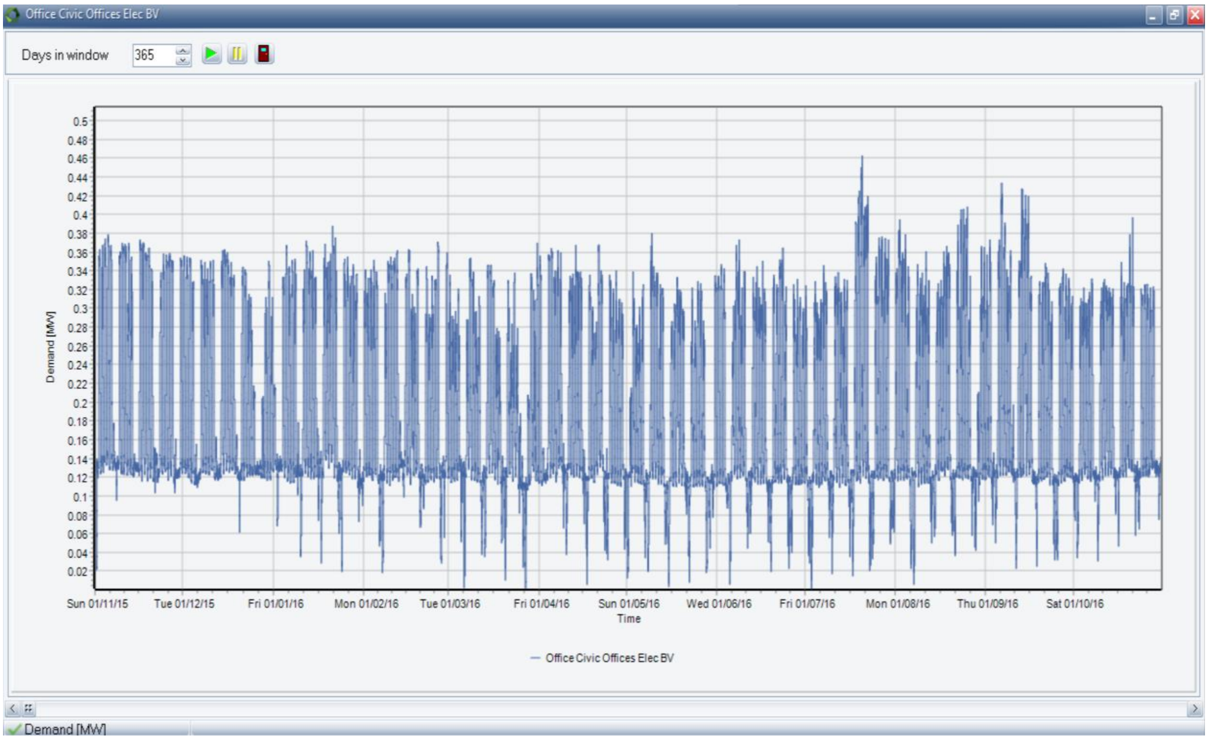


Figure 8 – Half-hourly electricity demand for the Civic offices

Where data was provided by the organisation, but on an annual or monthly basis, this was profiled half-hourly using the method below.

Other

For remaining sites the annual figures were either based on figures provided by Thameswey for newbuild sites, Display Energy Certificates data or benchmarks. For electricity, typical profiles were used for the different use types: (residential, hotel, police and office). These were from real half-hourly data for offices and the police from other sites and for residential and hotel were developed based on assumptions about usage patterns. In order to simulate diversity the profiles were shifted back and forward in time sequentially for each new connection of that type.

For heat, the annual gas figures provided were split using percentages into usage for heating and hot water (and catering those this was not used further), based on the TM45 protocol for the different use types (residential, hotel, police, and office). Heating and hot water were then converted to heat demand based on an assumed boiler efficiency of 80%. For space heating this annual heat demand figure was then assigned to each day based on average daily temperatures for Milton Keynes for 2014 and a base temperature of 15.5 deg C. For hot water is was assumed that the daily demand did not vary. Finally, for each use type, standard half-hourly profiles were then overlaid onto the usage.

The same approach to diversity was taken as described for electricity.

Modelled average and peak energy values are given in Appendix H: .

5.2. Losses

The existing distribution loss percentages derived for the existing scheme were applied as each new load was added to the model. These were 12.5% for heat and 8.9% for electricity (for electricity this included parasitic/energy centre ancillaries). See Sections 6.2 and 6.3 for design details.

5.3. Key Assumptions

The set of key assumptions utilized in the model are outlined below.

Expenditure

Gas Supply
Wholesale prices have been used for 2014 provided by Thameswey. These vary by month.

EU ETS
Where the connected loads required more than 20MWth of thermal plant to run simultaneously it was assumed that EU ETS would be paid for all gas used in the energy centre. A rate of £5/tonne CO_2 was used. This represents a worst-case scenario as CHP should in theory only be charged for the gas used to generate electricity.

Wholesale Electrical Import Rates
We have used half-hourly variable import prices based on actual wholesale figures provided for 2014. In addition to these wholesale prices High Voltage Duos and other charges (green levies etc) are incurred by Thameswey for imported electricity.

Standing Charges
Standing charges on imported electricity are based on 2014 data for the base case. We have not used Thameswey's standing charge figure in exactly as provided as it includes some variable charges. Instead DUoS capacity charges have been taken from Western Power Networks at 3.97p/KVA/day. Standing charges on imported gas are assumed to be £60,000 per year, based on 2014 data for the base case and increased in proportion to increases in new supply plant where it was needed.

Maintenance
Maintenance charges have been calculated based on current Thameswey charges as shown in the table below. Network and customer costs have been estimated by Thameswey as 60% heat related and 40%

power related. These charges have then been increased according to additional new energy centre plant and for the heat and electricity components, additional MWh of connections.

Energy Centre	£280,000
Network	£130,000
Customers	£61,000

Table 6 - Thameswey Maintenance Costs for Existing Energy Centre

Revenues

Heat supply

We have assumed a heat sales price of 2.7p/kWh for commercial customers and for residential sales 4.47 p/kWh as provided by Thameswey. These were the figures for 2014 and all numbers have been standardised for this year.

Private Wire Electricity Supply

Electricity sale prices have been assumed to be 7.99p/kWh during the day and 4.4 p/kWh at night again based on Thameswey data - for residential supply 12.53p/kWh at all times.

Residential Standing charge and Maintenance revenue

Standing charges and maintenances to residents for residential heat and power have been estimated based on data from Thameswey as follows (totals are shown for the base of 924 residential customers).

Residential	£ Per day	£ Per year	Customers	Total £
Electricity	0.1387	50.6255	924	46,778
Heat	0.1643	59.9695	924	55,412
Maintenance		135.78	924	125,461
TOTAL		**246.375**		**227,651**

Table 7 - Residential Standing Charges

Commercial Standing Charges

Standing charges to commercial customers for heat and power have been estimated based on data from Thameswey. The approach used for this final round of analysis was to calculate the ratio of standing charge to annual energy sales income for heat and power respectively for the current customer base and then apply the same ratio to new connections. Standing charges were a significant proportion of the tariff revenue, at 44% of total heat sales and 26% of electricity sales.

6. Technical Analysis

6.1. New Energy Centre

Basis for design

The proposed new energy centre will be of similar design to that which is currently operated by Thameswey, except for smaller CHPs (2 x 2.5 MWe compared to 2 x 3MWe), and additional boiler capacity.

The system shall operate in the most economic manner, further discussed in section 6.4, with any electricity not generated by the CHPs to be purchased from the grid connection. Likewise, any electricity production over the required electrical demand will be sold back to the grid.

Any heat capacity required over that which is being delivered by the CHPs, or available in the thermal stores, is to be generated using gas fired boilers, with the system sized to deliver a level of redundancy at peak heat demand. Any thermal energy generated by the CHP that is not required by the network will be held in the thermal storage.

As a worst case scenario of both CHPs being out of operation, for example in a power outage, the energy centre still needs to be able to supply heat to customers.

The thermal network of the new energy centre is to share the same pipework infrastructure as the current network, so an additional level of equipment redundancy is available. The private wire electrical networks are however to be kept separate due to the 5 MWe electricity supply licence limit.

Equipment Sizing

Electrical

Working within the private wire limit discussed above, the CHP is to be sized to maximum 5MWe capacity. It is proposed that 2 x 2.5 MWe units be installed which will give the ability to operate down to a continuous 1.5MWe at 60% output. This also provides a level of redundancy for power generation. If both CHPs are offline, sufficient supply will be available from the grid. Any electricity not generated by the CHPs will be purchased from the grid and resold to customers. This arrangement is necessary as sites can only have a single concurrent electrical connection and therefore all customer’s power must be supplied through the private wire network, necessitating the purchase of power not generated.

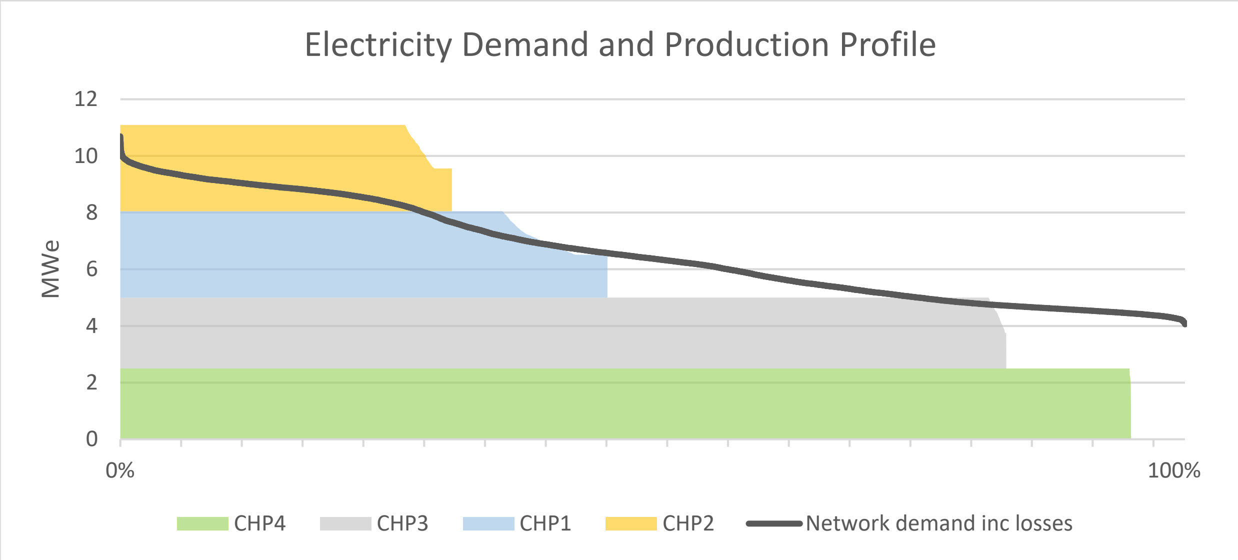


Figure 9 - Electrical demand profile

As engines would be staged between both the new and old energy centre to increase efficiency and viable run hours, it is practical to take a view of the system as a whole, therefore taking into account both the existing and new energy centres, the load and generation profiles can be seen in Figure 9 above. The black curve represents the electrical demand on both private wire networks, with any shortfall in generation purchased from the grid. Export will occur during times where generation exceeds network demand. As can be seen this occurs approximately 25% of the time.

Thermal

Average demand through the year varies from around 3MWth in Summer to approximately 8MWth in Winter. The spread of maximum demand varies significantly more, from approximately 8MWth during Summer to just over 30MWth during Winter, as can be seen in Figure 10.

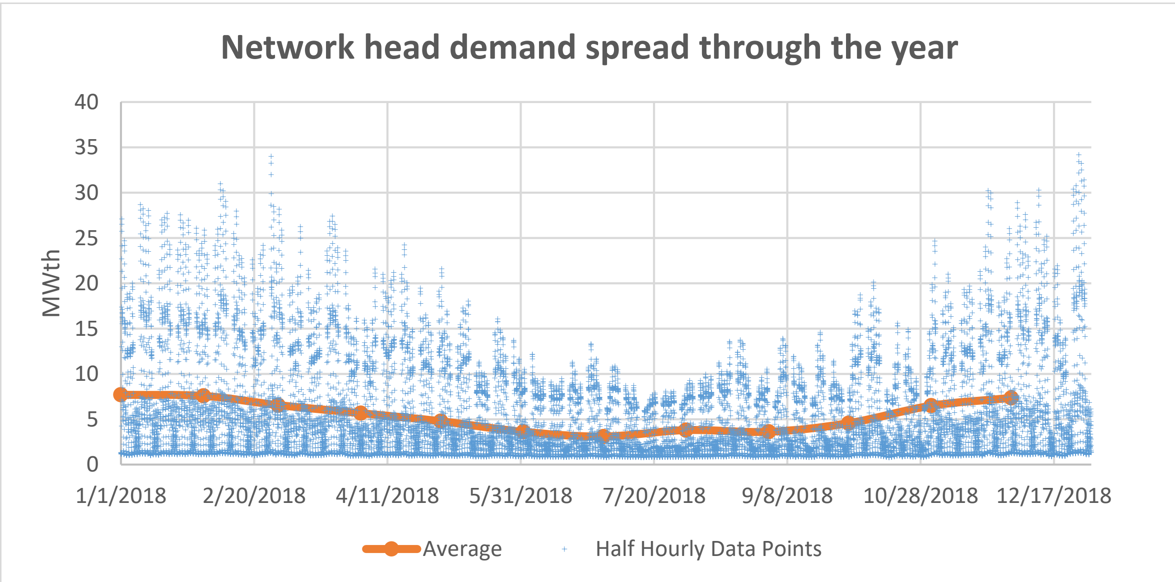


Figure 10 - Network Heat Demand

This graph plots all half-hourly data points through the year showing the complete annual heat profile. More densely populated areas of the graph show higher levels of demand, and as can be seen, most of the data points lie below the average with a large spread above. Banding can be noticed on this graph indicating extended periods with heat demand approximately twice that of the average, then small spikes of up to twice this value (peak demand of just over 30MWth).

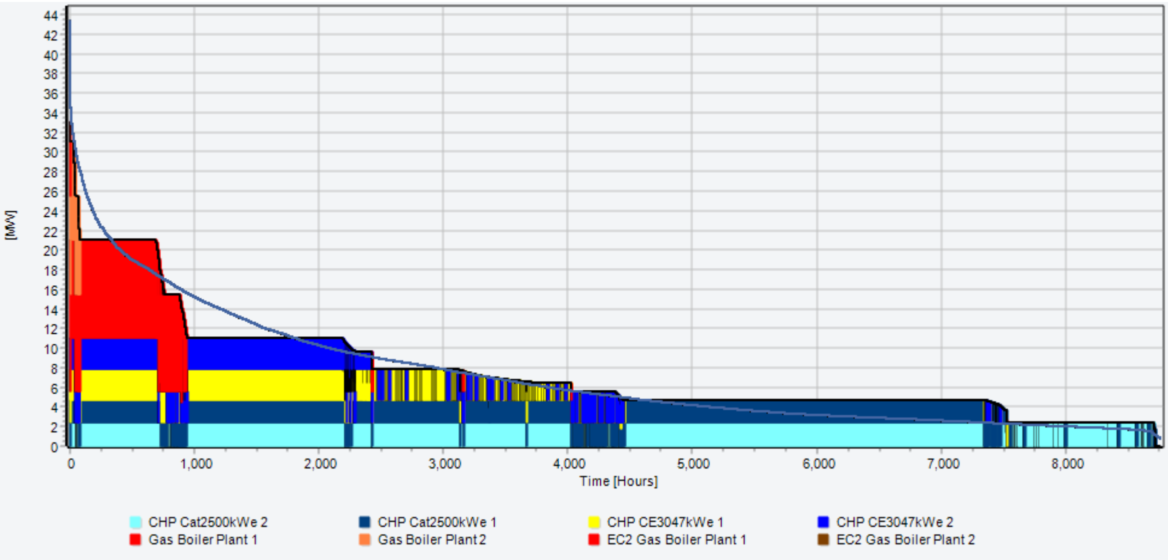


Figure 11 - Thermal Demand Profile

See above Figure 11 - Thermal Demand Profile for a thermal load duration curve for the full scheme including the existing load and energy centre. Any area below the demand line and above the supplied heat represents heat made up by the reservoir, with the area above the demand line and below the combined supplied heat represents either charging the thermal reservoir or heat rejection. See appendix I for further details of the energy analysis.

As the current and new schemes are thermally connected, the combined peak demand of 30-35 MWth needs to be considered when specifying appropriate equipment.

It is recommended that 3 additional boilers be installed to provide sufficient redundancy for the heat demand.

A 4 X 10 MW Boilers (1 existing, 3 new) specification provides redundancy through CHP heat supply, and in addition can fulfill demand for more than 95 % of the year with 3 Boilers only, and without the CHP operating.

To increase heat supply redundancy in the existing scheme, we would propose locating one of the new boilers in the existing energy centre prior to the new facility being built.

Storage Sizing

Sizing for storage has been determined by operational characteristics of the system as projected by EnergyPro. It is optimally sized to:

- Ensure consistent supply temperature with varying loads.
- Reduce cycling of boilers.
- Allow maximum usage of the CHP with minimal heat waste.

The additional thermal storage will integrate with the existing scheme's storage adding further heat buffering and operational gains.

Optimal sizing has been determined at 350m3 (350,000L).

CHPQA

EnergyPro analysis has shown that for the staged program, CHPQA standards will be met for nearly all years, except for the timeframe associated with the addition several new loads (16 through 19). This is due to a large additional electricity demand with not enough heat demand creating a situation where some heat is dumped. This has been accounted for in the modelling by applying the CCL levy to the fuel input for this period.

Location

There is an area adjacent to the existing energy centre that may be applicable for locating a second centre, however the design of the pipework is flexible enough that there is the option of locating the additional centre anywhere along the main spine near the centre. This will need to be further investigated once the requirement for the new energy centre arises.

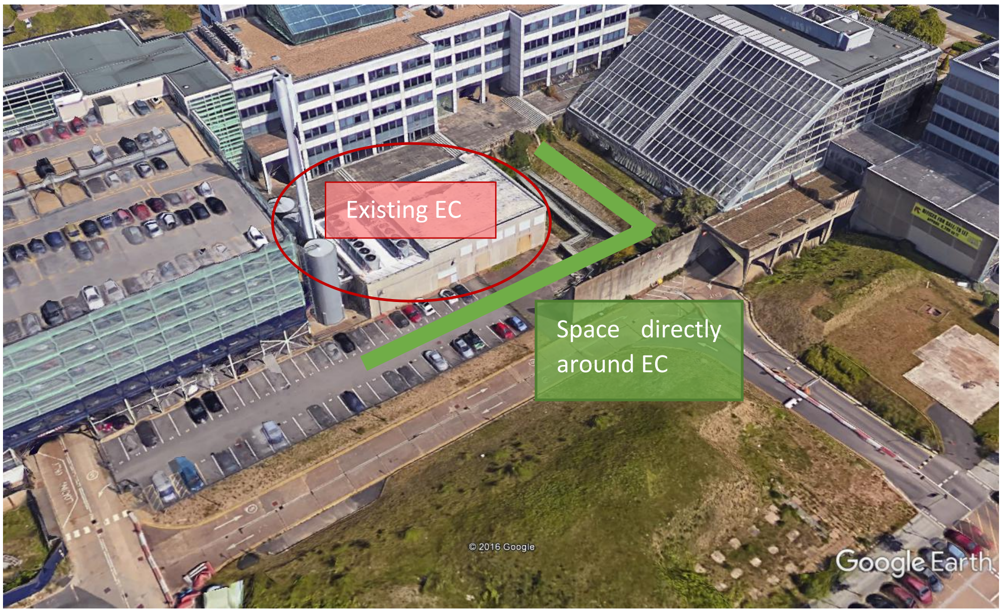


Figure 12 - Current Energy Centre Location

An important determining factor will be the timescale for a new energy centre, as a slow rollout will change the carbon reduction viability of natural gas CHP, and therefore impact on possible sites for an energy centre (see Section 8.5 for full details). Keeping sufficient capacity in the spine pipework will ensure the flexibility of adjusting energy centre locations later.

Capital costs

The new energy centre has been fully costed with appropriate allowance made for gas and electrical network connections as well as land. See Appendix H: Modelling and Costing Assumptions for more details.

The most significant costs are major equipment including CHPs, supplementary boilers and thermal storage, along with the allowance for land costs.

6.2. Pipe network

Basis for design

Pipework is to be designed to the maximum capacity of indicated connections with allowances for expansion and oversizing. Allowances have been made for the phased rollout of the network, with the ability of each spine to be extended in sections with little impact on operations and these have been priced on a section by section basis to provide flexibility in modelling and feasibility assessment. Ends of each section are to be valved and capped to allow for easy future connection capacity.

While there are benefits in operating a 30 degree temperature difference across flow/return in terms of capital expenditure there are often issues with integrating this into existing buildings. The current Thameswey run system was originally intentioned to run a 30 Degree Delta T (investigations have shown that it is currently running 20 Degrees), this study has used 20 Degree temperature flow/return temperature differences for the following reasons:

- Less risk of integration issues with existing site infrastructure.
- Sizing for 20 Degrees allows for the increase in delivery capacity if moving to a higher temperature differential (flexibility).
- Produces conservative estimates on capital costs.
- It is possible to operate a 20 deg C design at 30 deg C, but not the other way around.

As the new energy centre will be thermally integrating with the current network, temperatures will be dictated by the current operating conditions and end user requirements, which is currently 85/65 Degrees C.

Two options for chilling were considered. One was adding additional capacity for hot water absorption chillers located on-site at large loads, however the final scheme heat load in comparison to CHP heat output is quite sufficient and therefore has very little dumped heat. As mentioned elsewhere this system will meets CHPQA requirements. If pipework is oversized then this option will be retained for the future anyway. The other option is the addition of chilled water pipework in trenches shared with the LTHW pipework, however given the limited number of large cooling loads available in the area, any additional pipework will be very under-utilised and uneconomic.

CAPEX

Spine sections have been sized based on projected peak loads of connected sites. The required heat (kWth) capacity for each section based on final system configuration was determined and a 0.7 diversity factor applied for realistic estimate of max demand. The relatively high diversity factor is realistic given that similar profiles of energy consumption for buildings will cause peaks to occur at similar times.

Sizes of specified pipework	CAPEX Allowance	Capacity
NA	100%	100%
1 Size greater	106%	200%
2 Sizes greater	112%	400%

Table 8 - Oversizing Spine Options

Double the specified capacity can be reached for an extra 6% allowance over the base line civils and pipework cost. This future-proofing must however be balanced against the additional energy losses that occur with larger pipes.

There is the option of increasing spine sizing to increase flow capacity and therefore maximum network capacity. Costs for future proofing pipework are shown below.

Building tie-in

When integrating a building into the thermal network, two options arise. The thermal network can completely replace the existing boilers, which is likely to occur for customers whose boilers are reaching the end of service life, thus avoiding replacement costs. Alternatively heat supply can work in parallel with the site's existing boilers, reducing or replacing on-site boiler heat production when available from the network. For the purposes of this study, it is designed and modelled for an extended network having the capacity to meet the entire heat demand for each site at all times, and so for those customers keeping their current boiler systems, creates an extra level of redundancy for heat supply. Many prospective customers express concern that DH is a monopoly supply. However, if they can retain their boilers then there is always an alternative heat supply. It may also be possible for Thameswey to offer preferential heat tariffs for those retaining boiler capacity that can act as peak looping or standby capacity. The tariffs that are considered would provide an incentive to purchase heat from the network so a minimum take-off would be unlikely to be a necessity.

Heat demand in residential and commercial buildings is made up of two factors: space heating, and domestic hot water. Domestic hot water demand is relatively constant year-round, while space heating varies significantly between seasons.

Connections can either be directly, with the hot water supply from the network being fed directly into their building's heating circuits, or indirectly, where heat exchangers provide hydraulic separation between the building circuits and the network.

The CIBSE/ADE *Heat networks: Code of Practice for the UK* (CP1) gives advice on possible connection arrangements and both indirect and direct connections have been used in past UK schemes.

While direct connections generally have a lower cost and less complexity, keeping hydraulic circuits separate using indirect connections is proposed for this scheme for the following reasons:

- Leaks within the building's heating circuits do not affect the network.
- Building heating systems are not required to support the higher pressure of the network.
- Contamination of the building's heating circuits will not affect network.
- Water treatment is kept separate ensure that water supply maintains appropriate specifications for all ancillaries connected.
- Many customers prefer the separation from the main system for the independence factor.

In addition to connection pipework from spine to building, items that have been allowed for in site thermal tie-ins include:

- Appropriately sized heat exchangers for domestic and space heating circuits
- Heat Metering
- Controls
- Automatic Leak Detection (as per CIBSE/ADE *Heat networks: Code of Practice for the UK* version 1 (CP1))
- Estimated allowances for penetrations and internal pipework

Without detailed surveys and plans for internal connections, for costing purposes, sites have been classified into small and large demand and contractors have given budget pricing on this basis.

Duty and stand-by heat exchangers have been allowed for in each building. Each heat exchanger will be sized with a capacity to deliver 60% (total in aggregate 120%) of the heating and domestic hot water demand of each site. Costs can be reduced by using brazed plate heat exchangers.

CAPEX
Thermal spine connections and tie-in costs have been based on multiple contractor quotes to provide a high level of accuracy for economic evaluation. See connection details on Table 9.

	Connection Pipework and Civils	Building integration	Total Tie-in Cost
YMCA (Hostel & Resid)	£186,014	£63,155	£249,169
Police Headquarters	£195,252	£62,749	£258,002
Civic Offices	£48,952	£40,652	£89,604
Central Library	£87,444	£39,285	£126,728
B3.3N Pre-Planning	£106,044	£32,312	£138,356
1-199 North 9th Street Flats	£41,254	£42,686	£83,939
CBXIII – Pre-Planning 1200 site	£50,530	£55,781	£106,310
C3.1/2 Pre-Planning	£48,952	£40,367	£89,319
B4.1-B4.3 Pre-Planning	£84,745	£135,003	£219,748
Magistrates Court	£48,632	£96,520	£145,152
County Court	£48,313	£73,478	£121,791
Santander House	£50,961	£85,710	£136,671
Witan Gate House	£54,215	£77,587	£131,803
Central Business exchange	£49,468	£84,993	£134,460
Midsummer court	£56,197	£49,571	£105,768
Exchange House	£56,197	£40,351	£96,548
401 Grafton Gate	£45,911	£38,020	£83,931
Jurys Inn	£48,817	£77,084	£125,901
Avebury House	£91,604	£28,113	£119,718
Home Retail Group	£56,197	£80,893	£137,090
Ramada Encore	£65,120	£60,018	£125,138
Holiday INN	£56,197	£36,158	£92,356
Westminster House (Allianz	£50,440	£56,645	£107,085
Travelodge	£72,384	£57,819	£130,203
Sovereign Court	£69,626	£47,333	£116,958
Silbury Court	£98,879	£47,333	£146,212
Ashton House	£145,070	£35,200	£180,269
Norfolk House	£128,133	£19,746	£147,880
Lloyds Court (Refurbishment)	£91,966	£42,873	£134,839

Table 9 - Building Connection CAPEX

Building integration including heat exchangers and metering currently form a large percentage of connection costs, and these costs have been developed with specialist contractors. This integration is sight unseen and it is likely that these costs can be lowered based on detailed design including site inspections.

Most sites will require hard digs for pipework trenching, with most areas around Milton Keynes central either paved on concrete.

6.3. Private wire

Basis for design

The private wire distribution system will be based around an 11kV ring feeder, with a number of ring main substations based locally to connections. Substations will include ring main unit, transformers, with associated equipment and will supply customers at LV. Duplicated backup from the DNO Western Power is likely to be required to provide security of supply for customers. An allowance has been made for 8 substations supplying LV power to 14 sites, built out over 10 years.

As opposed to the thermal network which is interconnected between the existing new energy centres, electrical connections to the existing and new energy centre will be entirely separate networks. As discussed in Section 6.1, this is due to electricity supply license regulations which limit private wire networks to 5MWe supply.

Although implementation of the scheme is not adding any additional load to the western power network - most of the time it will in fact be reducing overall network load due to the natural gas CHP - it is the transfer of site loads from their existing LV supply to HV supply which impacts the DNO's network.

Initial contact with western power has indicated that there are currently limitations on the 11kV supply network which may have caused issues with connection if it was needed immediately. Connection is not projected to be needed until 2026, however it is recommended that negotiations with the DNO be commenced at an early stage.

Keeping with industry best practice we have referred to the DNO's existing service drawings when considering network routing and costing. A copy of these drawings is provided separately in an electronic file.

The electrical cabling will be laid in cable ducts or conduit sharing the same trench as thermal pipework.

The existing electrical network will be built-out to capacity as per the assumed schedule (Connections 1-8, 6 excluded), with following connections (9-15) being installed together with heating pipework, and brought online with the new energy centre. This approach allows a large electrical load of 6 buildings to be brought directly onto the new energy centre for 2027, with electrical revenues as far forward as possible, maximising value.

CAPEX

Electrical Connections

Allowances have been made for LV cables to be laid from the local ring-main substation to the buildings (installed in conduit through shared trenches with pipework). Integration is relatively straightforward, with cables brought directly to the site's MSB and a simple changeover of supply, and an allowance for additional metering as required.

	External cabling and ducting	Internal cabling and integration	Total
YMCA (Hostel & Residential)	£13,070	£12,500	£6,078
Police Headquarters	£13,742	£12,500	£7,921
Civic Offices	£2,800	£12,500	£9,678
Central Library	£5,600	£12,500	£4,167
B3.3N Pre-Planning	£6,720	£12,500	£3,788
1-199 North 9th Street Flats	£2,240	£12,500	£2,500
CBXIII – Pre-Planning 1200 site	£2,576	£12,500	£2,500

C3.1/2 Pre-Planning	£2,800	£12,500	£2,500
B4.1-B4.3 Pre-Planning	£4,480	£12,500	£2,500
Magistrates Court	£2,800	£12,500	£11,876
County Court	£2,800	£12,500	£11,876
Santander House	£2,240	£12,500	£4,064
Witan Gate House	£2,576	£12,500	£3,317
Central Business exchange	£2,240	£12,500	£41,487
Midsummer court	£2,800	£12,500	£17,167
Exchange House	£2,800	£12,500	£33,243
401 Grafton Gate	£2,240	£12,500	£27,688
Jurys Inn	£2,800	£12,500	£32,728
Avebury House	£5,600	£12,500	£12,785
Home Retail Group	£2,800	£12,500	£9,342
Ramada Encore	£4,032	£12,500	£8,547
Holiday INN	£2,800	£12,500	£27,364
Westminster House, Allianz	£2,800	£12,500	£5,818
Travelodge	£4,480	£12,500	£9,375
Sovereign Court	£4,032	£12,500	£17,571
Silbury Court	£6,160	£12,500	£3,688
Ashton House	£9,520	£12,500	£15,925
Norfolk House	£8,288	£12,500	£16,488
Lloyds Court (Refurb)	£5,600	£12,500	£10,517

Table 10 - Private Wire Connection CAPEX

It has been assumed that civils costs for private wire network are minimal as trenching is being shared with the pipework, which has already been costed.

Electrical Substations

Ring main substations have been preliminarily laid out and sized, with pricing estimates based on information from contractor and reference projects.

Substation Pricing	Price	Number of
500 kW	£40,000	3
1000 kW	£50,000	3
3000 kW	£60,000	2

Table 11 - Private Wire Substation CAPEX

Spine Sections

An additional £162,000 has been allocated to 11kV cabling and ducts, located in shared heating trenches. This has been reached in consultation with specialist contractors and results in a cost of approximately £100 per metre.

6.4. Operation

As explained in Section 5, the software energyPRO has been used for the core energy analysis. Efficient operational methodology would be developed in the same way. In the case of heat, each energy conversion unit whether a boiler, CHP or heat pump is assigned a priority in each simulation period (in this case 30minutes). The priority number is actually the cost of heat in £/MWh. In the case of a boiler this calculation is relatively simple: the cost of heat is simply the gas price plus any taxes divided by the efficiency of the boiler.

In the case of CHP the value of the electricity is taken into account. This value may vary half hourly and include a large number of different revenues/costs such as STOR, Triads, DUoS charges as well as the price of electricity. Where a private wire demand is included - as in this case - the software calculates a weighted value based on an estimate of how much electricity might be exported vs import offset, taking into account their potential to turn down and the operation of other units which might supply that demand. The units with the lowest number are assigned in the simulation first. Other physical attributes and settings may override this of course. If a unit has a minimum turn down which is higher than the available demand the unit won't be allowed to operate, for example.

The graphic below shows the cost of heat/priority numbers in a week in January. The boiler (in red) is a flat line – it costs £29 per MWh but for the two CHP units the cost of heat is actually negative and variable i.e. it would pay to operate in power only mode most of the time. The two hour period where the cost falls to low of -£1000 is due to the inclusion of TRIADs in the model. These have been simulated as twenty lots of two hour periods on the coldest days between November and February. The actual payment has been averaged across these periods. This simulates operation on a TRIAD warning service.

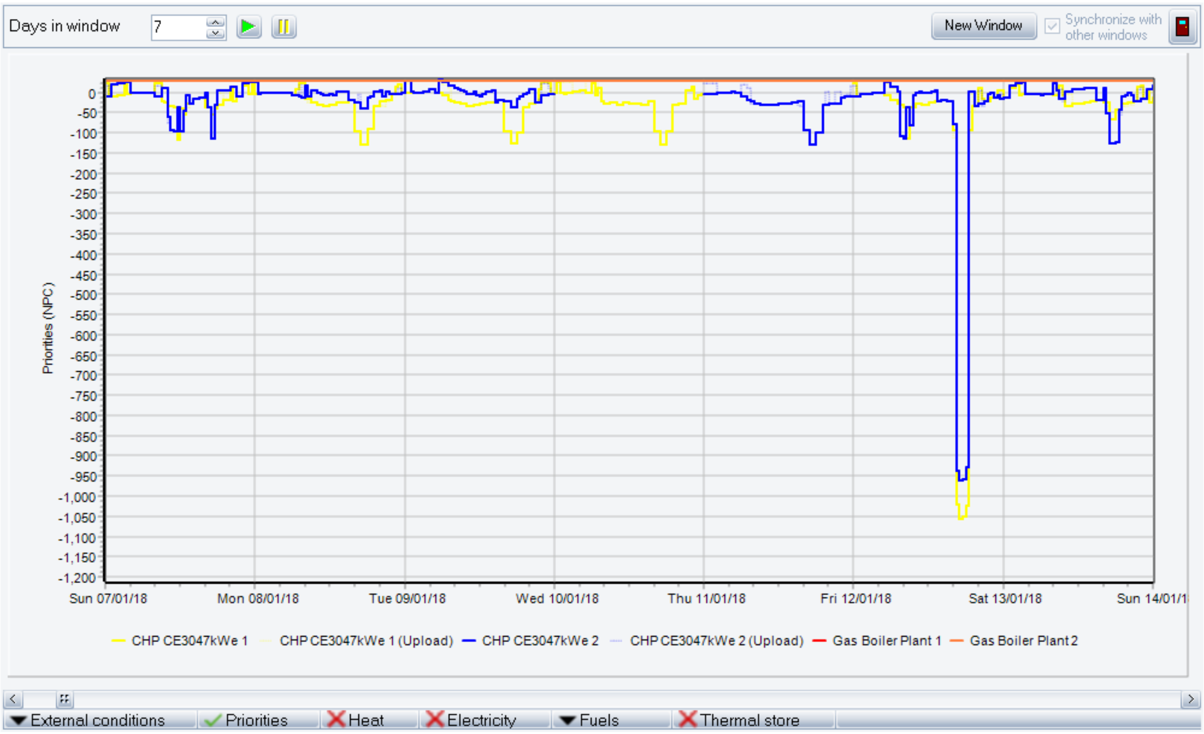


Figure 13 – Cost of heat calculation

The impact of the prioritisation can be shown below. This includes the operation of the thermal store. This is the base case model where the heat demand (top graph) is still quite low. For most of the time one engine is sufficient to supply the demand and the second engine only starts up periods of high electricity prices such a TRIAD or STOR calls. Thursday is day where maintenance downtime has been simulated for CHP1 hence CHP2 operates alone on that day. The thermal store plays a significant role allowing the 2 engines to avoid the low demand / low price night time periods. Heat demands are satisfied by the store in these periods. The content of the store can be seen rising and falling in the bottom graph of the three below.

Figure 14 – Simulated operation

Prior to integration of new energy centre.

For any given interval, energyPRO analyses the consumption and operational characteristics of the system and chooses the optimal financial combination by balancing all factors including:

- Electricity and Heat demand of system
- Thermal stores
- Availability and operation of CHP
- Gas and electricity prices

The current Thameswey operated scheme has been modelled and a base case, and simulated results have been compared against actual operational data to prove accuracy.

Entire scheme

Thermally, the two energy centres are integrated and loads are modelled from a shared perspective. From a technical perspective, close coordination between the operation of the two energy centres would be necessary to provide efficient and optimized operation of each.

Under a single or shared operation scenario, all plant would be treated as a single energy source equipment optimized accordingly. Under a two operator scenario, close coordination between each energy centre, with methods of cost transfers between entities to allow for efficient operation, improving efficiency for each through shared infrastructure and added redundancy. If each energy centre was operated completely separately, each would need to be controlled by demands of their customers and operational efficiency would reduce.

7. Economic Analysis of the Business Case

The following economic analysis has been prepared to clearly break down the costs and benefits of various parts of the scheme. This approach ensures a high level of flexibility in the modelling, and clear and strategic direction for the business case.

7.1. Approach to economic modelling

With the approach to energy modelling for the system described as per Section 5, further techno-economic modelling has been completed to allow as much flexibility to be built into the financial model as possible. This allows for detailed scenario and what-if analysis' to be completed, providing a basis for sound commercial decisions moving forward. This model has been provided to the council to be able to adjust and simulate further variations in business cases themselves.

In order to gain this flexibility in financial modelling, EnergyPro has been run a total of 30 times, each time adding the next connection and progressively building up the output in stages from the baseline scenario through to the full 29 additional connections. This allows the marginal benefit of each additional connection to be calculated and therefore the additional revenues and expenditures phased in over time and varied on a case by case basis. This overcomes one of the key issues that is overlooked in many reports that disregard the length of time required to roll out a district heating scheme.

Separation of build scenarios

The build-out has been modelled as per the scheduled rollout programme shown in Section 4.3 and connections completed until the full capacity of the existing energy centre is reached. From this point, cash-flows have been modelled giving the scenario of extending the current network without building a new energy centre.

Following that, modelling extends this cash-flow analysis to include the new energy centre, all further connections and spine pipework gives a full view of the project. The difference between the two cash-flows is the additional benefit of expanding the scheme past the limitations of the current network.

This approach allows the appropriate valuation of the larger scheme when taking into account the additional capacity in the existing infrastructure. These relative values will form the basis of the commercial agreement scenarios between the various stakeholders as discussed in Section 9.4.

These scenarios are represented in the following economic analysis with the following names:

Extension Only
The extension scenario considers building out the existing Thameswey operated network to its full capacity, without any further capacity increase, i.e. taking up the existing spare capacity.

New EC and further connections
This scenario considers separately the installation of the new energy centre as well as all subsequent building connections.

Full Scheme
All OPEX and CAPEX associated with the *extension* to the current scheme, the new energy centre build, and all further connections. This gives a view of the project in it's entirety and is the sum of the two scenarios above.

It should be noted that all scenarios exclude all existing CAPEX and OPEX associated with the currently installed energy network. It is an assumption that maintenance schedules and costs for currently installed Thameswey equipment remain unchanged with increased utilization.

Adjustment of tariff structures

The baseline tariffs for calculating revenues in the EnergyPro model are based on those currently in place for the existing Thameswey scheme. Prices are based on 2014 energy rates so have been escalated accordingly in the tariffs below.

These tariffs have been developed from the business model developed by Thameswey, which is to focus on customers who either have individual boilers that require replacement, or on new builds, therefore incentivising the connection.

The rollout schedule discussed in Section 4.3 was developed around this business model, and therefore with the introduction of the new tariffs it is likely that customers could be brought on earlier and therefore the rollout schedule accelerated. For this new structure, upfront connection fees are considered a disincentive so have not been charged.

The business model proposed in this study aims to widen the customer base by offering a range of tariffs suited to the customer's needs. Three tariff structures have been set up and allocated to each customers, such that there is an equal weighting of each tariff, to provide a realistic rollout scenario.

	Heat	Electricity	Connection	Standing Charges
Tariff 1	100%	120%	0%	100%
Tariff 2	70%	105%	0%	80%
Tariff 3	80%	100%	0%	50%

Table 12 – Incentive Tariff Rates

Tariff 1 is a loose representation of the existing Thameswey model which incentivises customers joining the scheme by replacing their ageing boiler infrastructure completely. This incentive mechanism is that the district network will be the sole heat supply for the building which means that on-site boilers are not required to be replaced at end of life, offsetting a large capital expense.

This tariff rate is also suitable for new builds which are obliged by local regulations to connect to the network unless technically or economically unfeasible. Thameswey uses a high connection charge to recover the cost of integrating the individual buildings into the network, however this study has not considered the use of this revenue stream as varying tariffs was considered a better option from a rollout perspective.

Tariff 2 provides a reduced rate incentive for those customers that don't require boiler replacements immediately at the time of connection, and therefore require other incentives to join prior to this timeframe. They will still receive the benefit of not being required to replace boilers at their end-of-life, however will also receive reduced rates for Heat, Electricity and Standing Charges.

Tariff 3 is heavily discounted for all rates and is useful for expanding reach of the network to those customers that would not otherwise join.

Build out schedule and capital costing adjustments

As discussed previously, the initial build out schedule has been planned per Thameswey's experience in connecting clients to their current network on a boiler replacement or new build business model.

This rollout speed adjustment is important as with the introduction of other incentive tariffs, it is likely that this connection rollout can be speeded up and more connections made earlier.

Capital is considered as being spent in the year before heat sales, with a 1 year connection lead time.

Rollout Speed	100%
Stage rollout lead time (Years)	1
Modelled build price correction (thermal/electrical networks only)	100%

Table 13 - Modelled Build-out Adjustments

An overall capital price adjustment has also been built into the model allowing sensitivity tests to be easily conducted against a variety of scenarios.

Energy escalators

Realistic gas and electricity escalation rates have been used based on best available information as seen in Table 14 below.

Electricity escalator	3.5%
Gas escalator	2%

Table 14 - Modelled Energy Escalators

It is expected that although the wholesale price of electricity will remain relatively stable over the next 5 years, the price charged to consumers is likely to increase significantly due to new or increasing charges such as the CfD-FIT and Capacity Market. See Figure 15 for further details.

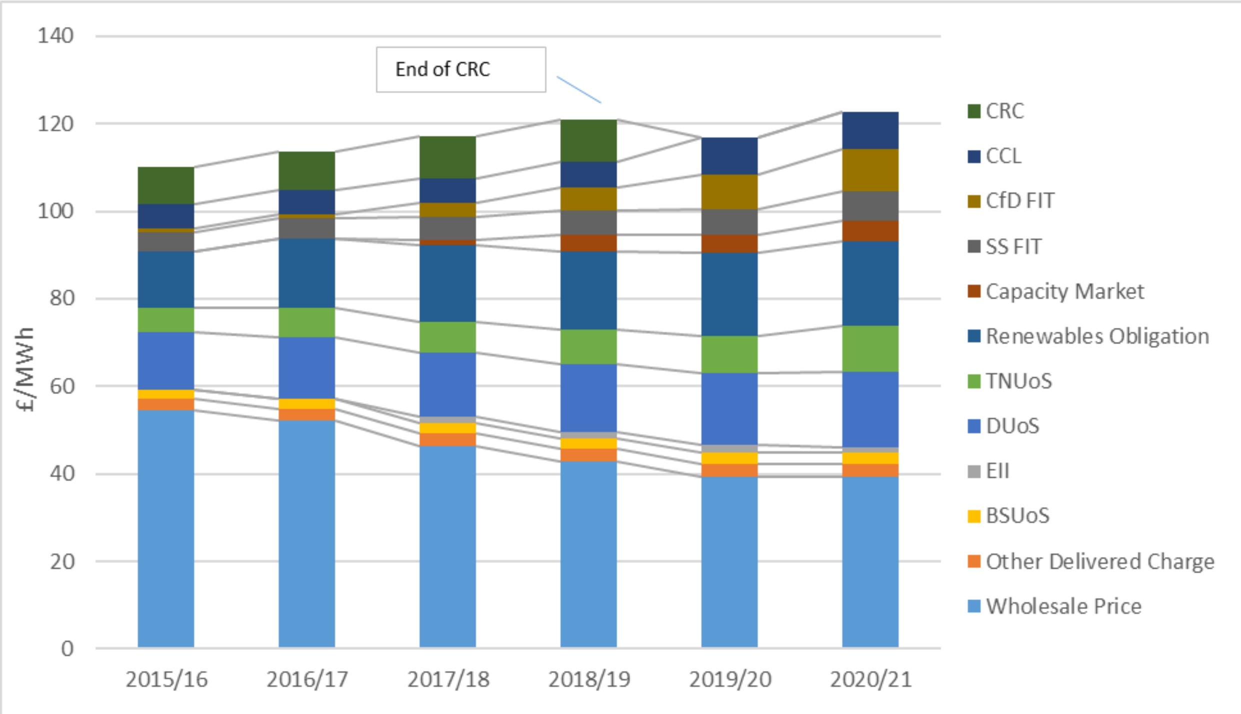


Figure 15 - Electricity Price Projections. Source: See Appendix H: Modelling and Costing Assumptions

This information allows us to predict that electricity prices will remain high, minimising the risks of adverse energy price movements, as discussed in Section 7.7.

Financial variables

For NPV purposes, baseline Discount Rate has been set at 4.5%, with a reasonable inflation rate of 2%. The 4.5% rate is representative of an expected private finance rate, which has been determined by discussions with private finance firms. This is specific to the rate which could be expected by Milton Keynes council in relation to a similar project.

These variables can be modified in the financial model and the sensitivity of financial outcomes to these are demonstrated in Section 7.6.

Discount Rate	4.5%
Inflation	2%

Table 15 - Modelled Financial Variables

7.2. Capital cost summary

Capital expenditure for the **Full Scheme** below has also been broken down into two sections

- **Extension Only** CAPEX to build-out the scheme to the capacity of the existing energy centre.
- **New EC and further connections** CAPEX to build new energy centre (EC) and add further connections to complete the schedule.

CAPEX	Extension Only	New Only	Full Scheme
Spine Pipework	£1,129,425	£1,553,794	£2,683,219
Spine Cabling	£76,041	£20,601	£96,642
Energy Centre	£0	£6,186,374	£6,186,374
Heat Connections	£2,035,010	£2,789,347	£4,824,357
Electrical Connections	£38,897	£20,477	£59,374
Substations	£216,884	£206,235	£423,119
Commissioning	£69,925	£215,537	£285,462
Design	£174,813	£538,841	£713,654
Project Management	£174,813	£538,841	£713,654
Legal	£174,813	£538,841	£713,654
Planning, Traffic Mgt etc	£69,925	£215,537	£285,462
Consultancy Charges	£104,888	£323,305	£428,193
Contingency	£279,701	£862,146	£1,141,847
Total CAPEX	**£4,545,135**	**£14,009,877**	**£18,555,012**

Table 16 - CAPEX Summary

CAPEX costs shown here includes the allowance for the transfer of 30% spine pipework costs from the existing to new scheme.

As standard input, a CAPEX allowance has been not been made to oversize the spine pipework, however this is likely to be a worthwhile invest, as discussed later.

Allowances for project fees have been set as a percentage of annual CAPEX fees, outlined in Table 17. These allocations were agreed upon by all parties before the commencement of the Round 3 study, and have been based around prior operational data gained from Thameswey on their existing scheme.

Fees allocation as % of annual CAPEX	
Commissioning	2%
Design	5%
Project Management	5%
Legal	5%
Planning, Traffic Mgt etc	2%
Consultancy Charges	3%
Contingency	8%

Table 17 - Fees Allocation

Heads of Terms.

A Heads of Terms document has been included in *Appendix E: Heads of Terms*, which would be suited to the construction of the entire scheme, and is based on and EPC contract, and could be tailored for use under governance structures such as Joint Venture, Council owned or ESCo.

The document has the following features:

- Includes both stages of installation; Piping and private Wire, and the Energy Centre
- Based on Fidic Silver or similar turnkey contracting book

- Based on an EPC contract as a separate agreement
- Could be used for a council funded option, Joint Venture or ESCO option
- Allows for independent sources of finance
- Option to hand over to separate company for Operation and Maintenance
- Front End Engineering Design (FEED) document would be the basis of the design
- Land is separately owned, and leased to the Energy Centre contractor

7.3. OPEX breakdown

OPEX numbers have been modelled with the industry-standard EnergyPro modelling software on a site by site basis. OPEX figures have then been modified per applied tariff structures and inflators before being assembled into the correct rollout schedule and analysed for financial outcomes. The scheme baseline figures for the existing network were modelled first, and the results checked against operational data from Thameswey on the existing scheme, to verify the accuracy of the model.

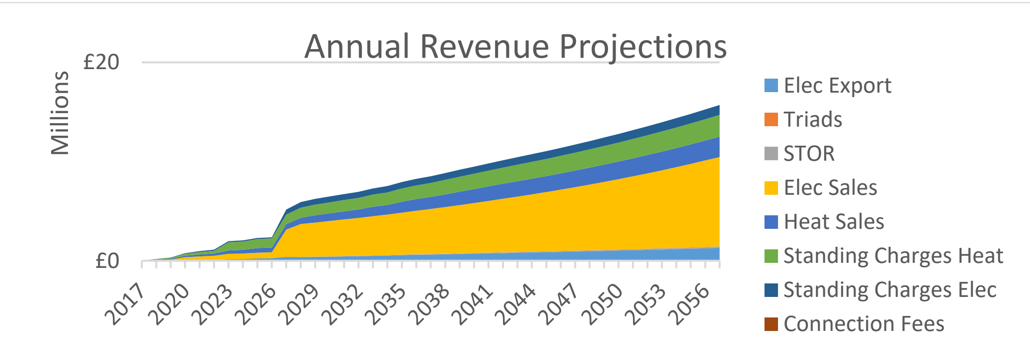


Figure 16 - Annual Revenue Projections

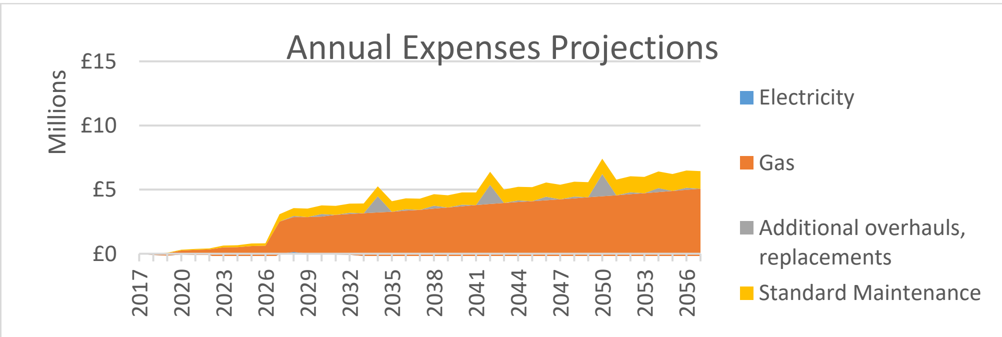


Figure 17 - Annual Expenses Projections

The ability to check these modelled outcomes against real-life collected costs and data is a key advantage in this case, as it allows verification that EnergyPro is correctly modelling the scenario. This gives additional confidence in the resulting data.

	Extension only	New EC & Further Connections	Full scheme
Revenues			
Elec Export	£16,720,377	£8,631,032	£25,351,409
Triads	-£2,472,807	£2,798,036	£325,229
STOR	-£11,917	£1,770,795	£1,758,879
Elec Sales Total	£38,086,155	£140,212,980	£178,299,134
Heat Sales Total	£22,721,169	£23,204,759	£45,925,929
Standing Charges Heat	£44,383,742	£9,601,085	£53,984,827
Standing Charges Elec	£5,739,444	£18,351,470	£24,090,914
Connection Fees	£0	£0	£0
Total Revenues	£125,166,162	£204,570,158	£329,736,320
Expenditures			
Electricity Total	-£38,781,489	£22,374,388	-£16,407,102
Gas Total	£60,394,970	£78,712,512	£139,107,482
New Energy Centre Overhauls and replacement	£0	£6,467,296	£6,467,296
Maintenance Total	£9,385,562	£22,432,396	£31,817,958
Total Expenditures	£30,999,043	£129,986,592	£160,985,635
Net Revenue	**£94,167,119**	**£74,583,566**	**£168,750,685**

Table 18 - OPEX Summary

These revenues and expenditures for the Extension to Existing and New Energy Centre will vary depending on commercial and financing agreement around shared infrastructure.

7.4. Financial Indicators

Full scheme

The results from the modelling are included in the table below. The project returns show a healthy 20% IRR over both 25 and 40 year timescales.

The 40 Year NPV is significantly higher than the 25 year figure, due to increased revenue from additional energy sales. Figures are inclusive of all operating expenses including energy centre plant replacement and overhauls.

	25 Year	40 Year
NPV	£18,318,646	£42,568,938
IRR	19%	20%

Table 19 - Economic Indicators

The NPV/CAPEX ratios are below 1, over both timescales with the long term 40 year view giving high returns in comparison to Capital expenditure.

As returns are spread over a very long time-period, Discount Rate plays a very large role in determining resulting NPV. The quantitative effect of this is investigated in Section 7.6.

Project Value Comparisons

This comparison provides a view of the overall potential values and returns if considering the extension to the existing Thameswey scheme as a separate project. This situation analyses the case where the existing scheme is built out with the selected plan, to full capacity, and those costs and revenues are included below.

As a consideration that the new energy centre and further connections will then share in the benefits of an already partially-constructed thermal network, the capital cost of the shared infrastructure has been split per predicted revenue over 40 Years which correlates to the new scheme paying 30% of the constructed spine costs back to the extension only scheme. If calculated over 25 years this could be a lower proportion of 10%. The resulting effect of this on the IRR of either scheme is minimal.

To make a fair comparison of values of the potential schemes, the cash flows of the new energy centre scheme have been extended past the original 2057 40 Year outlook to compensate for the build of the new energy centre in year 9. This gives the result of 40 operational years for each scenario.

	40 Year	
	IRR	**NPV**
Extension Only	27%	£30,234,764
New Energy Centre & Further Connections Only	12%	£29,273,653

Table 20 - Rollout Value Comparison

7.5. Resulting tariffs

Resulting rates for each site have been calculated, based on:

- Annual revenues calculated via EnergyPro
- Assigned tariff structure
- Energy Usage

Average rates for each tariff inclusive of standing charges, weighted to building consumption, have been calculated and are shown below in Table 21.

	Heat	**Electricity**
	*pence/kWh gas equiv**	*pence/kWhe*
Tariff 1	4.3	10.6
Tariff 2	2.4	10.9
Tariff 3	2.2	11.1

Table 21 - Resulting Incentive Tariffs

*Based on on-site boiler efficiency of 80%.

These indicate a comparison of the rates from the client's point of view, in regards to the alternative scenario of purchasing electricity from the grid, or producing heat on-site from natural gas.

Tariff 1 shows that a higher rate for heat as a reflection of the incentive for these sites benefiting from the savings of not installing new or replacement boiler plant. Tariff 2 and 3 show that from a heating perspective the rates are significantly lower than the 3p/kWh that would otherwise be paid purchasing natural gas, providing a strong incentive to join the network.

This represents on average, a 13% savings for heat, and a 6% savings for power for customers compared with typical market rates.

Differences in rates between building types, as well as time of consumption rate variations both affect the average rate charged for each, accounting for the small variations in electricity tariffs.

Pre-adjusted EnergyPro modelled on and off-peak tariff rates are further outlined in Appendix I: EnergyPro modelling factors.

7.6. Sensitivity analysis

Sensitivity studies have been performed around the key risks identified that may affect project economic performance into the future. These risks have been identified as:

- Energy inflators, specifically the relative price movements between gas and electricity
- Discount Rate and Inflation
- Capital Cost
- Speed of rollout

All IRR and NPV figures in this section are shown as 40 year figures.

Energy inflators

Various energy inflation rates have been analysed using the financial model to determine 40 year IRRs. Electricity rates have been varied from 1.5% to 5.5% increase annually, and gas from 1% through 6% increase. The base case scenario if 3.5% for electricity, and 2% for gas.

		Electricity				
		1.5%	*2.5%*	*3.5%*	*4.5%*	*5.5%*
Gas	*1%*	16%	19%	21%	23%	25%
	2%	15%	17%	20%	22%	24%
	3%	12%	16%	19%	21%	23%
	4%	6%	13%	17%	20%	22%
	5%	-	-	14%	18%	21%
	6%	-	-	-	15%	19%

Table 22 - Sensitivity of 40 Year IRR to Energy Inflators for Entire Scheme

Taking for example a 14% cut-off point for project viability, it is found that given a relatively stable gas inflator, the electricity escalator would need to fall below 1.5% to cross the threshold. Alternatively, taking a stable electricity inflator, gas would need to increase beyond 5% per annum for 40 year IRR to fall below 14%.

More realistically, a situation for a small decrease in electricity (unlikely), and a small increase in gas (possible), does not affect the IRR beyond the threshold rate. There would need to be a movement of 3 percent in the adverse direction among either variable for a significant impact on project viability.

Financial Variables

Inflation rates and Discount Rate have been identified as having a possible significant effect on project outcomes. With the baseline Discount Rate having been specified as 4.5%, possible variations span 1% through 9%.

		Inflation			
		1%	*2%*	*3%*	*4%*
Discount Rate	*2%*	£93,113,905	£97,079,582	£102,422,600	£109,612,930
	3%	£61,360,180	£63,805,457	£67,098,277	£71,523,351
	4.5%	£41,056,945	£42,568,938	£44,608,703	£47,350,935
	6.0%	£27,828,489	£28,760,545	£30,024,803	£31,729,798
	7.5%	£19,047,264	£19,614,977	£20,393,732	£21,451,781
	9.0%	£13,110,327	£13,447,001	£13,918,719	£14,568,899
	10.5%	£9,024,119	£9,213,235	£9,489,156	£9,879,810

Table 23 - Sensitivity of 40 year NPV to Financial Variables

Inflation has a modest impact on financial outcomes, with a positive correlation between inflation rate and NPV. This is due to some charges being pegged to inflation and therefore increasing revenue accordingly.

Due to the majority of revenues coming in over a long period of time, even a small change in the Discount Rate has a very large effect on project NPV. High rates of capital will quickly push down project viability.

Capital Cost

A scenario of +/-20% CAPEX has been reviewed and the results are included below.

% of Predicted Build Price	40 Year IRR	40 Year NPV
80%	23%	£65,751,966.37
90%	21%	£64,964,366.64
100%	20%	£64,176,766.91
110%	19%	£63,389,167.18
120%	18%	£62,601,567.45

Table 24 - Sensitivity of 40 Year NPV and IRR to CAPEX

All capital expenditure occurs within the first 25 Years of the project, so if taking the long term investment view of this project, reductions in the NPV are modest with increases in capital expenditure.

Speed of Rollout

Looking at the sensitivity of project financials against the speed of rollout an interesting effect comes through. IRR is more sensitive to bringing forward large capital spending, so although modest, an increase in rollout speed causes a reduction in project IRR. This is opposed to the overall 40 year NPV which increases due to higher revenue levels delivered earlier in the project. The risk of delayed rollout is relatively low, with a 25% reduction in connection speed causing limited effect on the IRR, with a 6% drop in project value over 40 years.

% of Scheduled Rollout Speed	40 Year IRR	40 Year NPV
50%	19.72%	£50,955,500.43
75%	20.06%	£60,481,896.09
100%	19.90%	£64,176,766.91
150%	19.40%	£68,691,616.07
200%	18.52%	£70,822,835.48

Table 25 – Sensitivity of 40 Year IRR to rollout speed

7.7. Adverse Scenarios

In addition to the risks outlined in Section 0, scenarios resulting in adverse outcomes have been modelled and are outlined in Figure 18 below.

20% Higher Capital Cost

This scenario covers cost over-runs and scope expansion as well as situations whereby thermal and electrical loads are not as high as expected. This would mean that for full energy generation and revenue collection potential, more connections are required, leading to higher capital expenditure.

Adverse energy price movement

Any reductions in electricity prices, or increases in gas prices will have an adverse effect on project returns. CHP relies on a favourable "spark spread" to achieve economic efficiency, so this scenario considers the effect of gas prices rising faster than expected (3% inflator), and electricity prices rising more slowly than selected (2.5% inflator). As discussed in Section 7.1 this situation is unlikely to occur, as electricity prices are expected to continue to increase dramatically in the short term.

10% Reduced overall revenue

This scenario considers the risk of customers being unwilling to pay tariffs as high as those projected. In this situation, revenues will decrease without a significant and corresponding decrease in expenses.

The effect of each scenario has been modelled and the resulting 40 year IRR and NPV are shown below.

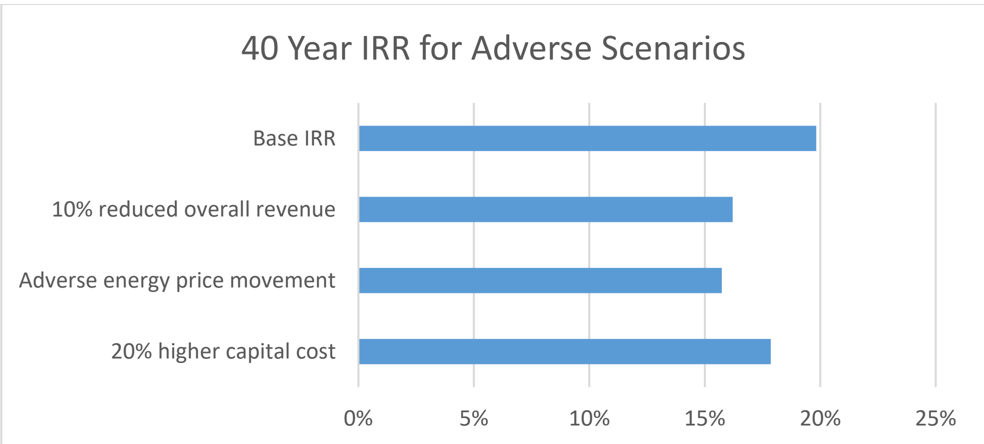


Figure 18 - 40 Year IRR for adverse Scenarios

Notably, adverse movements in energy prices have a large impact on project IRR, with over a 5% reduction from the baseline scenario.

Also, it is important to note that cost over-runs or other capital price increases have a limited effect on project viability.

These finding demonstrate that while there are multiple important factors in determining project outcomes, there should not be any stumbling blocks that should affect project viability drastically.

7.8. Impact of scheme on key social criteria

This scheme aligns effectively with the following social criteria relevant to the local authorities objectives and drivers.

Supportive business environment

An expanded energy network will provide a larger number of local businesses the opportunity to access green, reliable, low maintenance heat for reasonable prices, lowering operating costs and therefore promoting the development of local business.

Energy poverty

Delivering reliable low-cost heat to residential properties lowers energy costs for consumers and can potentially support energy poverty reduction goals. Possible application of specifically discounted rates for low-income consumers.

Local employment

Major construction projects such as this will engage local businesses and simulate the local economy, providing jobs for local residents throughout the lengthy project period.

Green and resilient infrastructure

Developing sustainable infrastructure that is adaptable to suit future changes ensures that the financial and carbon viability of the network continues long into the future.

Carbon reduction

Delivering low-carbon heat supports not only the reduction targets of council facilities, but also promotes the up-take of low carbon energy sources throughout the community. It provides a platform for heat distribution that is flexible enough to allow for integration of future technologies.

8. Carbon Impact

Carbon reduction achieved in the Heat Network (including system losses) is based on the following methodology:

1. Annual carbon saving = Baseline carbon emissions – Anticipated scheme carbon emissions.
2. Baseline carbon emissions will assume gas-fired boilers supply all heat and supply of electricity from the grid. This is the case for all new customers being considered for this scheme.
3. The anticipated carbon emissions will be calculated including all fuel and energy use required to deliver energy to consumers.
4. Emissions factors taken from the latest guidance from DBEIS on greenhouse gas reporting will be used in all calculations of carbon emissions.

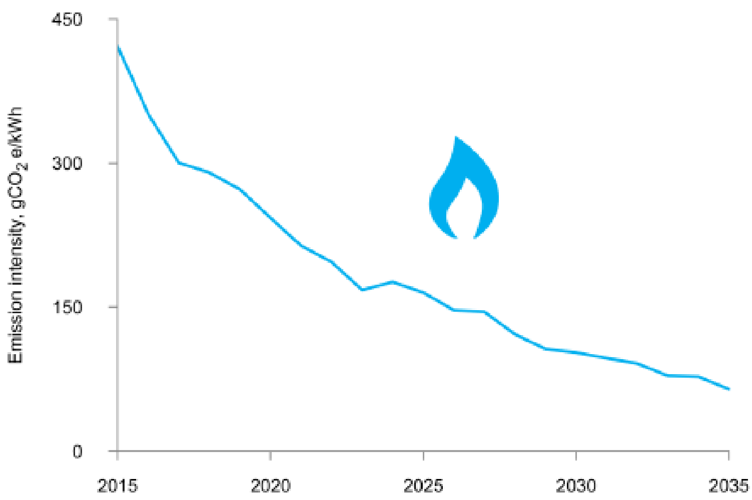
8.1. Assumptions

Calculation of the carbon savings includes:

- Baseline annual carbon emissions
- Anticipated scheme annual carbon emissions
- Annual waste heat consumption of plant
- Annual gas consumption of thermal plant
- Annual electrical consumption of thermal plant
- Annual electrical consumption of all ancillary plant (excluding pumping)
- Annual electrical consumption of pumping
- Annual losses associated with thermal distribution of Primary Heating Network
- Annual thermal energy delivered to Customers

The electrical grid is projected to decarbonise in the coming decades and therefore the benefit of generating power from natural gas while utilising waste heat will decrease.

The figure below is taken from the *Updated energy and emissions projections 2015*, DECC, and shows the projected pathway of grid emission intensity reducing to 0.1 kg/kWh by 2035.



Source: *Updated energy and emissions projects 2015*, DECC

Figure 19 - Grid Emissions Intensity Projects

These figures have been tempered for the purposes of projecting the emissions intensities for future years, using a target of 0.15kgCO2e per kWh by 2045.

8.2. Carbon savings of the energy network

The scheme has been modelled using the above emissions escalation equation and annual as well as cumulative carbon savings are predicted as per Figure 20 below.

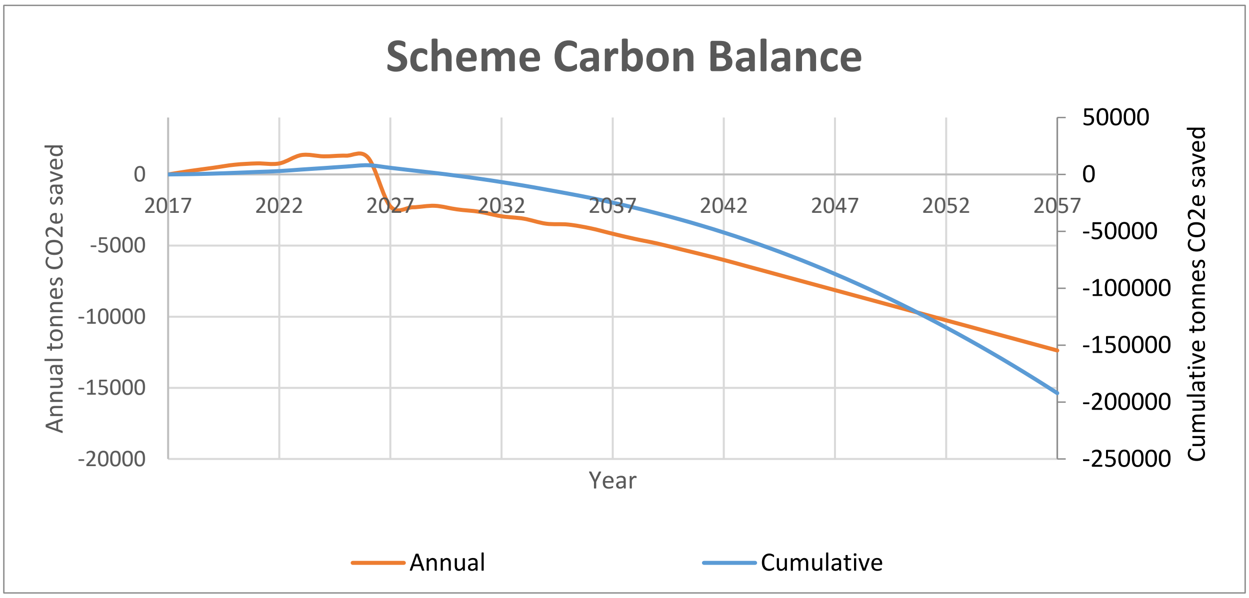


Figure 20 - Annual and Cumulative Carbon Savings Prediction

The area between the curves and the zero line show the relative amount of carbon savings/costs over time. The above graph is representative of the predicted rollout schedule, and the annual carbon benefit of the system as shown by the orange line drop below zero by 2029 and quickly offsets the carbon benefits produced during the years of operation up to that point.

Looking at Figure 21, this represents varying the rollout speed and the resulting effect on the annual carbon savings.

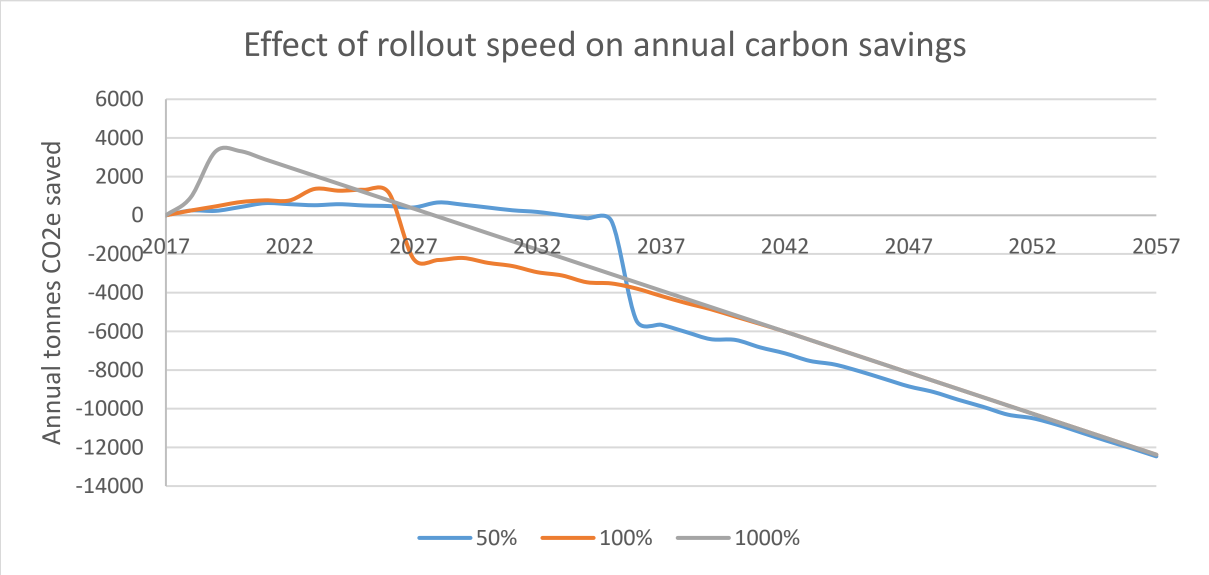


Figure 21 - Effect of rollout speed on annual carbon savings

A faster (relatively immediate) rollout speed, represented as 1000% in the above graph shows a markedly better savings initially from higher output earlier, while the carbon intensity of the grid remains high. The sharp decline in both is due to the build of the new energy centre and bringing on new electrical loads, where full waste heat usage is not possible. Overall efficiency decreases during this time, and under the standard rollout schedule scenario, the project fails to return to a positive carbon benefit after this time due to the falling emissions factor. This suggests that from a carbon reduction perspective, that unless the scheme can be rolled out quickly and the new energy centre built almost immediately, a new natural gas CHP-based energy centre will not be an efficient solution.

	Year of neutral benefit *(zero point)*	**Carbon savings up to that year** *tCO2e*
50%	2034	6,660
100%	2027	8,059
1000%	2028	18,898

Table 26 - Effect of rollout speed on Carbon Abatement

At the time where natural gas fired CHP can no longer deliver low enough carbon intensity energy to compete with the grid, lower carbon intensity sources of heat and electricity can be fed into the existing infrastructure to bolster the carbon reduction potential of the system. Options for this are discussed in Section 8.4.

8.3. Carbon savings on a site basis

Marginal annual carbon savings for the addition of each site at *current* emissions factor levels have been calculated below in Table 27 - Site Carbon Savings.

Grid Electricity Scope 2 + 3 : 0.44932 tonnes CO2e per kWh

Natural Gas Scope 1 : 0.18400 tonnes CO2e per kWh (HHV basis)

		Annual Carbon Savings *tCO2e p.a.*
YMCA (Hostel & Resid)		264
Police Headquarters		263
Civic Offices		70
Central Library		73
B3.3N Pre-Planning		176
1-199 North 9th Street Flats		90
CBXIII – Pre-Planning 1200 site		107
C3.1/2 Pre-Planning		93
B4.1-B4.3 Pre-Planning	*	1063
Magistrates Court	*	53
County Court	*	32
Santander House	*	341
Witan Gate House	*	31
Central Business exchange	**	-1375
Midsummer court		503
Exchange House		635
401 Grafton Gate		195
Jurys Inn		241
Avebury House		108
Home Retail Group		353
Ramada Encore		66
Holiday INN		473
Westminster House (Allianz		232
Travelodge		39
Sovereign Court		101
Silbury Court		155
Ashton House		75
Norfolk House		83
Lloyds Court (Refurbishment)		53

Table 27 - Site Carbon Savings

Notes on Table 27 - Site Carbon Savings
*Limited representation as does not include electricity.
** Central Business Exchange includes electricity production for 5 previous buildings.

Savings range from 39 tonnes CO2e per annum for a small heat only user such as Travelodge through to over 1000 tonnes CO2e per annum for a large energy user with both electricity and gas supply such as the new *B4.1-B4.3.*

8.4. Opportunities for future decarbonisation

Reductions in the carbon impact of grid-purchased electrical energy can be made on the supply side by improving the mix between renewable and non-renewable sources, however opportunities for supply-side improvements in the natural gas network are uncertain. A recent study "2050 Energy Scenarios, The UK Gas Networks role in a 2050 whole energy system" by KPMG in collaboration with ENA and KIWA suggests there exists a significant opportunity for a decarbonized gas grid, however working towards a zero carbon future, the clear opportunity for the switch to carbon-efficient heating occurs on the demand side, with local thermal networks being an important method for distributing this heat. This therefore secures the future efficacy of the Milton Keynes district heating network.

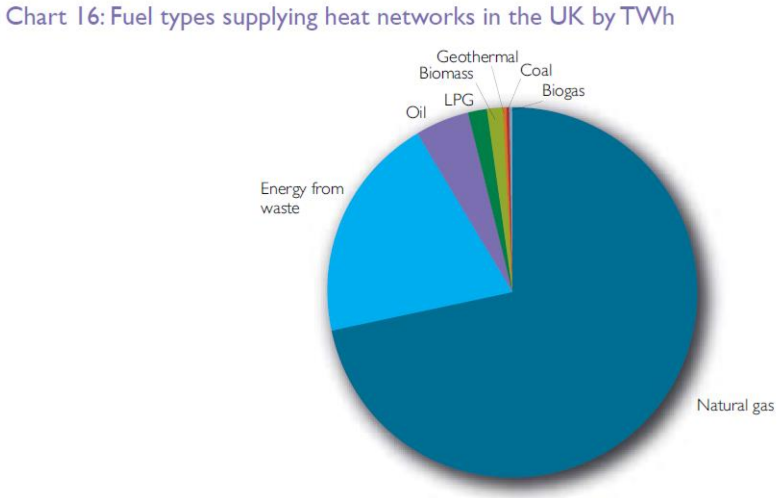


Figure 22 - Fuel Types supplying heat networks. Source: The Future of Heating: Meeting the Challenge (DECC, 2013)

As shown in Figure 22, as of 2013 the large majority (72%) of heat networks are fueled by natural gas fired CHP with supplementary boilers, however this is expected to decline with dropping life cycle costs of renewable energy sources and reducing carbon benefit of natural gas CHP, giving a strong preference for renewable heat sources.

There are a range of technologies currently available and undergoing development that will play a part in reducing the carbon impact of the UK's heat demand into the future. The applicability of various technologies will be based around the future development and economics of solutions, and possible options that may be considered into the future are discussed below.

Heat Pumps

Currently a mature technology, heat pumps use electrical energy provided by the grid or other sources to transfer heat from one area to another, and through the compression and expansion of an intermediate fluid, the temperature can be increased to a level usable for space heating and domestic hot water. Sources of stable heat can include industrial waste streams, large bodies of water such as lakes and rivers, stable ground temperatures, even the air.

Heats pumps market share will continue expanding to become an important source of renewable heat into the future as the electrical grid, and therefore the work input into the process, de-carbonises. Technology is currently available that can take a 5-8 degree source and deliver output temperatures up to 90 Degrees, suitable for large-scale heat distribution. For further details of various heat pump energy sources see table below.

	Industrial Process	Ground	Water	Air
Installation Difficulty	Varies depending on type of waste heat available. Straightforward for liquid waste streams.	Significant ground works required, either expensive vertical bore holes or shallow yet large area holes for heat transfer coils.	Straightforward heat transfer equipment, however restricted to locations near to source.	Simple installation with integration only for delivered heat.
Land Use	Limited area required for plant equipment only.	Horizontal type requires large amount of land area for heat transfer coils. Vertical bore hole type requires less however still significant. Ground above can be used for other purposes.	Limited area required for plant equipment only.	Dedicated area required for both plant equipment as well as large fluid-to-air heat exchangers.
Operation and Maintenance	Varies, however usually standard maintenance only of heat exchangers and plant.	Standard maintenance of heat exchangers and plant only.	Standard maintenance of heat exchangers and plant only.	In addition, condenser/evaporator fins require regular cleaning to maintain heat transfer effectiveness.
Stability of Heat Source	Varies, dependent on availability of waste stream.	Ground, especially vertical borehole style offers minimal temperature variation year-round.	Water temperatures of large water bodies remain relatively stable year round.	Air temperature fluctuates significant daily and between seasons.
Efficiency	Varies depending on temperature. Often relatively high quality waste heat available giving high COP.	Stable ground temperatures of approximately 10 Deg C gives consistent output and efficiency year round.	Stable water temperatures gives consistent output and efficiency year round.	Heating loads are generally larger with colder atmospheric temperature, which drops COP significantly. Average efficiency relatively high.
Sustainability	Heat source available as long as process remains, however limited by waste steam volume.	Ground heat source availability can decline over time. Use as heat sink in cooling cycle during hot weather improves sustainability.	Rivers and large bodies of water that are consistently replenished will remain at a stable temperature into the future.	Air temperatures will remain relatively stable in the long term.

Table 28 - Summary of heat pump technologies

Biomass Combustion Boiler

While currently a low market share (Figure 22), energy from biomass is likely to become an increasingly important part of the mix for future heat demand in the UK. Unlike conventional boiler plant which have fuel delivered on-demand through a pipeline, biomass requires significant storage and material handling facilities, impacting on the viability of urban sites.

Standard combustion of biomass with an associated hot water or steam heat recovery boiler is an established and proven method of heat and power generation. Power generation can be integrated through use of a Rankine Cycle steam system, should a steam heat recovery boiler be installed, or Organic Rankine Cycle (ORC) turbine system from lower temperature heat recovery.

Combustion boiler feedstocks can include:

- Wood waste
- Municipal waste
- Agricultural wastes
- Crops

Input waste processed in combustion systems generally have higher emissions compared to equivalent gasification or pyrolysis, however high quality feedstocks such as virgin or processed wood waste can deliver relatively low emissions levels for each technology.

There are significant questions being raised about air quality from biomass in towns and cities and Air quality LA officers are often resistant to large biomass boiler technology. Key problems however are in fuel supply including where from and at what price, how to deliver to site, where to store and how to keep dry. Concerns about safety of storage are also an issue. Also, RHI for biomass has reduced significantly and this has a significant effect on viability.

Gasification & Pyrolysis

Gasification & Pyrolysis are the processes of reacting organic material at high temperature in an oxygen limited environment. Under these carefully controlled conditions, organic material undergoes several reaction stages and produces a gas high in combustible CO and H2, known as synthetic gas (syngas).

This syngas, usually high in tars and other contaminants can be fired directly within a combustion chamber when combined with oxygen, with heat recovered in a steam or hot water boiler, and applied to a Rankine or Organic Rankine cycle steam system to generate power. Alternatively, the syngas can be scrubbed to remove contaminants and fired in CHP engine or gas turbine.

Gasifier and pyrolysis feedstocks can include:

- Wood waste
- Municipal waste
- Agricultural wastes
- Crops

Gasification for coal is an established technology, and there has been a resurgence in new biomass gasifier projects over the last 5 years. Biomass gasification, especially when producing both heat and power, is still in its infancy, with several high profile failed projects, however technology is improving with companies continuing to work to overcome the technical hurdles associated with this process.

Emissions around particulates and combustion efficiency is lower for gasification and pyrolysis plants compared to an equivalent biomass combustion boiler plant, so improvements in technology may see this preferred in urban areas where air quality is of high concern.

Biogas

Methane-rich digester gas can be obtained through a series of biological processes in which microorganisms break down biological matter in the absence of oxygen. After being treated, the resulting gas which contains on average 40-60% combustible methane (the principal component of natural gas), can be used in a gas fired boiler or CHP to produce energy.

Feedstocks for supplying anaerobic digesters include:

- Food and drink waste
- Processing wastes high in organic matter
- Agricultural residues
- Crops
- Sewage sludge

The process is sensitive to quality of feedstocks and temperatures, so inputs and process conditions need to be carefully monitored and controlled.

Feasibility is dependent on availability, quality and cost of feedstock, and capital requirements are often prohibitively high.

Carbon Capture and Storage (CCS)

Carbon capture and storage is a carbon sequestration process involving the removal and capture of carbon dioxide (CO2) from the emissions of burning fuels (usually fossil fuels), and securely storing this captured CO2 underground, thus preventing its release into the atmosphere.

This is an emerging technology, with implementation currently restricted to large-scale power plants and industrial processes (i.e. 400MW+), however it is likely that continued investment on the large scale will bring down the price and allow smaller scale implementations such as for district heating.

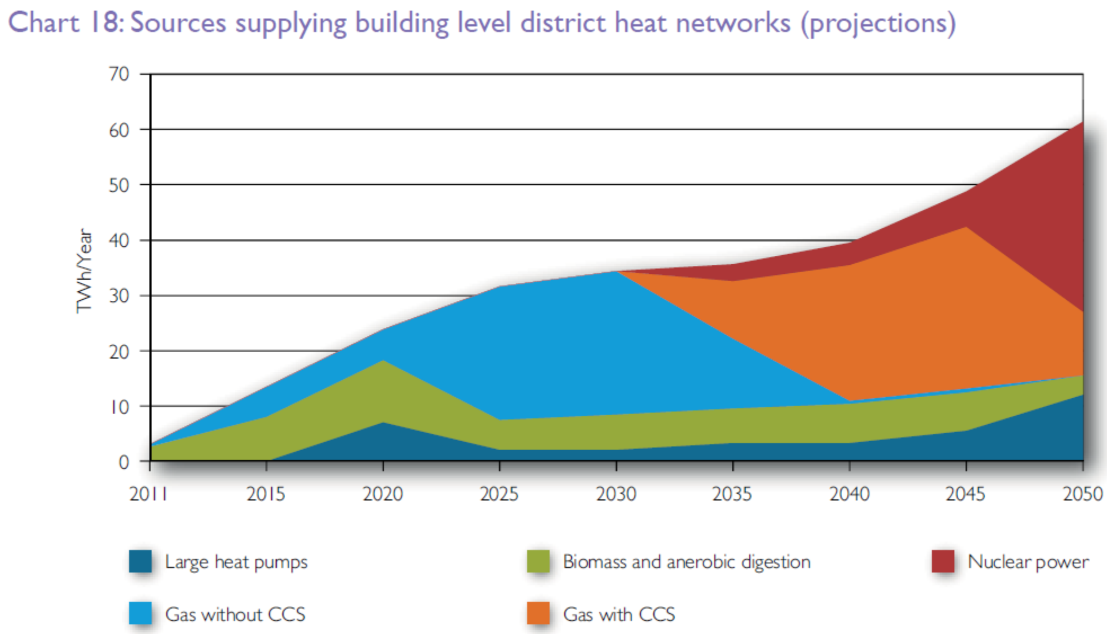


Figure 23 - Projections of future sources of heat for district level heat networks. Source: The Future of Heating: Meeting the Challenge (DECC, 2013)

According to future projection by the Department of Energy and Climate Change (The Future of Heating: Meeting the Challenge, 2013), gas fired CHP and boilers with Carbon capture and storage for district heating will start to emerge beyond 2030, once the natural gas vs grid electricity carbon factors become unfavorable for natural gas CHP, and the technology has been developed to scale down economically.

In addition, when combined with biomass combustion or gasification, carbon capture and storage can be used to give power production a carbon negative footprint. This occurs through grown biomass taking CO2 out of the atmosphere through photosynthesis, the carbon stores in the biomass being combusted, with CO2 emissions captured and stored underground. As it is purely a carbon reduction technology, future demand for carbon capture and storage will primarily be driven by the economics of the process decreasing to the value of carbon reduction into the future.

8.5. Future-proofing the Milton Keynes energy network

As technological progress stands currently, heat pumps from locally available stable temperature sources are likely to offer the highest value heating potential with low carbon impact. Possible local sources of heat that could be investigated include:

- New energy from waste plant
- Canal and River
- Waste heat from sewage treatment plant
- Other industrial waste heat sources in the vicinity

Initial investigation around the currently-proposed thermal network showed that these sources are likely to be too far away to prove viable in the short-term, however this may change in the context of an ever-expanding Milton Keynes network.

The Grand Union canal runs through the MK area but it is right on the edge of our red line boundary and initial assessment shows it is too far from any significant building loads to allow a SWSHP. The exception is MK hospital which is about 300m from the canal and 250m from the MK Marina. There are however two significant roads to cross to get canal water to a WSHP making it less viable. The waste burning plant to the NorthWest was not studies as it is considered too far from the red line boundary of this study. This can be assessed further at a later date.

There are several high-profile examples of similar heat pump district heating schemes such as the Drammen Fjernvarme Heat Pump in Norway, a 14MW district heating system taking heat from 8°C water from a local fjord and heating the local network to 90°C.

Biomass, and more specifically gasification may offer high potential for combined heat and power, with the possibility of a much higher electrical generation efficiency than that of a Rankine steam cycle biomass system. That said, gasification technology is not yet sufficiently developed to provide proven and reliable heat and power generation in a gas fired engine or turbine. As CHP-engines may be adapted to run on various types of gas, syngas from gasification or pyrolysis, or biogas from anaerobic digestion may provide a method of converting natural gas fired CHP engines to produce zero carbon electricity and heat.

Unlike gas or liquid fueled boilers, biomass powered heat generation has an intrinsic lag in the system, meaning the response to varying loads in slow. This is similar to CHP, with each more effectively operating as a base load boiler. Sufficient hot water storage will minimize large disruptions in transient demands, however it is likely that a stored or grid source gas fired boiler will be necessary to maintain sufficient transient system response.

When considering possible energy centre locations, thought should be given to possible future installation of biomass equipment such that:

-Extra space needed for biomass storage.

-Truck access requirements for biomass delivery.

Alternatively, a biomass based heating or CHP system could be situated at a different location just out of the urban centre, while remaining close to the network to minimize pipework and cable costs.

Should CCS improve such that it becomes economically viable on the smaller scale, this technology could be used an intermediate solution to reduce carbon emissions from the already installed CHP.

The uncertain carbon benefit of private wire networks in the long term

Further detailed analysis at the point of future investment will be required due to uncertainty around future pricing, new technologies and grid emissions factors. From a carbon minimization perspective, it could arise that the carbon factor of grid-purchased electricity is low enough that the carbon incentive of retaining or investing further in on-site power generation no longer makes sense.

While this uncertainty may impact the long-term business case for the continued expansion and development of the electricity network, it is unlikely to affect the decision to proceed with an electrical private wire for the following reasons:

- Limited extra capital is required for the electrical network, given that thermal network is to be installed. This is due to shared trenches and the 5MW limit peak demand limit giving a relatively small number of connection required to reach maximum network capacity.
- Revenue from electricity sales provides much of the project financial benefit, so gives a quick payback for the investment in capital infrastructure on both the thermal and electrical side.
- This financial benefit is at the start of the project where grid emissions factor is high, and therefore carbon benefits correspondingly high.

The decision would be made at a later point based on future carbon and financial goals as to whether future combined heat and power is suitable based on projected economic conditions. It is likely since infrastructure is already in place, that continued investment in electrical distribution would be economically feasible.

9. Delivery Options

There are many delivery model options available for a district heat network scheme, with varying levels of risk and investment by Milton Keynes Council. Given the favourable technical and economic performance highlighted in this report, there should be interest from third party as well as expansion by Thameswey or indeed by Milton Keynes Council.

Furthermore, HNIP funding is available for DHN projects where rates of return are seen as unfavourable by third party commercial investors, but have not been included in the economic assessment below.

9.1. Economic factors

The governance model selection should consider the key factors below:

Return on Investment (IRR)

Commercial investment will require the return on investment to be attractive in various stress-tested scenarios. The current economic climate is making ever lower costs of capital available for such Heat Network schemes, particularly as pension funds seek to lock in returns that would not have been considered previously.

Involvement with existing Heat Network

This report has highlighted that the expansion of the heat network spines would allow the surplus heat capacity of the existing Thameswey operated energy centre to be utilised. The same spines would also be used to supply additional customers beyond this via a new 5MW energy centre.

We have treated the initial expansion by Thameswey as one economic opportunity, and the new energy centre as a separate investment. This allows Thameswey to make a distinction between business as usual, and provides a vehicle to build out the heat network and expand the heating supply.

Hence there is a possibility to have two separate governance structures, one for each phase of the new scheme. Given the projected build out schedule for new connections will take 10 years to fully utilise the current energy centre's surplus heat capacity, it would make sense that the initial phase of investment is undertaken largely by the current operators.

It should also be considered that the future energy centre will require shared use of the spine, and also that additional investment is made in increased spine diameter. The mechanism for funding this additional capacity could be in the form of a shared capital investment from the second phase investment vehicle, or possibly via a pay for use of the spine at the time of use. It is anticipated that the return on investment would be higher for the former scenario, given that Thameswey's Discount Rate is likely to be higher than the alternatives.

Finally, any scheme that did not include co-operation between the existing and future energy centre operators, could result in competition in heat pricing between the schemes. While this would be a benefit to consumers, it would be a deterrent to any investors in the second scheme.

Connections and customers

The selected governance of the new scheme may affect customer willingness to participate. The involvement of the Council would be seen as a lower risk option, particularly for longer term connection contracts.

Energy Centre Location

The new location for the energy centre has not yet been identified, however provision has been made in the piping costs for a variety of locations. The current timeline for build out of the new energy centre is 10 years from now. There may be fewer options for location available at that time. Whether the land is council owned or privately owned will also impact on the potential governance structure.

Timeframe

While the current projection for the new energy centre is 10 years, this could be expedited by enhanced marketing and offering more attractive tariffs to new customers. In order for this to be feasible, the projected operating profits for the existing scheme would need to match, or exceed the current business case. This could be achieved by increasing the investment from the second phase investors to the shared piping network.

Investment from connections

Traditional investment models have not typically considered the customers as sources of investment. However, a single new and high usage end user could also consider a minority investment in a joint venture energy centre.

9.2. Scheme roles

The development and operation of a district heat network and energy centre offer a number of roles. Key stakeholders include Thameswey, the Milton Keynes council, building connections, property developers and third party ESCos.

Key roles for the development of the scheme include:

Asset Owner; heat network and energy centre

The party that invests in and owns the physical assets, including the heat network and private wire scheme as well as the energy centre infrastructure. There is scope to have separate ownership structures for the energy generation and distribution assets.

Asset Operator

The party responsible for the day to day running of the scheme. This would include all operation and maintenance required to generate heat and power, as well as maintenance of the physical distribution and metering network.

Energy Retailer

The party responsible for the retailing of the heat and power, as well as billing, and marketing for new connections.

The allocation of roles will depend on each stakeholder’s ability to provide funding, and affinity for risk. Milton Keynes Council may wish to transfer risks to an operator such as Thameswey or an ESCo, yet still invest in the scheme. The level of return expected by each party in this arrangement would depend on the level of risk being held by each party. The level of expertise and skills brought by the third party would also be a factor in the level of risk they would be willing to take on.

9.3. Council Involvement in the scheme

Whether a council is willing to invest in a district heating scheme, and their relationship with the private sector, will depend on a number of factors:

Financial

Should the rate of return be sufficient, there is the opportunity to attract investment from the private sector. Where the rates of return are too low, council funding or HNIP funding would be required. This scheme should be sufficiently attractive for private investors.

Discount Rate

Where schemes have a poor return on investment, a lower Discount Rate is often required. Typically, councils have access to funding at lower levels than availably privately. We have assumed a council funding cost of 3%, however private funding could be available at rates as low as 4%, depending on the risks transferred.

Availability of capital

The availability of capital to public and private sectors will depend on the risks involved for each party. The timeframe of this scheme is currently 10 years before the new energy centre is needed, so the assessment of risk would be based on prevailing market factors at that time.

Control of the scheme

The council may wish to have greater control over the scheme than would be acceptable to third party financiers. For example, the tariff levels may be capped, in order to make the town a more attractive destination for developers and investors, but would reduce the return on the investment in the energy centre.

9.4. Scheme commercial structures

One of the differentiators between the proposed scheme and district heat networks operated in other areas is the presence of an existing energy centre. The existing energy centre, with significant surplus capacity is undoubtedly a key stakeholder in the heat network expansion. Consultation with Thameswey regarding commercially acceptable approach to the commercial structures and financial arrangements is certainly a requirement before proceeding with investment options.

For the purpose of comparing several scheme investment scenarios, we have made the assumption that any scheme would need to be more financially attractive than the current business case being pursued by Thameswey. This is currently represented in the cashflow model as a capital transfer from the new energy centre operator to Thameswey, allowing access to the new pipework spine infrastructure. While this may not represent the final actual mechanism, it allows comparison on the basis of cost of finance, accepted IRR and varying legal costs of the mechanisms.

The options include:

Council owned and operated:

The Council would procure the construction of the scheme, and retain responsibility for running the plant. The council would operate and maintain the scheme, would have more control of operation, but would be taking on more risk. Any surplus or shortfall in operating revenue would be the Councils responsibility.

Council owned but not operated (DBOOM)

The likely ownership structure for the Council is a Design, Build, Operate and Maintain contract (DBOM), where a private contractor is engaged and responsible for the complete design, construction and operation of the scheme. In this case, the risk of capital cost and operating cost are transferred to the private entity, but the council would potentially retain liability for ensuring revenues are sufficient to make the scheme viable.

Joint Venture

A Joint Venture contract would be drawn up between the Council and a third party, possibly Thameswey or a private ESCo. The council could gradually increase ownership of the scheme over time, so that the higher risks at the outset of a scheme are borne by the third party. Once the operating cashflow of the scheme is established, there is a reduced risk for the Council in increasing ownership share.

Private ESCo

The scheme is designed, installed, owned and operated by a private ESCo company. There would be no risk for ownership and operation for the council.

As there are two separate schemes, the heat and power distribution network, and the new energy centre, we have considered the option of separate ownership structures for each. There is also the factor of the significant delay between build out of the distribution network, utilisation of spare capacity in the existing scheme and construction of a new energy centre.

9.5. Heat Network commercial structures

The heat and power network represents 60% of the capital cost, but does not in itself generate revenue. This presents an issue, as any shared investment between the owners of the current and future energy centres would potentially not benefit the future energy centre investors for 10 years. However, additional investment is required in a larger spine piping diameter, than would otherwise be required, in order to allow for the distribution to future connections to the new energy centre. This would likely limit or prohibit any private ESCo investment to the future energy centre.

A potential approach this would be a joint venture between Thameswey and the Council, where the Council funded the additional capital required to oversize the piping, and allow for separate private wire cable costs. There is also an opportunity for the Council's funding element to be provided by HNIP, particularly as this is seed funding that would enable a significant future expansion of the Milton Keynes heat network.

9.6. Future Energy Centre commercial structures

The future energy centre commercial structure would be suited to any of the three structures discussed above; Council funded, Joint Venture of Private ESCo.

When the future energy centre is constructed, there are several options to allow access to the distribution network;

The Council could retain ownership, and charge a usage tariff to the new energy centre

The Council could transfer ownership, to the new energy centre or Thameswey

The table below shows the effect of the Discount Rate on the NPV of the new energy centre. Similarly, there will be a reduction in IRR as interest rates increase. As each commercial structure benefits from differing capital costs, this will also have a bearing on the governance structure selected.

Discount Rate	**Extension to Existing** *40 Year NPV*	**New EC & further connections** *40 Year NPV*
Baseline (3%)	£30,234,764	£29,273,653
3%	£42,522,943	£46,310,152
4%	£33,788,077	£34,138,028
5%	£30,234,764	£29,273,653
5%	£27,122,540	£25,060,982
6%	£21,983,799	£18,216,046
7%	£17,981,571	£12,994,594
8%	£14,832,922	£8,963,976
9%	£12,331,141	£5,814,153
10%	£10,324,004	£3,321,131
11%	£8,698,523	£1,321,732

Figure 24 - 40 Year NPV of separate stages

9.7. Risk Summary

Both the expansion of the heat network and the additional of generating capacity have demonstrated solid technical and commercial performance. However, there are several scenarios where adverse conditions can affect these outcomes. A risk log, stating the external factor and our recommended mitigations is included in *Appendix A: Risk Register*.

Risks to the commercial performance have also been analysed in detail in a previous section of this report, which identified capital cost, energy price and build out speed as key risk factors that should be considered.

10. Recommendations and next steps

Based on the findings from all phases, the following recommendations can be made for moving forward.

1. **Provide incentives for uptake of district energy quickly.** There are still a vast number of significant heat and energy loads located in central Milton Keynes that are not yet connected to a thermal network presenting a good business case for significantly expanding the Milton Keynes heat network. The current operator's planned connection schedule is relatively slow and the requirement for an expansion of generation capacity would not be reached until approximately 2026. Any council incentives provided to local businesses to connect to a low-carbon energy network would reduce the rollout timeframes, benefiting all parties.
2. **Oversize all new heat network infrastructure.** Any new spine pipework infrastructure investments by the current operator should be oversized to cater for additional loads of a second energy centre as well as an allowance for further extension of the Milton Keynes heat network. The increase in capital associated with a larger pipe size is minimal in context of the overall works of an energy network. Rather than tapering the spine pipework towards the end of the network, spine pipework should be of a large size throughout to allow increased flexibility for energy centre location. This is especially important considering the opportunity for biomass generation which due to factors discussed in this report would likely be positioned just outside of the central city.
3. **Subsidise current operator to provide increased capacity in network.** As the current network reaches its installed capacity after approximately 12 additional connections, an increase in total installed pipe size would not support the business case of the current operator, so a financial incentive would be required to ensure the rollout of a network that will cater to future opportunities. Methods of this transfer are discussed in the report body.
4. **Switch to low-carbon heat sources if not building new energy centre soon.** Based on current forecasts for grid de-carbonisation, on the current rollout schedule the additional energy centre to be installed in 2026/2027 would be unlikely to provide a significant or even positive carbon impact with standard natural gas CHP. An investment in high-carbon infrastructure would be unlikely to be supported from a public sector perspective, so at this time a report into the most effective low-carbon heat and power generation should be commissioned. This will ensure the long-term future of the Milton Keynes energy network.
5. **Roll out connections as quickly as possible by offering incentive tariffs.** It would be of significant benefit to long-term project value both from an economic and environmental perspective for rollout speed to be significantly increased. Uses of incentive techniques through zero or low connection fees, as well as discounted tariffs will encourage earlier uptake from potential customers. Offers for tariff rates will need to be carefully considered through discussions and surveys of these potential customers.
6. **Choose the commercial structure which caters for the lowest possible cost of finance.** Financing rate presents the greatest effect on the value of the project, so funding options at the time of capital expenditure will determine the most effective commercial structure for the venture. It is likely that a publicly funded source, if available, will present the lowest available rate suitable for the long payback of the energy network.
7. **Explore farther afield energy-dense thermal network opportunities.** Phase two report concluded that there is the possibility of setting up the Hospital and Woughton area as a separate energy network as it is uneconomic to connect this area to the central Milton Keynes network. This could be constructed in parallel and could provide benefits in its own right.

Appendix A: Risk Register

Methodology

Consequence Score (1-5)		
Score	*Consequence*	*Description*
1	Insignificant	Negligible impact on business case
2	Minor	Minor impact on business case of project. Reduction in long-term value of project
3	Moderate	Large impact on long-term financial benefit of project
4	Major	Causing severe financial losses
5	Catastrophic	Irreparable damage to commercial parties involved

Likelihood score (1-5)		
Score	*Frequency*	*Description*
1	Rare	This will probably never happen
2	Unlikely	Do not expect it to happen but it is possible it may do so
3	Possible	Might happen occasionally
4	Likely	Will probably happen
5	Almost certain	Will undoubtedly happen

CONSEQUENCE	**LIKELIHOOD**				
	Rare (1)	*Unlikely (2)*	*Possible (3)*	*Likely (4)*	*Almost certain (5)*
Catastrophic (5)	**5**	**10**	**15**	**20**	**25**
Major (4)	**4**	**8**	**12**	**16**	**20**
Moderate (3)	**3**	**6**	**9**	**12**	**15**
Minor (2)	**2**	**4**	**6**	**8**	**10**
Insignificant (1)	**1**	**2**	**3**	**4**	**5**

Risk Score	*Risk*	*Description*
1-3	**Very Low risk**	Risk will not require additional actions or considerations
4-7	**Low risk**	Minor risk to commercial or technical development of the project that is unlikely to warrant further actions
8-14	**Significant risk**	Moderate risk that will require careful consideration in design and final business case to ensure that it has been reduced where possible or other measures developed.
15 or more	**High risk**	Major financial or technical challenge for the project that almost certainly requires additional control or mitigation measures.

Project development and installation

Risk or Challenge	*Possible Mitigation*	*Consequence*	*Likelihood*	*Risk*
Capital costs exceed budget figures	• Detailed budgeting for each stage of the project • Use of piping contractors familiar with the Thameswey scheme, to mitigate against unknown underground services • Use of an OJEU compliant procurement organisation, such as District Energy Procurement Agency, in order to benefit from procurement terms and access to expertise	2	3	Low
Suitable sources of finance	• Use of Council funding can reduce project financing risk • Ensure that the scheme economics are suitable for several sources of finance, such as an extension of the Thameswey scheme or other ESCO • Ensure the scheme is suitable for HNIP, by considering low-carbon options	4	2	Significant
Disruption of road network due to installation of heat network	• Follow guidance of Code of Practice • Use oversized spines to reduce necessity for future disruption • Select soft-dig (verges) routes where possible to avoid roadworks • Locate T-offs off the road network • Installation to be aligned with other public works schemes • Engagement with the public • Engagement with Milton Keynes transport bodies	3	2	Low

Insufficient connections or delayed connections to fully utilise scheme capacity	• Ensure capacity of existing Thameswey scheme is utilised prior to adding further generating capacity • Ensure that there are appropriate tariff levels to attract connections for longer terms, particularly to anchor connections • Approximately one third of the connections are on the higher tariff level, which assumes the customer recognises the benefit of the avoided costs of owning and operating heating systems.	4	2	Significant
Health and Safety	• Follow guidance in CIBSE Heat Network Code of Practice, and other industry standards relating to health and safety	5	1	Low

Operation and Maintenance

Risk or Challenge	*Possible Mitigation*	*Consequence*	*Likelihood*	*Risk*
Performance and reliability of new energy centre	• All network and equipment is correctly sized and selected as "fit for purpose" • Main plant and pumping systems have been duplicated to provide an availability of 100% and to ensure reliability of supply • Special attention is given to the selection of equipment and the quality of the complete infrastructure • Full consideration to safe plant operation is incorporated in the design solution • Access of equipment and future maintenance requirements in included within the design solution	3	2	Low
Delay in connecting loads	• Ensure the connecting tariff is of commercial benefit to the customer • Planning policy requiring new builds to consider connection to the heat network • Do not add further generating capacity to the scheme until the existing capacity is fully utilised • Monitor development and the effect of delayed connections to the financial status; ensure there is contingency for delays	2	3	Low

Lack of demand from customers to connect to the heat network	• Use effective marketing to attract connections; this could include reduced or zero costs for connection or transitional periods of reduced tariffs • Customers may have differing views of the benefit of savings in running and replacing their existing boilers. Allow for several tariff levels to accommodate this • Clear communication of carbon benefits of the scheme to connections • Offer reduced tariffs where a customer is connecting to their own absorption chiller, as head demand would be during off-peak summer periods • Offer guaranteed heating supply, by including backup boilers and thermal storage in the scheme design • Attract anchor loads to allow further extension of the scheme, with provision for connections up to that new anchor load	4	2	Significant
A single heat network could be seen a monopoly, and hence customers may be reluctant to connect	• Use low cost sources of finance, and effective procurement to reduce installation and financing costs. This will allow a lower, 'better than market rate' supply tariff • Follow the CIBSE Heat Network Code of practice, which sets best practice standards, and would provide greater confidence to connecting loads • Offer temporary heating supplies where the scheme connection cannot meet new build schedules	3	1	Very Low

Customers may have different heating temperature conditions for their buildings	• Follow the CIBSE Heat Network Code of practice • Use best practice design and commissioning • Allow for operation of the system with a lower delta T across the network; this results in larger pipe diameters, but fewer issues with local connection commissioning • Design duty and stand-by heat exchangers in each Substation. Each heat exchanger will be sized with a capacity to deliver 60% (total in aggregate 120%) of the heating and domestic hot water demand of the Development	3	1	Very Low
Customers may reduce their energy demand in the future	• Ensure a varied customer base, and closely monitor changes in demand over time • Include adequate thermal storage to minimise dumping of heat, or of reducing plant output • Target new possible connections as required	3	1	Very Low
Risk of key customers not connecting	• Ensure tariffs are set below market rate, or benefit connections • Model the scheme IRR to include adverse scenarios where customers do not connect • Mitigate by having a wide pool of potential connections, but do not assume they will all connect, even if it is economically favourable to do so • Oversize the spine diameters so that energy can be supplied to alternative connections in other areas	2	2	Low
Operational Health and Safety	• Training of staff in areas of regulation such as COSHH and DSEAR • Training of staff in operating procedures such as DSB (Disaster Recovery Plan) • Follow guidance in CIBSE Heat Network Code of Practice relating to health and safety • ISO 18001, occupational health and Safety standard	5	1	Low

Planning objections relating to flu location and plant emissions	• Dispersion modelling to ensure the flue route is away from buildings • Engage with Milton Keynes environmental health officer over NOx limits • Design for lower 250 NOx emission levels, as changing regulations may require lower levels in the future	3	1	Very Low
Maintenance of underground piping network	• Quality product selection and specification • Automatic leak detection and monitoring systems • Provide accurate as-built drawings of piping network to the highways authority, water, gas, electricity, broadband and other service providers	3	1	Very Low

Risks for end users

Risk or Challenge	Possible Mitigation	*Consequence*	*Likelihood*	*Risk*
Contract structure such as minimum take, take or pay or high fixed charges are unattractive when customers reduce demand	• Avoid such contract structures; offer contracts that are competitive even at reduced levels of demand • Included competitive comparison clauses in the customer contracts for annual pricing review and market testing	4	1	Low
Risk of CO2 savings reducing due to grid decarbonisation	• Ensure the scheme is energy efficient from the beginning, with high CHP performance, good use of thermal storage, low heat dumping rates and high thermal performance of network piping infrastructure • Consider future addition of heat pumps to the system, which would be low carbon intensity for a decarbonised grid supply • Will require future studies and considerations	3	3	Significant

Risk of tariffs becoming uncompetitive with changing future gas and electricity prices	• Use contract structures which review market rates on an annual basis	3	2	Low

Appendix B: Equipment life

Capital costs are based on component parts of the Heat Network to meet the following minimum requirements:

Minimum Design Life Compliance Statement

Component	**Minimum Design Life (Years)**
Energy Centre Roof	60
Energy Centre Facade	40
Energy Centre Structure & Civil Works	60
Boilers	40
CHP	20
Pumps	20
Controls	15
Pressurisation Units	20
Thermal Stores	50
Ventilation Plant	25
Above-ground pipework	50
Below-ground pipework	50

Appendix C: Standards and Codes of Practice

The design, construction, installation, testing and commissioning is in accordance with current best practice European and British Standards, including, but not limited to:

- ✓ EN 13941: Design and installation of Pre-insulated bonded pipe systems for district heating
- ✓ EN 253:2009: Fitting assemblies of straight steel service pipes, polyurethane thermal insulation (PUR) and outer casing of polyethylene (PE)
- ✓ EN 448:2009: Fitting assemblies of steel service pipes, polyurethane thermal insulation (PUR) and outer casing of polyethylene (PE)
- ✓ EN 488:2009: Steel valve assembly for steel service pipes, polyurethane thermal insulation (PUR) and outer casing of polyethylene (PE)
- ✓ EN 489:2009: Joint assembly for steel service pipes, polyurethane thermal insulation (PUR) and outer casing of polyethylene (PE)
- ✓ EN 13941:2009: District heating system - Design and installation of pre-insulated bonded pipe systems for district heating with impact proof insulation between service pipe and outer casing
- ✓ EN 14419:2009: District heating system – Pre-insulated bonded pipe systems for directly buried hot water networks - Surveillance systems
- ✓ EN 15698-1:2009: District heating system – Pre-insulated bonded twin pipe systems for directly buried hot water networks. Twin pipe assembly of steel service pipe, polyurethane thermal insulation and outer casing of polyethylene(PE)
- ✓ EN 15632-2: District heating pipes. Pre-insulated flexible pipe systems. Bonded plastic service pipes. Requirements and test methods

The pipework should be installed in accordance with the general requirement of the National Joint Utilities Guidelines (NJUG) Volume 1 and 2, The New Road and Street Works Act, and the Specification for Highway Works (DoT).

- ✓ All steel pipe welding is to be undertaken by certified coded welders. Certification shall be in compliance with current British and European Standards. Current original certificates for individual welders are to be made available upon request with signed copies to form part of a Pre- Construction Health & Safety Plan. Welders may be submitted to a welding test with at least the same acceptance criteria as the criteria for the finished work, with reference to EN ISO 5817, quality level B.
- ✓ Class 1 welders should be used however a project specific weld procedure would be compiled and the welders are then tested against this. The weld procedure (acceptance criteria) is based on the pipe supplier product so the Class 1 welders would be trained and competent to carry out welding on a similar product on any project. There is normally 20% NDT requirement and Class 1 welders are retested every 2 years. The first 10 welds of any new welder are tested and if any weld fails NDT testing then the next 10 continuous welds for that same welder are tested.
- ✓ The requirements for weld identification and testing

- ✓ All pipe insulation joints will comply with EN489:2003. The choice of joint type will be compatible with the pipe material and pipe type.
- ✓ The requirements for installation of insulation joints, insulation joints, testing of pipe insulation joints and pipe insulation joint identification
- ✓ The main pipe will be laid at a minimum depth of 800mm to the top of the pipe with branches from the main pipe will be laid at a minimum depth of 600mm to the top of the pipe.
- ✓ Any stress calculations to calculate how the design of the network will deal with expansion and contraction will be submitted to the manufacturer for approval to the manufacturer.
- ✓ Ensure best industry practice for the installation of isolation valves, system venting, monitoring and control systems, trench installation, connections & entries to buildings, pipework alarm & monitoring system, pipework testing, and system flushing, draining & filling

Appendix D: Implementation Plan

Construction Management

In delivering the Energy Centre and the Strategic Heat Network the whole design and construction approach will ensure compliance with law and regulations that might impact on the project, including:

- ✓ the Building Regulations 2010,
- ✓ Construction (Design and Management) Regulations 2015 (CDM 2007),
- ✓ the Sustainable and Secure Buildings Act 2004,
- ✓ the Workplace (Health, Safety and Welfare) Regulations,
- ✓ the Fire Precautions Act,
- ✓ the Disability Discrimination Act,
- ✓ the Equality Act,
- ✓ the Bribery Act

National and international standards such as ISO (i.e. ISO 23045 Building Environment Design, ISO 22301 Business Continuity Management, and ISO 31000 Risk Management) and BSI (i.e. BS OHSAS 18001 Occupational Health and Safety Management), will be followed closely.

The understanding and compliance with the above will enable serving MKC in a systematic and regulated way while dealing with risks and covering critical topics such as fire precautions, procedures and means of escape, security, disabled access, CDM regulations and M&E services in critical environments and energy efficiency and sustainability including waste liability and landfill issues.

All work and equipment will be designed, supplied, installed, tested and commissioned to meet the requirements of the MKC specification, along with full compliance with all relevant Legislations, Approved Code of Practices and

European, British and International Standards or where no standard Code of Practice exists follow recognised up to date best engineering practice in the Industry.

Any reference to Standards, Legislation or Codes of Practice shall be constructed equally as reference to an equivalent or updated one.

The contractor will ensure that all works carried out on its premises are compliant with all Environment Agency, Health and Safety Executive and Local Authority requirements and that the highest standards of workmanship is achieved.

A designated project manager will have the authority to the run the project on a day-to-day basis from the design phase through to the commissioning and handover to the operations team. The project Manager will be responsible for managing the team, work of consultants, sub- contractors, allocating and utilising resources in an efficient manner and maintaining a co-operative, motivated and successful team.

The contractor will fully assign competent management staff at the construction site and give them the resources and authority to complete our contract obligations safely, timely, and in a professional manner. Each member of the on-site management team, headed by the Site Manager, will have the authority to make project decisions commensurate with their position. Key members of the site project management team include the Site Manager who will also be the Senior Construction Manager, Project Construction Manager (engineering subcontractor representative), Site Safety Manager, and Project Administrator.

Construction subcontractors will be interviewed from the local area as well as on a regional and national basis. The contractor will attempt to maximise the use of local firms in an effort to support the local economy and mitigate mobilisation and travel costs associated with using subcontractors from outside the local area. Of course, the construction subcontractors will be key to successful project implementation, and qualifications and price are both considerations in subcontractor selection. Each subcontractor will provide a project foreman and safety and quality control personnel.

The site project team will have all the resources necessary to ensure project success available including the support of corporate resources from anywhere within the Contractor organisation beginning with the Contractor corporate staff. While most construction and project administration activities will be accomplished by the onsite staff, contract administration, accounting, subcontract administration, and project legal counsel will be self-performed by division or corporate staff.

Technical oversight of engineering, construction management, and safety will also be accomplished by the corporate resources.

Environmental Health and Safety approach

Health and safety of all employees, contractors, customers, and communities is highly important. Protecting and responsibly managing natural resources are critical to the quality of life in the areas we serve, the environment, and Ameresco long term business.

No financial goal, work task, client deliverable, or schedule demand is worth an injury or environmental compromise. It is the responsibility of every Contractor employee, supplier, contractor, partner, and vendor to strive at all times, on every work assignment, to work safely and environmentally correct.

To this end, the contractor shall commit to achieving the following goals

- ✓ Zero Accidents
- ✓ Achieving and Maintaining Total Compliance
- ✓ Utilising Integrated Safety Management within All Activities
- ✓ Maintaining a Safe and Healthy Work Environment
- ✓ Being a Good Steward of Our Environment
- ✓ Achieving "World-Class" Safety Performance and Recognition

The contractor shall adopt the Integrated Safety Management System (ISMS) as the overarching philosophy and approach to integrate systematically safety into work activities. The ISMS is the formal, organised process whereby the Contractor plans, performs, assesses, and improves safe conduct of work. Each subcontractor shall be committed to these fundamental principles and functions through contractual agreement. The use and implementation of this plan is verified through the self-assessment and independent assessment processes.

The contractor and its subcontractors shall be committed to ensuring the health and safety of workers and the public and to protecting the environment. All work will be performed safely and will adhere to all applicable laws and requirements. Integral to this being accomplished is the workers' commitment to work safely and to work to the requirements.

Principles of Integrated Safety Management System

The fundamental principles of ISMS's shall be used to help ensure that facilities are adequately preserved, that work is conducted safely, and that suitable measures exist to prevent and mitigate accidents. The ISMS includes:

- ✓ Worker and Line Management Responsibility for Safety

Line management is accountable for empowering workers with the training and authority necessary to establish and maintain safe operating methods commensurate with their assigned duties. Management expectations are clearly communicated to all personnel, personnel are empowered, their feedback is solicited, the tools necessary to accomplish the work safely are provided, and personnel are held accountable for their actions. Each individual, in turn, is responsible for his or her actions.

Line managers are responsible for training, motivating, and enabling their workers to understand and comply with the Ameresco commitment to safety, and for ensuring that work is accomplished within the authorisation basis. Line managers are also responsible, by personal example and by involving their workers, for providing a working environment in which everyone is dedicated to meeting the commitment to safety.

- ✓ Clear Lines of Authority

The Safety & Health Program organisational structure focuses on management and worker involvement, and is centered on work planning and execution. Clear and unambiguous roles and lines of responsibility, authority, and accountability at all organizational levels must be established. Environmental, Safety, and Health (ES&H) responsibility will be integrated into all work activities, and interfaces for processes and organizations will be clearly established to provide for good understanding and communication.

- ✓ Personnel Experience, Knowledge, and Skill

Each Subcontractor must commit to using a workforce on site that has the ability to do work safely and efficiently. Each individual associated with the Project or Facility shall possess the experience, knowledge, skills, and abilities necessary to discharge his or her responsibilities. Line managers must ensure that their workers are competent to safely accomplish the work through the hiring and training processes. Line management must ensure that training and qualification requirements are flowed down to their personnel, and are responsible for their performance.

- ✓ Balanced Priorities

The contractor shall ensure a “safety first” culture by effectively allocating, training, and monitoring resources to ensure that work is performed safely. A “safety first” attitude is a must for all personnel. Stop work authority is given to each employee to use when he or she believes an activity is unsafe. Restart approval is given at the appropriate management level. Specific job tasks are planned with appropriate worker involvement, and the work plan is required to be followed to ensure safe operation and environmental compliance.

- ✓ Work and Associated Hazards

Before work is performed, the associated hazards are evaluated and an agreed-upon set controls is established, which, if properly implemented, provides adequate assurance that the public, the workers, and the environment are protected from adverse consequences.

- ✓ Administrative and Engineering Controls

Administrative controls and engineering controls are essential elements of the ISMS. Wherever feasible, engineered controls are designed into the Project/Facilities, and administrative controls are used to supplement engineered controls as appropriate. These controls are established through the work planning process.

- ✓ Authorisation Agreement

The conditions and requirements to be satisfied for operations to be initiated and conducted are clearly established and agreed upon by all employees and contractors.

- ✓ Core Functions of Integrated Safety Management System

These five functions are not independent and not necessarily sequential. Rather, they are linked and interdependent such that outcomes during the accomplishment of one may affect others. In particular, identifying and implementing opportunities for improvement may arise at any stage of the work process. The five functions are Define the Scope of Work, Identify and Analyze Hazards, Develop and Implement Hazards Controls, Perform Work within Controls, and Provide Feedback and Continuous Improvement. The contractor and its Subcontractors line management must commit to these core functions of integrated safety management.

Project Health and Safety management

Under CDM 2015, Ameresco will be the Principal Designer, Designer and Principal Contractor as appointed by the Client.

Ameresco and Construction sub-contractors are fully accredited with CHAS (Contractor Health and Safety Assessment Scheme) and Safecontractor and approved as Designer and Principal Contractor under the CDM by many organisations where energy efficiency projects have been completed. All employees hold CSCS (Construction Skills) card, and are trained in CDM and Asbestos Awareness. Project Managers, Designers, and Energy Analysts undergo training under IOSH (Institute of Occupational Health and Safety) Managing Safely course to enhance the Company Safety Culture and ensure we maintain a Zero Lost Time record.

The contractor will complete an initial evaluation of all potential hazards associated with the project by conducting a thorough review of the defined scope and work activities. Hazards are identified, defined, and appropriate controls are incorporated into the written site specific Construction Phase safety and health plan for the specific operation.

Once the draft site specific plan is completed, it goes through a series of reviews and a comment period to ensure it is complete and meets all applicable regulatory standards. Once the final plan is completed it is signed off by the Contractor's Operations Manager and Director of Safety & Risk Management.

Prior to start-up of work activities all employees and applicable subcontractors receive initial safety training and a safety plan review. All safety plans, policies, procedures, and training requirements are frequently reviewed by the assigned Project Direct, Project Manager and Construction Manager and/or corporate safety staff through self-assessments to ensure it continues to identify potential hazards and contains updated hazard controls.

Employer's Environmental Policy

The contractor will confirm that they will fully comply with the MKC Environmental Policy to identify, source and use environmentally and socially responsible materials.

The contractor will identify and evaluate opportunities for the reuse of secondary materials within the construction process. The contractor will provide evidence of compliance and develop a project based system to allow measurement of outcomes against specified key performance indicators such as:

- ✓ using a percentage (to be agreed) of secondary materials by value; and
- ✓ using a level of percentage (to be agreed) of recycled aggregate, by weight.

The contractor shall submit prompt and timely environmental monitoring and reports.

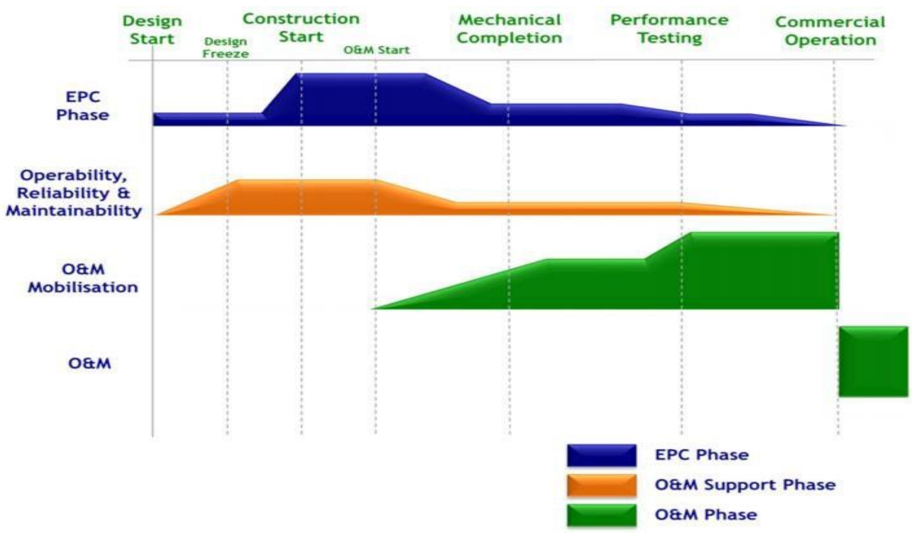
Project Programme

Ameresco are pleased to submit a detailed project programme against the RIBA Plan of Work 2013. We have taken into account all interfaces between design, procurement, pre-construction, construction, & commissioning activities. We have identified delivery, offload, positioning and installation of major plant items and will ensure that these elements are coordinated with construction of the main energy centre taking into account any constraints related to weather protection, availability of the prepared foundations and other activities competed in parallel. We will ensure that that, in addition to meeting the requirements of these conditions, we would ensure that Safe Systems of Work are maintained at all times.

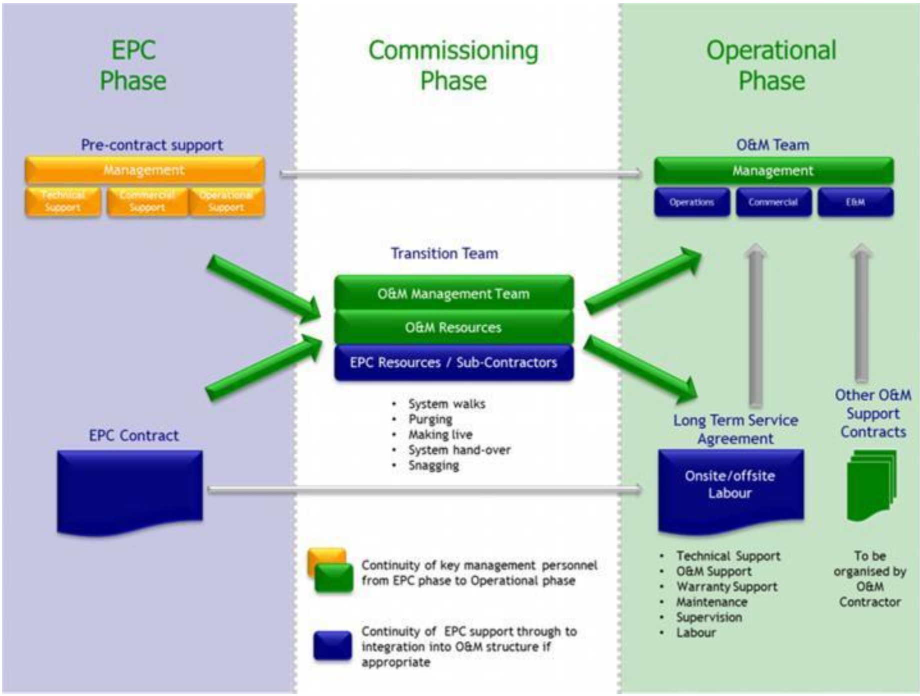
In parallel to the main energy centre works, we have fully programmed the network installation as shown in the detailed programme, again taking full account of public/traffic, road closure, and bridge and rail crossings constraints into account.

Operation and Maintenance

Prior to start of the Commercial Operations the Contractor will ensure that a range of pre-operations services associated with operability, reliability and maintainability of the plant is completed. Prior to the start of Commercial Operations and during the design and construction phase of the project operational support will be utilised by engaging with the Operations team.



This approach will allow the contractor to access and engage with the experienced O&M team at an early stage to ensure valuable operational input can be raised at the critical design stages of the project and carry this experience and knowledge through to the O&M phase of the project i.e.:



Project Implementation Stages

The O & M team is responsible for assuring that all operational and maintenance activities are conducted in a safe and responsible manner including but not limited to:

- ✓ Planning, organising, shift operations and to assure that plant reliability, safety, and environmental requirements are met.
- ✓ Watch-standing, daily logs and system inspections, record keeping, and reporting
- ✓ Establishing plant operating configuration and equipment selection for plant loads
- ✓ Closely communicating with the LVHN on system statuses
- ✓ Preparing reports and coordinate maintenance tasks and contractors
- ✓ Investigating operating incidents and abnormalities, and generating equipment maintenance work requests
- ✓ Communicating and notifying the contracted service companies for emergency services and equipment problems
- ✓ Interacting with outside teams

Appendix E: Heads of Terms

Milton Keynes Heat Network and Energy Centre

Heads of Terms for DB Contract

Reference	Term
Parties	(1) Milton Keynes Council ("**Employer**"); (2) [company name] ("**Contractor**").
Form of Contract	JCT or FIDIC Silver (the "**DB Contract**"/ "**Agreement**") The DB Contract is to be executed as a Deed
Plant	The Contractor will be responsible for the design, procurement, construction, testing and commissioning of a [5] MW gas fired CHP facility, 10 MW boiler and associated heat network and private wire (the "**Plant**") at a site central Milton Keynes, U.K (the "**Project**")
External Financing	The Contractor acknowledges that the Plant will be externally financed by one or more financial institutions (the **"Lenders"**) and any breach by the Contractor may cause the Employer to be in breach of its obligations under the financing agreements and that any resulting loss is reasonably foreseeable The Employer shall be freely entitled to assign its rights in relation to the Agreement to the Lenders by way of security
Project Interface Arrangements	The O&M Contractor shall have an opportunity to input into the Design Review Procedure. Mechanism for the O&M Contractor to provide comments to be developed. The Contractor and the O&M Contractor shall agree a protocol which governs the Contractor's access to the Site/Plant following Take Over to rectify Defects or carry out the Guarantee Performance Tests, so as to minimise disruption to the operation of the Plant. Any protocols or interface agreement agreed between the Contractor and O&M Contractor will deal only with operational interface issues and will not oblige them to bring contractual claims direct amongst themselves.

Reference	Term
Professional Team	The professional Team will comprise [*consultants to be listed*]/ the Contractor shall appoint the Professional Team in consultation with and subject to the approval of the Employer. Professional Team collateral warranties will be offered to the Employer and the Lenders.
Contract Price and Payment	The Contract Price shall be a fixed lump sum of [ ]. The Contract Price excludes VAT (if applicable). The Contract Price may be adjusted pursuant to the terms of the DB Contract (for example, in relation to Variations or Changes in Legislation).
Payment Schedule	The Contractor shall be paid Construction Act compliant interim payments, according to an agreed milestone drawdown schedule. The milestone drawdown schedule (to be agreed before signing the Agreement) will provide for an initial mobilisation payment followed by payment against easily definable milestones/key dates for the Works, as signed off by the technical advisor appointed by the Lenders. Payments against the milestone drawdown schedule will be made subject to a retention of 5% of the relevant amount, which shall be reduced as follows: • A reduction to 3% on the issue by the Independent Certifier of the Taking-Over Certificate • A reduction to 0% at the end of the Defects Notification Period The Contractor may provide a bond in lieu of the cash retention from a financial institution acceptable to the Employer and its Lenders. Title to plant and machinery shall pass on payment, such that a security interest can be created. Risk in the Plant shall remain with the Contractor in accordance with the Agreement.

Reference	Term
Key Dates	Commencement Date – [ ] days from the date of the Agreement. Time for Completion – [] months from the Commencement Date. Employer's Taking Over – [ ] months from the Commencement Date. Longstop Date – [ ] months from the Commencement Date (giving rise to termination).

Key Obligations	Design
	The Contractor shall be fully responsible for the workmanship, preparing, developing and coordinating all Final Design works which shall be based on the Outline Design prepared under the Agreement for Front End Engineering Design Services dated [date] and entered into between the Employer and the Contractor, to enable the Works to be constructed and/or be fully operational in accordance with the Employer's Requirements and all other requirements of the Agreement. The Contractor shall by fully responsible for any errors or omissions in the Outline Design and Final Design (including design criteria and calculations). The Contractor shall be fully responsible for the suitability, adequacy, integrity, durability and practicality of the Contractor's Documents (including Works Method Statements, Works Delivery Plans, Quality Management Systems). The Contractor shall submit Reviewable Design Data to the Employer for review under the Design Review Procedure (to be agreed, including definitive time periods for comments to enable the Contractor to maintain its programme) but without any assumption of liability by the Employer for the Contractor's Design Proposals. The Contractor shall maintain a Design Database. The Contractor shall design the Works so as to: • comply with the Outline Design, the Contractor's Design Proposals and Employer's Requirements; • comply with laws and Good Industry Practice; and • ensure the design is compatible with the operating parameters included in the Employer's Requirements. Design errors to be corrected at the Contractor's cost, notwithstanding any consent or approval by the Employer. **Carrying out the Works** The Contractor shall carry out and discharge the obligations relating to the Works in accordance with: • the Contractor's Design Proposals and Employer's Requirements); • Good Industry Practice;

Reference	Term
	• all applicable Regulations and Legislation; • the Contractor's Documents; • Planning Consent and the Environmental Permit; • all applicable consents; • all applicable CDM requirements; • the Construction Programme • the Commissioning Requirements; • in a manner not reasonably likely to be injurious to health or cause damage to property; • so as not to cause nuisance or interference with any third parties or neighbouring properties; and • in a manner that ensures that all goods used in the Works shall be new and of satisfactory quality and all plant and equipment shall be suitable for the purposes set out in the Employer's Requirements. The Contractor shall warrant that, when completed, the Works shall be fit for the purposes for which the Works are intended as defined in the DB Contract *[detailed definition to be included]*. **CDM** The Contractor will perform role of Principal Designer and Principal Contractor under the CDM Regulations. **Inspection** The Employer (and the Lenders' Technical Adviser) shall have the right to inspect the Works at any time, subject to complying with relevant Site Rules (for health and safety). **Grid Connection** The Contractor shall be responsible for the design and delivery of the grid connection, and attendance of the DNO to witness G59 testing.

Reference	Term
	Testing & Commissioning The Contractor shall comply with the Testing and Commissioning Procedure (to be agreed), key features of which shall include a set of Minimum Performance Tests and Reliability Tests to be undertaken and satisfied prior to Take Over (which will demonstrate entire Plant performance) and a set of Guarantee Performance Tests and a one year Availability Test following Take Over. The Testing & Commissioning sequence and periods will be built into the Construction Programme. Commissioning and testing to be certified by an independent engineer. If the Minimum Performance Tests or Reliability Tests are not satisfied after a period of correction and retesting (to be agreed) then the Employer shall have the right to reject the Works. **Post Taking Over** Subject to feedback from the Lenders, it is proposed by that from and after Taking Over the Contractor shall remain responsible for conducting and co-ordinating all the Tests after Completion
Construction Programme	The Parties shall agree a Construction Programme which shall include all key dates, milestones and a critical path analysis. If there is delay to the Required Commercial Operational Date (Take Over), the Contractor shall pay Delay Damages for lost output calculated as [ ] for each day of delay, capped at [20%] of the Contract Price. The Contractor will be entitled to relief where the delay is attributable to Force Majeure, a Compensation Event or a Relief Event.

Performance Guarantees	General approach: The Employer is seeking an Energy Centre and associated heat network and private wire system. comprising a number of systems and components, each of which has to meet a prescribed performance conforming with the overall design of the Contractor and performance guarantees for the plant as a whole. It is essential that the Performance Tests clearly identify a problem in any component or sub-system so that it can be properly addressed. So far as possible, the performance guarantees and reference conditions will be expressed so that published test standards can be used for the proving of the performance of individual components such as boilers and steam turbine generation sets. The following base case technical assumptions are made:

Description	Units	Base Case
Boiler heat generation capacity	MWth	10 MWth
Generator Data		
Gas engine thermal efficiency	%	40%
Gross Power Production	MWe	2 x 2.5MWe
Gross Power Efficiency	%	40%
Parasitic Load	MWe	0.5 MWe
Net Power Production	MWe	4.5 MWe
Net Power Efficiency	%	40%
Annual Power Production	**MWe/a**	[ ]

The Contractor shall provide the following guaranteed performance:

A. Whole plant performance

1. [Annual Power Export: the Plant shall export [ ] MW/h/y electricity];
2. [Overall Plant Availability: [ ]% time-based availability (approximately [ ] hours per annum];
3. [Net Power/Electrical Efficiency:];
4. [Auxiliary Load Levels:]

B. Systems/Components performance

5. [Boilers: [heat release], [water flow rate], and [water temperatures]

Reference	Term
	6. [Noise limits: in compliance with the planning consent and environmental permit]; The Contractor shall pay Performance Liquidated Damages for performance shortfall (where the minimum/rejection levels are satisfied – to be agreed) during the first year post Taking Over calculated as [ ] and capped at [20% of the Contract Price]. Plant Availability exclusions are to be agreed and shall include: • Plant shut down or failure due to Employer/O&M Contractor misuse or other 3rd party not controlled by the Contractor; • Force Majeure events; • Vandalism or theft (provided not attributable to Contractor breach of the DB Contract); and • Losses due to failures of components which were not procured by the Contractor within the scope of the Works under the DB Contract.
Defects	Minor defects in the Works (snagging matters) will not prevent Taking Over. The Contractor shall remedy any Defects in the Works that come to light during the Defects Notification Period to the satisfaction of the Employer. The Defects Notification Period shall be for a period of 2 years from Taking Over, with an evergreen extension of 2 years in relation to repaired/replaced elements of the Works, subject to an overall maximum period of [6] years. Notwithstanding the Contractor's right to rectify Defects during the Defects Notification Period, The Employer shall retain the right at common law to pursue the Contractor for damages for breach of contract if any Defects in the Works arise during the period of 12 years from Taking Over (the statutory limitation period). No double counting with Performance LD's covering loss of Availability due to Defects.

Reference	Term
Manufacturer Product Warranties	[To be discussed/agreed] • [Boiler/] Warranty – minimum [ ] years product/performance warranty • [CHP and Auxiliaries Warranty] – minimum [ ] years product/performance warranty • [Transformers Warranty] - minimum [ ] years product/performance warranty • [Piping Warranty] - minimum [ ] years product/performance warranty Warranties to be extended to the Employer, assignable to the Lenders.
Land	Employer shall grant to the Contractor an exclusive license or lease.
Access	The Employer shall be responsible for securing a means of access to the Site from a public highway. The Contractor shall be responsible for the transportation of all plant, machinery and materials to the Site and for securing any and all transportation, shipping and export or import permits. The Employer shall provide the Contractor the right of access to the Site from the Commencement Date.
Health & Safety	The Contractor will be required to: • submit a H&S Plan for the Works; • comply with the [Environmental and Social Mitigation and Measurement Plan (ESMMP)], if any; and • comply with all environmental laws/ Environmental Permits

Reference	Term
Planning, Site Matters and Consents	The Contractor shall be responsible for Site conditions and shall carry out such investigations into Site conditions as it considers necessary, subject to the following: • the Employer shall assign the benefit of any environmental surveys/hydrological testing/ground testing, etc; • the Employer shall retain liability for (i) pre-existing contamination (ii) fossils & antiquities (iii) contamination that migrates onto the Site from neighbouring sites; • [risk of unforeseen sub-surface conditions to be discussed] • [title risk – exercise of adverse third party property rights over the Site – to be discussed] The Contractor shall be responsible for, and hold the Employer harmless from, cleaning up or otherwise dealing with any Contamination it causes (or its subcontractors cause) at the Site or to any neighbouring sites. The Contractor shall discharge all relevant Planning Conditions, and shall obtain all consents and approvals in relation to or required for the Works including all grid connections, statutory connections, telecommunications connections, utility connections and statutory consultations (but excluding the Environmental Permit). The Employer shall obtain the Environmental Permit in relation to the Project. The Contractor shall be responsible for the security of the Site and any protestor action or vandalism.
Lenders Direct Agreement	The Contractor and the Guarantor shall enter into a direct agreement with the Lenders, such direct agreement to: • require the Contractor to give notification prior to exercising any right to terminate the DB Contract; • provide step-in rights for the Lenders to 'cure' the circumstances giving rise to termination; • allow an alternative Employer to be substituted by the Lenders under the DB Contract; • subordinate the claims of the Contractor behind those of the Lenders.

Reference	Term
Force Majeure and Compensation Events	**Force Majeure** • Each of the Parties shall be relieved from the relevant obligation under the DB Contract if they are unable to discharge that obligation due to Force Majeure (to include customary FM events). • The Contractor shall not be entitled to any payment, save in respect of work carried out which has not yet been paid for in accordance with the DB Contract. **Compensation Events** • The Contractor shall be entitled to apply for (i) relief from its obligations (ii) extensions of time and (iii) additional costs + agreed Margin if as a result of a Compensation Event it is unable to comply with its obligations under the DB Contract. • Compensation Events to include breaches of the DB Contract by the Employer.
Change in Law	The Contractor shall be entitled to time and money in respect of any unforeseeable specific changes of law relevant to the waste or power sectors. General changes in law shall be the Contractor's risk.
Variations/ Change Procedure	A Change Procedure shall be incorporated into the DB Contract that will enable the Employer to instruct variations to the Works. The Contractor shall submit its proposal for undertaking the variation to the Works no later than 1 week from the Employer's request. If any variation requires additional Works, the Contractor shall not be entitled to claim more than its Cost plus agreed Margin. The Contractor will be entitled to an appropriate time adjustment in respect of the Construction Programme.

Reference	Term
Indemnities	The Contractor shall indemnify the Employer in relation to: • losses incurred by the Employer arising from a failure by the Contractor to comply with the reasonable requirements of the Employer's insurers where a claim has been made under the Required Insurances; • losses in respect of injury or death arising during the performance of the Works (unless attributable to negligence/ wilful act or breach of the DB Contract by the Employer); • damage or loss of any property (other than the Works) caused by the Contractor. For the avoidance of doubt, the above indemnity shall be given on the proviso that the Employer shall use reasonable endeavours to mitigate such losses and such losses shall be limited to those losses which are reasonably foreseeable (except where caused by the Contractor's wilful default, fraud or gross negligence). The Employer shall indemnify the Contractor in relation to: • losses in respect of injury or death attributable to negligence/ wilful act or breach of the DB Contract by the Employer; • damage or loss of any property caused by the Employer.

Reference	Term
Insurance	The Contractor shall be required to take out: • statutory insurances required of a contractor carrying the Works; • construction all risk insurance – minimum of [ ] million each claim and in the aggregate; • Professional indemnity insurance – minimum indemnity limit of £10 million • public liability insurance - minimum of [ ] million each claim and in the aggregate; • [marine cargo and shipping insurance – minimum of [110%] of the value of each shipment;] The Contractor shall be liable for: • any excess/deductible for any claim made by the Employer under its insurances to the extent that the loss/damage/liability was caused by the Contractor's acts, omissions, negligence or defaults; • any increase in premia/excess/deductibles caused by the Employer's claims on such policies due to the Contractor's acts, omissions, negligence or defaults.` . These insurance requirements shall be subject to review, modification and supplement by the Lenders Insurance Advisor.

Reference	**Term**
Limits of Liability	Global liability cap – 100% Delay LD's – [20]% Performance LD's – [20]% Global cap exclusions: • death or personal injury or third party property damage; • any liability of the Contractor arising from its deliberate acts or omissions including abandonment of the Works; • any liability of the Contractor to the Employer to the extent such liability is covered by insurance required to be maintained by the Contractor by the terms of the DB Contract (whether or not such insurance has in fact been effected by the Contractor, or if effected, has been vitiated by any act or omission of the Contractor (or any Contractor Related Party); • any liability arising out of any fraudulent misrepresentations, fraud or wilful misconduct of the Contractor; • any payment of interest by the Contractor to the Employer on sums payable. Following Taking-Over, the Contractor's liability shall be reduced to [50%] of the Contract Price. The Contractor shall have no liability for indirect or consequential loss except where arising from the Contractor's fraud or wilful misconduct.

Termination	**Contractor breach** Termination limbs and triggers including. • any negligent act, omission, breach or other default on the part of the Contractor and or any Contractor Related Party that causes a Loan Agreement Event of Default; • failure to commence the Works by [1] month after the date in the Construction Programme as varied from time to time; • Persistent Breach; • material breach including a material breach which results in a health and safety conviction in relation to the Project; • the Taking-Over Certificate not being issued by the Long Stop Date; • wrongful abandonment of the Works; • Contractor or Parent insolvency or any other analogous insolvent event; • a breach by the Contractor of its obligations to take out and maintain any of the required insurances which the Contractor is required to procure; • the Contractor fails to procure a required security instrument (e.g. bond), or a required security document is or becomes invalid or unenforceable and replacements are not provided within [five (5)] business days of demand by the Employer; • the long term credit rating of the provider of any Bond drops below the Required Bond Rating and a replacement Bond is not provided (on the same or substantially the same terms as the Performance Bond being replaced or with such changes as may be approved by the Lenders) by a financial institution having the Required Bond Rating within [10] Business Days of the long term credit rating falling below the Required Bond Rating; • failure to replace any guarantor where it falls below the financial thresholds; • the Contractor's liability exceeds any agreed caps, or exceeds [seventy percent (70%)] of the overall cap and the Contractor elects not to refresh the cap; **Employer breach** The Contractor's rights of termination under the DB Contract shall be subject to the direct agreement with the Lenders. The Contractor's right to terminate shall be limited to insolvency, non-payment of monies over a specified threshold for an extended duration (except where being disputed in good faith) and failure to perform its material obligations such that the Contractor is substantively frustrated from performing its obligations.

Reference	Term
Dispute Resolution Procedure	Adjudication, with final resolution in the English courts.
Parent Company Guarantee	The Contractor shall procure that the Contractor's parent shall provide a parent company guarantee which shall guarantee all of the Contractor' obligations under the DB Contract and any other document that the Contractor and the Employer are party to, subject to the parent's liability being co-extensive with the Contractor's and having the same rights of defence etc.
Security (bonds)	The Contractor shall provide: • [an Advance Payment Bond in an amount to cover the [Mobilisation Payment], which shall reduce at appropriate Milestone Events]; • [a Retention Bond in no less than [5]% of the Contract Price]; • a Performance Bond (Adjudication Bond) of not less than [fifteen percent (15%)] of the Contract Sum until Taking-Over from an insurance company or bank acceptable to the Employer and the Lenders. Following Taking Over, this may reduce to [5%] and shall be maintained at least until [two (2)] years after Taking Over. The bond shall be 'on demand' for insolvency of the Contractor; • A Warranty Bond of [ ]% of the Contract Price. The cost of the Bonds shall be included in the Contract Price and shall be capable of assignment to the Lenders.
Confidentiality and IP	Commercially sensitive information is to be protected so far as possible. The Contractor shall grant to the Employer (in so far as it is legally able), or shall procure the grant to the Employer, a perpetual, transferable, non-exclusive, royalty free, irrevocable licence in respect of the Intellectual Property Rights arising or used under the DB Contract such that such Intellectual Property Rights can be used in connection with the Project, including in termination scenarios.

Reference	Term
Assignment and Sub-Contracting	The Contractor shall seek the approval of the Employer prior to entering into any Key Subcontract *[value of Key Subcontract to be determined]*. The Contractor shall remain liable for the Works notwithstanding any elements of the Works that may be sub-contracted. The Contractor will be required to obtain collateral warranties executed in an agreed form in favour of the Employer and the Finance Parties from each and every of the Key Subcontractors and professional consultants. The Contractor may not assign, charge sell, or otherwise deal with the DB Contract without the written consent of the Employer. The Employer shall be entitled to assign the DB Contract by way of security to the Finance Parties.
Entire Agreement	The DB Contract shall be the subject of an entire agreement provision such that the DB Contract sets out the entire agreement of the parties.
Governing Law	The laws of England and Wales.

Appendix F: Letter to stakeholders

Dear …,

Below is a quick summary of what we, Ameresco, are working on with Milton Keynes Council and it would be much appreciated if you can point me in the right direction to where the information requested below can be obtained

Many thanks in advance, please see summary below.

Ameresco are carrying out a heat and power mapping exercise on behalf of Milton Keynes Council to identify opportunities for improved low carbon methods of energy supply. In particular, Ameresco are investigating opportunities to help building owners reduce energy costs by connecting to the existing district heating scheme in central Milton Keynes. The work is being carried out in partnership with Thameswey Ltd who operate the existing district heating scheme in central Milton Keynes. A letter of introduction from Milton Keynes Council is attached.

We are seeking information about the energy consumption and floor area of your building. In particular:

- Electricity consumption (kWh) – half hourly data and total
- Gas consumption (kWh) – half hour data and total
- Building type/activity
- Building hours of use
- Building total floor area
- Type of heating i.e. hot water, burner or electric.

We would be very grateful if you could send us any information on the above (e.g monthly consumption data) . We can then use this to assess if it would be cost effective for you to connect to the existing low carbon district heating and private wire electricity scheme. All data will remain confidential within the study team.

Do please contact me to discuss any questions about the data we need for the study. Thank you in anticipation and we look forward to receiving data about you building.

Yours sincerely

Appendix G: Summary of Phase 2: Hospital

Introduction

Phase 1 and 2 used a strategic clustering approach across central Milton Keynes and indicated nine main potential heat network clusters along three main pipework routes that warrant further investigation. Clusters 1-3 are based on supply from the existing energy centre whereas 4 is an entirely separate scheme with a new energy centre at the hospital. The clustering options for the hospital are discussed below with the maps showing indicative spine pipework relative to buildings with relatively high heat and power demands. These maps do not show smaller local pipework to each building but costs for this have been included in the analysis.

Cluster 4a – (Hospital) a separate heat network supplying MK University Hospital buildings and some surrounding care homes plus a school. A new energy centre would be located at the hospital.

Cluster 4a (Hospital) buildings and indicative pipework

Cluster 4a + 4b (Hospital plus Woughton) an extension to the hospital heat network to supply both the Woughton campus including Woughton Leisure Centre, St Paul's RC School, MK Academy and MK College.

Cluster 4b (Hospital + Woughton) buildings and indicative pipework

Load and Energy Summary

The below table shows an extract of the cluster heat loads (MWh thermal) with indicative lengths of spine and secondary pipework. This also shows an indicative linear heat density (MWh/m) that indicates heat load per meter of pipe to reach the energy centre. Anything above 2 MWh/m is likely to be economic and worthy of detailed investigation. In Milton Keynes all the clusters are above 2 MWh/m. The table also shows the indicative size of a CHP that might be required to meet the loads in each cluster. This also shows the additional plant added in each of the models to meet the cluster demands. It is notable that most of the 'a' clusters are within the spare capacity of the existing energy centre and sometimes 'a' and 'b' are only a little greater than the spare capacity.

It is worth noting again that Clusters 4a (Hospital) and 4b (Woughton) have been modelled as an entirely separate heat network scheme for the reasons discussed earlier.

LOAD SUMMARY	Cluster 4a (Hospital)	Cluster 4a (Hospital) plus Coffee Hall	Cluster 4a (Hospital) plus Netherfield	Cluster 4a+4b (Hospital + Woughton)
MWh thermal	32,196	37,616	39,507	38,423
Total pipework length	1,229	4,109	4,319	1,380
Indicative MWh/m thermal	26	9	9	28
Indicative CHP (kWth)	5,366	6,269	6,585	6,404
Modellled CHP (additional) MWth	5.3	6.4	6.8	1.3

Economic Analysis

The results of Phase 2 EnergyPro software modelling can be seen in Section 5, with each individual cluster indicating potential viability.

The following assumptions were applied for the purposes of the phase 2 modelling.

- A 25 and 40 year life has been assumed for the modelled schemes with a discount factor of 3.5%. A 20 year life cycle has been assumed for most plant (CHP, pumps, storage vessels etc.) the pipework infrastructure is expected to last up to 50 years. Both the 25 year and 40 year models therefore include major plant replacement after 20 years.
- District Heating – we have assumed an 85°C/65°C DH system with 12.5% heat losses from the pipework but would hope that careful design and optimisation of existing heating systems could take this to 75°C/55°C with smaller pipework and even lower heat losses.
- Carbon factors – are taken from the National Calculation Methodology 216g/kWh for gas and 519g/kWh for electricity.
- Modelling is based on 2014 prices taken from the existing Thameswey system with variable export and import prices based on wholesale market prices and a variable gas price.

- No assumptions have been made on boiler efficiency as we have used actual heat and electricity sale prices as supplied by Thameswey.

MILTON KEYNES	Simple payback (Years)	IRR (25 years)	NPV (£ x 1000) (25 years)	Operating Surplus 2014 (£ x 1000)	CO2 Saving (Tonnes/yr)	INITIAL CAPEX (£ x 1000)
Cluster 4a (Hospital)	8.2	10.05%	5,897	1,075	6,301	8,818
Cluster 4a (Hospital) plus Coffee Hall	10.6	6.30%	4,386	1,498	7,433	15,939
Cluster 4a (Hospital) plus Netherfield	10.8	6.10%	4,399	1,619	7,759	17,422
Cluster 4a+4b (Hospital + Woughton)	9.4	8.01%	5,730	1,351	7,532	12,747

Cluster 4a (Hospital) has been modelled as a separate scheme with a new energy centre that would ultimately supply 4b as well. Although the energy demands are high in the hospital and Woughton clusters, the additional capex for the new energy centre plant and the long pipework required provides a lower return on investment. Modelled NPV for the additional hospital cluster network shows a much lower NPV than the other options studied, with a very low NPV/CAPEX ration indicating low project value.

Appendix H: Modelling and Costing Assumptions

Site

	Gas (MWh pa)	Average Heat Load (kWth)	Peak Thermal Load (kWth) (Estimated)	Pipe Size	Length (m)	Heat Connection Cost**
YMCA (Hostel & Resid)	2189	200	700	DN75	110	£249,169
Police Headquarters	2161	197	691	DN75	116	£258,002
Civic Offices	907	83	290	DN65	25	£89,604
1-199 North 9th Street Flats	847	77	271	DN65	50	£138,356
Central Library	573	52	183	DN50	60	£106,310
CBXIII – Pre-Planning 1200 site	1000	91	320	DN65	20	£126,728
B3.3N Pre-Planning	1708	156	546	DN75	23	£83,939
C3.1/2 Pre-Planning	894	82	286	DN65	25	£89,319
B4.1-B4.3 Pre-Planning	10003	913	3197	DN150	40	£219,748
Santander House	5113	467	1634	DN50	25	£145,152
Witan Gate House	2963	271	947	DN45	25	£121,791
Central Business exchange	4032	368	1289	DN125	20	£136,671
Midsummer court	3304	302	1056	DN100	23	£131,803
Exchange House	3965	362	1267	DN100	20	£134,460
401 Grafton Gate	1349	123	431	DN100	25	£105,768
Jurys Inn	894	82	286	DN100	25	£96,548
Avebury House	793	72	254	DN75	20	£83,931
Home Retail Group	3261	298	1042	DN65	25	£125,901
Ramada Encore	434	40	139	DN50	50	£119,718
Holiday INN	3591	328	1148	DN100	25	£137,090
Westminster House (Allianz	1977	181	632	DN45	36	£125,138
Travelodge	718	66	229	DN100	25	£92,356
Sovereign Court	1761	161	563	DN75	25	£107,085
Silbury Court	1835	168	586	DN50	40	£130,203
Ashton House	1230	112	393	DN75	36	£116,958
Norfolk House	1230	112	393	DN75	55	£146,212
Magistrates Court	680	62	217	DN65	85	£180,269
County Court	214	20	68	DN65	74	£147,880
Lloyds Court (Refurbishment)	1009	92	322	DN65	50	£134,839

**Stated cost is at current value. Model applies escalation.

Spine

	Peak Load *(kWth)**	Pipe Size	Length	Spine Pipework Costs**	Spine Electrical Costs**
S1	3274	DN200	100	£176,345	£10,000
S2	2880	DN200	79	£138,369	£7,900
S3	2197	DN200	92	£157,312	£9,200
S4	1786	DN200	93	£157,651	£9,300
S5	1511	DN200	100	£169,677	£10,000
S6	746	DN75	130	£208,451	£13,000
S7	543	DN75	100	£162,261	
S8	415	DN75	93	£151,540	
S9	226	DN50	92	£149,344	
S10	684	DN75	79	£129,985	£7,900
S11	636	DN75	79	£129,065	£7,900
S12	3602	DN200	169	£288,973	£16,900
S13	2863	DN200	56	£101,074	
S14	1976	DN200	25	£51,093	
S15	1172	DN150	125	£210,161	

*Estimated based on 0.7 diversity factor.

**Stated cost is at current value. Model applies escalation.

Pipework Assumptions

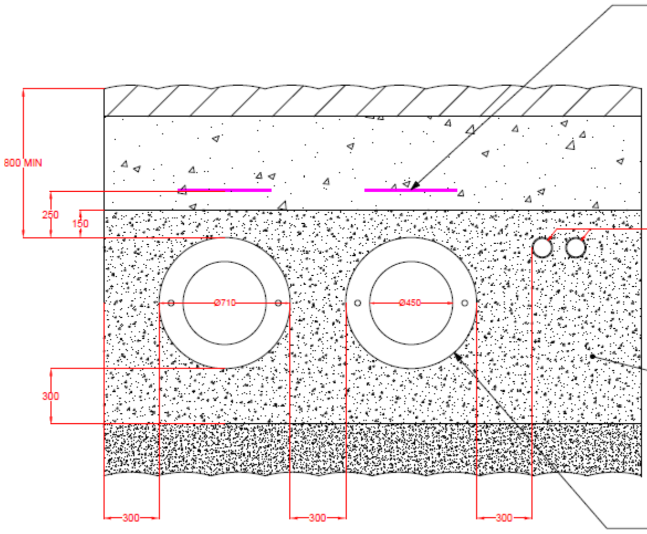
- Series 2 Pipework flow and return

Inclusive of

- Flushing and Cleaning
- NDT Testings
- Design & Stress Calculation inc 3D model, GPR
- TM, Road Closures, Consent, Licence
- Leak detection
- Fibre optic
- Documentation

Civils Assumption

- Assume trench 1.1m width, 1.5m depth.
- Pits for valves, ducts pits every 100m.
- Most trenching hard dig. Majority of spine pipework running beside main road through paved carparks.



Sample trench and pipework drawings

Maintenance and plant replacement charges and cost inclusion summary

Maintenance and upkeep of the energy centre, heat network and electrical network are modelled in EnergyPro based on actual servicing and upkeep costs from Thameswey. These costs are considered all-inclusive except for overhauls and engine replacements for the CHP. For further details see Section 5.3.

Component	*Annual Cost*
Energy Centre	£280,000
Network	£130,000
Customers	£61,000

An additional charge per residence for residential connections is levied to cover maintenance and equipment replacement as required. The total for the full scheme is shown below.

	Annual £ per residence	Residences	Annual Charge per annum
Maintenance	135.78	924	125,461

These costs are considered to include regular maintenance and ongoing replacements over the projected timeframes. Infrastructure such as thermal and electrical distribution, as well as boiler plant are considered to have a lifetime of longer than 40 years, so replacement costs have not been considered in the economic analysis. Overhauls and engine replacements for the CHP have been considered separately and are shown below.

Costing for CHP overhauls

Assumptions

- Existing energy centre overhauls schedule will not change with increased energy delivery
- Common maintenance arrangements between energy centres
- Trained energy centre staff complete many servicing requirements. Some reduction in normal overhaul price due to this
- Overhauls are performed at the same time

Modelled costs for 2.5 MWe. Prices are additional so are cumulative based on schedule.

	Additional Cost	Years	Starting year
Minor Overhaul	£37,500	4	2
Minor + Extras	£75,000	8	4
Major Overhaul	£150,000	8	8
Replacement	£300,000	8	16

Energy price projections

Figure 15 - Electricity Price Projections. Source: See

Price sources, Methodology and Assumptions
Wholesale Price - Ameresco / Spectron

TNUoS - first value SEW, average rate increase there on

Elexon – Haven Power, escalated a little for later years

AAHEDC – Haven Power, increased at same rate

BSUoS – Haven Power high case, increased at same rate

RO - Haven Powercentral case, increased at same rate

SS FIT - 'small scale' - Haven Power mid case, IASR

CfD FIT - Haven Power mid case, IASR

Capacity market – Haven Power, flat into 2020 and beyond

DUoS - 5% increase

CCL - As per SEW

Losses - 3% of w/s cost

Energy Centre CAPEX

Additional Energy Centre Pricing Information	**5MWe Centre**	**Note**
Plant (Additional CHP)	£2,068,450	*Supplier prices, 2G, Edina, CAT*
Plant room building works	£300,000	*Based on simple plantroom, prior experience*
Mechanical Installation	£400,000	*Assumption on similar prior projects*
HV Switchgear and RMU	£110,000	*From supplier pricing*
Electrical Cabling and Install	£155,000	*Assumption on similar prior projects*
LV Switchboard/MCC	£45,000	*Supplier pricing/prior experience*
Pumping	£50,000	*Supplier pricing/prior experience*
Land (allowance)	£400,000	*Assumed value*
Gas Supply	£50,000	*Indicative from prior experience*
Electrical Supply Connection	£100,000	*Indicative from DNO*
Thermal Storage	£350,000	*Industry standard 1000 per m3*
Supplementary Boiler (Lead/Lag) 3 X 10MW	£472,838	*Supplier prices, Carnot Consulting, Hoval*
Total	£4,501,288	
Total Delivered @ 15% Margin	£5,176,481	
Price per kw (excluding land)	£955	

Issued model inputs for report results

Model User Inputs

Sensitivity analysis tables at bottom of page

Equipment

One or two stage Energy Centre Delivery	1 Stage
Include additional thermal storage?	Yes
Oversize spline pipework by	NA

Energy

Electricity escalator	3.5%
Gas escalator	2.0%

Reference client grid energy prices (comparison only, does not change model outputs)

	Gas	Electricity
Mixed	£ 0.0300	£ 0.1000
Commercial	£ 0.0250	£ 0.0800

Build

Rollout Speed	100%	
Stage rollout lead time	1	year
Modelled build price correction (thermal/electrical networks only)	100%	

Carbon

Electricity Grid Factor	0.4121	kg CO2e per kWh
Natural Gas Factor	0.2044	kg CO2e per kWh
Boiler offset Efficiency	80%	
Predicted electricity grid factor for 2045	0.1500	kg CO2e per kWh

Assumption of relatively linear reduction in electricity grid emissions intensity

OUTPUT Table : Basic Carbon Balance

Positive indicates Carbon Saving compared to grid source

Years 1-10	5804	*tonnes CO2e*
Years 11-20	-30592	*tonnes CO2e*
Years 21-30	-62684	*tonnes CO2e*
Years 31-40	-104674	*tonnes CO2e*
Total	-192147	***tonnes CO2e***

OUTPUT Table : Basic Financials

Indirect results from outputs page

Press F9 to recalculate data tables following input changes.

Basic Financial Indicators

	25 Year	40 Year
NPV	£18,318,646	£42,568,938
IRR	19%	20%

Extension only — *Up to and including connection 13*

	25 Year	40 Year
NPV	£17,979,779	£30,234,764
IRR	27%	27%

Financial Variables

Cost of Capital	4.5%
Inflation	2.0%
Expansion spine cost allocation to new scheme	30%

Tariffs

Notes

Standard heat, electricity, and standing charges are based upon 2014 rates charged by Thamesway

Standard (100%) connection fee is based on the actual cost of integrating the building with the network.

Tariff Modifier Setup	Heat	Electricity	Connection	Standing Charges
Custom	*Set in below table*			
Tariff 1	100%	120%	0%	100%
Tariff 2	70%	105%	0%	80%
Tariff 3	80%	100%	0%	50%

For each site select a tariff type. If custom is selected enter values in the subsequent custom tariff columnbs for heat, electricity, connection fees, standing charge

Site	Connection Order	Tariff	Custom Tariff Modifier				Connection Type
			Heat Tariff	Electricity Tariff	Connection Fe	Standing Charge	
YMCA (Hostel & Resid)	1	Tariff 1					Heat/Electricity
Police Headquarters	2	Tariff 2					Heat/Electricity
Civic Offices	3	Tariff 2					Heat/Electricity
Central Library	4	Tariff 3					Heat/Electricity
B3.3N Pre-Planning	5	Tariff 1					Heat/Electricity
1-199 North 9th Street Flats	6	Tariff 2					Heat Only
CBXIII – Pre-Planning 1200 site	7	Tariff 1					Heat/Electricity
C3.1/2 Pre-Planning	8	Tariff 1					Heat/Electricity
B4.1-B4.3 Pre-Planning	9	Tariff 1					Heat/Electricity
Magistrates Court	10	Tariff 2					Heat/Electricity
County Court	11	Tariff 3					Heat/Electricity
Santander House	12	Tariff 2					Heat/Electricity
Witan Gate House	13	Tariff 3					Heat/Electricity
Central Business exchange	14	Tariff 2					Heat/Electricity
Midsummer court	15	Tariff 3					Heat/Electricity
Exchange House	16	Tariff 1					Heat Only
401 Grafton Gate	17	Tariff 2					Heat Only
Jurys Inn	18	Tariff 2					Heat Only
Avebury House	19	Tariff 3					Heat Only
Home Retail Group	20	Tariff 1					Heat Only
Ramada Encore	21	Tariff 2					Heat Only
Holiday INN	22	Tariff 1					Heat Only
Westminster House (Allianz	23	Tariff 1					Heat Only
Travelodge	24	Tariff 2					Heat Only
Sovereign Court	25	Tariff 1					Heat Only
Silbury Court	26	Tariff 3					Heat Only
Ashton House	27	Tariff 2					Heat Only
Norfolk House	28	Tariff 2					Heat Only
Lloyds Court (Refurbishment)	29	Tariff 3					Heat Only

Appendix J: EnergyPro Additional Results

Electrical Private Wire

See below split for overall electricity supply division for the new private wire only.

	Amount (*Annual MWh*)
Private Wire Supply	27,558
Export	2,742
Imported	2,604
Electricity Produced	27,696
Losses	3,000

Appendix K: Sample Performance Specification

CHP

ENGINE SPEED (rpm):	1500	RATING STRATEGY:	HIGH EFFICIENCY
COMPRESSION RATIO:	12.1:1	APPLICATION:	GENSET
AFTERCOOLER TYPE:	SCAC	RATING LEVEL:	CONTINUOUS
AFTERCOOLER - STAGE 2 INLET (°C):	48	FUEL:	NAT GAS
AFTERCOOLER - STAGE 1 INLET (°C):	89	FUEL SYSTEM:	CAT LOW PRESSURE
JACKET WATER OUTLET (°C):	99		WITH AIR FUEL RATIO CONTROL
ASPIRATION:	TA	FUEL PRESSURE RANGE(kPag):	14-35
COOLING SYSTEM:	JW+OC+1AC, 2AC	FUEL METHANE NUMBER:	85
CONTROL SYSTEM:	ADEM4 W/ IM	FUEL LHV (MJ/Nm3):	35.64
EXHAUST MANIFOLD:	DRY	ALTITUDE CAPABILITY AT 25°C INLET AIR TEMP. (m):	750
COMBUSTION:	LOW EMISSION	POWER FACTOR:	0.8
NOx EMISSION LEVEL (mg/Nm3 NOx):	500	VOLTAGE(V):	6600-11000

RATING		NOTES	LOAD	100%	75%	50%
GENSET POWER	(WITHOUT FAN)	(1)(2)	ekW	2500	1875	1250
GENSET POWER	(WITHOUT FAN)	(1)(2)	kVA	3125	2344	1562
ENGINE POWER	(WITHOUT FAN)	(2)	bkW	2586	1943	1305
GENERATOR EFFICIENCY		(1)	%	96.7	96.5	95.8
GENSET EFFICIENCY(@ 1.0 Power Factor)	(ISO 3046/1)	(3)(4)	%	45.3	44.5	42.6
THERMAL EFFICIENCY		(3)(5)	%	41.0	42.3	44.8
TOTAL EFFICIENCY (@ 1.0 Power Factor)		(3)(6)	%	86.3	86.8	87.4
ENGINE DATA						
GENSET FUEL CONSUMPTION	(ISO 3046/1)	(7)	MJ/ekW-hr	8.00	8.15	8.49
GENSET FUEL CONSUMPTION	(NOMINAL)	(7)	MJ/ekW-hr	8.27	8.43	8.78
ENGINE FUEL CONSUMPTION	(NOMINAL)	(7)	MJ/bkW-hr	8.00	8.13	8.41
AIR FLOW (0°C, 101.3 kPa)	(WET)	(8)	Nm3/bkW-hr	3.79	3.74	3.72
AIR FLOW	(WET)	(8)	kg/bkW-hr	4.90	4.83	4.80
FUEL FLOW (0ºC, 101.3 kPa)			Nm3/hr	580	443	308
COMPRESSOR OUT PRESSURE			kPa(abs)	474	360	250
COMPRESSOR OUT TEMPERATURE			°C	234	191	140
AFTERCOOLER AIR OUT TEMPERATURE			°C	53	50	49
INLET MAN. PRESSURE		(9)	kPa(abs)	453	338	230
INLET MAN. TEMPERATURE	(MEASURED IN PLENUM)	(10)	°C	53	51	49
TIMING		(11)	°BTDC	22	20	16
EXHAUST TEMPERATURE - ENGINE OUTLET		(12)	°C	394	430	485
EXHAUST GAS FLOW (0 °C, 101.3 kPa)	(WET)	(13)	Nm3/bkW-hr	4.02	3.97	3.96
EXHAUST GAS MASS FLOW	(WET)	(13)	kg/bkW-hr	5.07	5.01	4.98
MAX INLET RESTRICTION		(14)	kPa	3.60	2.50	1.81
MAX EXHAUST RESTRICTION		(14)	kPa	5.00	2.81	1.33
EMISSIONS DATA - ENGINE OUT						
NOx (as NO2)	(corr. to 5% O2)	(15)(16)	mg/Nm3 DRY	500	500	500
CO	(corr. to 5% O2)	(15)(17)	mg/Nm3 DRY	808	764	715
THC (mol. wt. of 15.84)	(corr. to 5% O2)	(15)(17)	mg/Nm3 DRY	1199	1234	1153
NMHC (mol. wt. of 15.84)	(corr. to 5% O2)	(15)(17)	mg/Nm3 DRY	168	173	161
NMNEHC (VOCs) (mol. wt. of 15.84)	(corr. to 5% O2)	(15)(17)(18)	mg/Nm3 DRY	132	136	127
HCHO (Formaldehyde)	(corr. to 5% O2)	(15)(17)	mg/Nm3 DRY	104	104	102
CO2	(corr. to 5% O2)	(15)(17)	g/Nm3 DRY	211	212	209
EXHAUST OXYGEN		(15)(19)	% DRY	9.7	9.4	8.9
LAMBDA		(15)(19)		1.78	1.72	1.66
ENERGY BALANCE DATA						
LHV INPUT		(20)	kW	5746	4390	3049
HEAT REJECTION TO JACKET WATER (JW)		(21)(28)	kW	593	507	416
HEAT REJECTION TO ATMOSPHERE		(22)	kW	76	63	51
HEAT REJECTION TO LUBE OIL (OC)		(23)(28)	kW	231	207	178
HEAT REJECTION TO EXHAUST (LHV TO 25°C)		(24)(25)	kW	1538	1245	916
HEAT REJECTION TO EXHAUST (LHV TO 120°C)		(24)	kW	1092	910	693
HEAT REJECTION TO A/C - STAGE 1 (1AC)		(26)(28)	kW	439	233	78
HEAT REJECTION TO A/C - STAGE 2 (2AC)		(27)(29)	kW	283	193	105

CONDITIONS AND DEFINITIONS

Engine rating obtained and presented in accordance with ISO 3046/1. (Standard reference conditions of 25°C, 100 kPa barometric pressure.) No overload permitted at rating shown. Consult the altitude deration factor chart for applications that exceed the rated altitude or temperature.

Emission levels are at engine exhaust flange prior to any after treatment. Values are based on engine operating at steady state conditions, adjusted to the specified NOx level at 100% load and corrected to 5 % exhaust oxygen. Tolerances specified are dependent upon fuel quality. Fuel methane number cannot vary more than ± 3.

For notes information consult page three.

Appendix I: EnergyPro modelling factors

MK Thameswey lead option combined.epp

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Catalogue of Economic Assumptions

1 Project Description

No assumption remarks attached to projectdescription

2 External Conditions

Currency: £
Nominal discount rate for Present value calculation: 0.0

2.1 Inflation and other indexes

CO2 DECC Grid factors

Month/Year	Index
January,2016	0.52
January,2017	0.51
January,2018	0.49
January,2019	0.44
January,2020	0.41
January,2021	0.39
January,2022	0.37
January,2023	0.36
January,2024	0.34
January,2025	0.32
January,2026	0.29
January,2027	0.28
January,2028	0.27
January,2029	0.27
January,2030	0.27
January,2031	0.26

Inflation
Annual increase   0.00%

Annual changes

	2018
Inflation *)	**0.0%**
CO2 DECC Grid factors	-10.2%

*) Index used for inflation

3 Payments

3.1 Revenues

Elec Export	EExp(_)Increasing with inflation	
Triads	Triad(_)Increasing with inflation	
STOR	STOR(_)Increasing with inflation	

Elec Sales

Existing Residential	125.3000 £ /	Increasing with inflation
Existing Comm Night	44.4000 £ /	Increasing with inflation
Existing Comm Day	79.9000 £ /	Increasing with inflation
YMCA BV Night	44.4000 £ /	Increasing with inflation
YMCA BV Day	79.9000 £ /	Increasing with inflation
Police HQ BV Night	44.4000 £ /	Increasing with inflation
Police HQ BV Day	79.9000 £ /	Increasing with inflation
Civic Offices BV Night	44.4000 £ /	Increasing with inflation
Civic Offices BV Day	79.9000 £ /	Increasing with inflation
Central Library BV Night	44.4000 £ /	Increasing with inflation

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Central Library BV Day	79.9000 £ /	Increasing with inflation
B33N BV Night	44.4000 £ /	Increasing with inflation
B33N BV Day	79.9000 £ /	Increasing with inflation
North Ninth Street Flats	125.3000 £ /	Increasing with inflation
CBXIII 1200 Site BV Night	44.4000 £ /	Increasing with inflation
CBXIII 1200 Site BV Day	79.9000 £ /	Increasing with inflation
C312 BV Night	44.4000 £ /	Increasing with inflation
C312 BV Day	79.9000 £ /	Increasing with inflation
B4143 BV Night	44.4000 £ /	Increasing with inflation
B4143 BV Day	79.9000 £ /	Increasing with inflation
Magistrates Court BV Night	44.4000 £ /	Increasing with inflation
Magistrates Court BV Day	79.9000 £ /	Increasing with inflation
County Court BV Night	44.4000 £ /	Increasing with inflation
County Court BV Day	79.9000 £ /	Increasing with inflation
Santander House BV Night	44.4000 £ /	Increasing with inflation
Santander House BV Day	79.9000 £ /	Increasing with inflation
Witan Gate BV Night	44.4000 £ /	Increasing with inflation
Witan Gate BV Day	79.9000 £ /	Increasing with inflation
Central Business Ex BV Night	44.4000 £ /	Increasing with inflation
Central Business Ex BV Day	79.9000 £ /	Increasing with inflation
Midsummer Court BV Night	44.4000 £ /	Increasing with inflation
Midsummer Court BV Day	79.9000 £ /	Increasing with inflation
Exchange House BV Night	44.4000 £ /	Increasing with inflation
Exchange House BV Day	79.9000 £ /	Increasing with inflation
Grafton Gate BV Night	44.4000 £ /	Increasing with inflation
Grafton Gate BV Day	79.9000 £ /	Increasing with inflation
Jurys Inn BV Night	44.4000 £ /	Increasing with inflation
Jurys Inn BV Day	79.9000 £ /	Increasing with inflation
Avebury House BV Night	44.4000 £ /	Increasing with inflation
Avebury House BV Day	79.9000 £ /	Increasing with inflation
Home Retail Group BV Night	44.4000 £ /	Increasing with inflation
Home Retail Group BV Day	79.9000 £ /	Increasing with inflation
Ramada Encore BV Night	44.4000 £ /	Increasing with inflation
Ramada Encore BV Day	79.9000 £ /	Increasing with inflation
Holiday Inn BV Night	44.4000 £ /	Increasing with inflation
Holiday Inn BV Day	79.9000 £ /	Increasing with inflation
Westminster House BV Night	44.4000 £ /	Increasing with inflation
Westminster House BV Day	79.9000 £ /	Increasing with inflation
Travelodge BV Night	44.4000 £ /	Increasing with inflation
Travelodge BV Day	79.9000 £ /	Increasing with inflation
Sovereign Court BV Night	44.4000 £ /	Increasing with inflation
Sovereign Court BV Day	79.9000 £ /	Increasing with inflation
Silbury Court BV Night	44.4000 £ /	Increasing with inflation
Silbury Court BV Day	79.9000 £ /	Increasing with inflation
Ashton House BV Night	44.4000 £ /	Increasing with inflation
Ashton House BV Day	79.9000 £ /	Increasing with inflation
Norfolk House BV Night	44.4000 £ /	Increasing with inflation
Norfolk House BV Day	79.9000 £ /	Increasing with inflation
Lloyds Court BV Night	44.4000 £ /	Increasing with inflation
Lloyds Court BV Day	79.9000 £ /	Increasing with inflation
Heat Sales		
Existing Commercial	27.7000 £ /	Increasing with inflation
Existing Residential	44.7000 £ /	Increasing with inflation
YMCA SH	HPr(_)Increasing with inflation	
YMCA DHW	HPr(_)Increasing with inflation	
Police HQ SH	HPr(_)Increasing with inflation	
Police HQ DHW	HPr(_)Increasing with inflation	
Civic Offices SH	HPr(_)Increasing with inflation	
Civic Offices DHW	HPr(_)Increasing with inflation	
Central Library SH	HPr(_)Increasing with inflation	
Central Library DHW	HPr(_)Increasing with inflation	
Res B33N SH	44.7000 £ /	Increasing with inflation
Res B33N DHW	44.7000 £ /	Increasing with inflation
B33N SH	HPr(_)Increasing with inflation	

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Catalogue of Economic Assumptions

B33N DHW	HPr(_)Increasing with inflation	
North 9th St Flats SH	44.7000 £ /	Increasing with inflation
North 9th St Flats DHW	44.7000 £ /	Increasing with inflation
CBXIII 1200 Site SH	HPr(_)Increasing with inflation	
CBXIII 1200 Site DHW	HPr(_)Increasing with inflation	
Res C312 SH	HPr(_)Increasing with inflation	
Res C312 DHW	HPr(_)Increasing with inflation	
C312 SH	HPr(_)Increasing with inflation	
C312 DHW	HPr(_)Increasing with inflation	
Res B4143 SH	HPr(_)Increasing with inflation	
Res B4143 DHW	HPr(_)Increasing with inflation	
B4143 SH	HPr(_)Increasing with inflation	
B4143 DHW	HPr(_)Increasing with inflation	
Magistrates Court SH	HPr(_)Increasing with inflation	
Magistrates Court DHW	HPr(_)Increasing with inflation	
County Court SH	HPr(_)Increasing with inflation	
County Court DHW	HPr(_)Increasing with inflation	
Santander House SH	HPr(_)Increasing with inflation	
Santander House DHW	HPr(_)Increasing with inflation	
Witan Gate SH	HPr(_)Increasing with inflation	
Witan Gate DHW	HPr(_)Increasing with inflation	
Central Business Ex SH	HPr(_)Increasing with inflation	
Central Business Ex DHW	HPr(_)Increasing with inflation	
Midsummer Court SH	HPr(_)Increasing with inflation	
Midsummer Court DHW	HPr(_)Increasing with inflation	
Exchange House SH	HPr(_)Increasing with inflation	
Exchange House DHW	HPr(_)Increasing with inflation	
Grafton Gate SH	HPr(_)Increasing with inflation	
Grafton Gate DHW	HPr(_)Increasing with inflation	
Jurys Inn SH	HPr(_)Increasing with inflation	
Jurys Inn DHW	HPr(_)Increasing with inflation	
Avebury House SH	HPr(_)Increasing with inflation	
Avebury House DHW	HPr(_)Increasing with inflation	
Home Retail Group SH	HPr(_)Increasing with inflation	
Home Retail Group DHW	HPr(_)Increasing with inflation	
Ramada Encore SH	HPr(_)Increasing with inflation	
Ramada Encore DHW	HPr(_)Increasing with inflation	
Holiday Inn SH	HPr(_)Increasing with inflation	
Holiday Inn DHW	HPr(_)Increasing with inflation	
Westminster House SH	HPr(_)Increasing with inflation	
Westminster House DHW	HPr(_)Increasing with inflation	
Travelodge SH	HPr(_)Increasing with inflation	
Travelodge DHW	HPr(_)Increasing with inflation	
Sovereign Court SH	HPr(_)Increasing with inflation	
Sovereign Court DHW	HPr(_)Increasing with inflation	
Silbury Court SH	HPr(_)Increasing with inflation	
Silbury Court DHW	HPr(_)Increasing with inflation	
Ashton House SH	HPr(_)Increasing with inflation	
Ashton House DHW	HPr(_)Increasing with inflation	
Norfolk House SH	HPr(_)Increasing with inflation	
Norfolk House DHW	HPr(_)Increasing with inflation	
Lloyds Court SH	HPr(_)Increasing with inflation	
Lloyds Court DHW	HPr(_)Increasing with inflation	
Standing Charges		
Elec Comm Standing Charges	979,767.0000 £ /Year	Increasing with inflation
Heat Comm Standing Charge	686,460.0000 £ /Year	Increasing with inflation
Elec Res Standing Charges	0.0692 £ /Res	Increasing with inflation
Heat Res Standing Charges	0.0820 £ /Res	Increasing with inflation
Res Maintenance Charges	0.1857 £ /Res	Increasing with inflation

3.2 Operating Expenditures

Electricity		
Elec Import	EImp(_)Increasing with inflation	

Catalogue of Economic Assumptions

Elec Import Duos	Duos(_)Increasing with inflation	
Elec CCL	5.5900 £ /MWh	Increasing with inflation
Triads	Triad(_)Increasing with inflation	
Standing Charges	125,670.0000 £ /Year	Increasing with inflation
Gas		
Gas	GP(_)Increasing with inflation	
Gas CCL	1.9500 £ /	Increasing with inflation
Gas CCL Removed	-1.9500 £ /MWh	Increasing with inflation
Standing Charges	138,484.0000 £ /Year	Increasing with inflation
EU ETS	5.0000 £ /tonne	Increasing with inflation
CHP CCL	1.9500 £ /MWh	Increasing with inflation
Maintenance		
Energy Centre	489,508.0000 £ /Year	Increasing with inflation
Heat Network etc maintenance	501,774.0000 £ /Year	Increasing with inflation
Elec Network etc maintenance	138,887.0000 £ /Year	Increasing with inflation

4 Investments

No INVESTMENTS is attached to the project

5 Financing

Cash Account

Cash account at opening: 0 £

Annual interest: 0.00 % at positive amount
Annual interest: 0.00 % at negative amount

No FINANCING is attached to the project

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Catalogue of Economic Assumptions

APPENDIX: Formulas

Payment formulas

Elec Export	ExportedElectricity(Electricity Market;All Periods)
Triads	ExportedElectricity(Electricity Market;All Periods)
STOR	ExportedElectricity(Electricity Market;All Periods)
Elec Sales	
Existing Residential	ED(Existing PW Res Elec Demand;All Periods) / UnitOfDemand(Existing PW Res Elec Demand)
Existing Comm Night	ED(Existing PW Comm Elec Demand;Night) / UnitOfDemand(Existing PW Comm Elec Demand)
Existing Comm Day	ED(Existing PW Comm Elec Demand;Day) / UnitOfDemand(Existing PW Comm Elec Demand)
YMCA BV Night	ED(Res YMCA Elec;Night) / UnitOfDemand(Res YMCA Elec)
YMCA BV Day	ED(Res YMCA Elec;Day) / UnitOfDemand(Res YMCA Elec)
Police HQ BV Night	ED(EPH Police HQ Elec BV;Night) / UnitOfDemand(EPH Police HQ Elec BV)
Police HQ BV Day	ED(EPH Police HQ Elec BV;Day) / UnitOfDemand(EPH Police HQ Elec BV)
Civic Offices BV Night	ED(Office Civic Offices Elec BV;Night) / UnitOfDemand(Office Civic Offices Elec BV)
Civic Offices BV Day	ED(Office Civic Offices Elec BV;Day) / UnitOfDemand(Office Civic Offices Elec BV)
Central Library BV Night	ED(Library Central Library Elec BV;Night) / UnitOfDemand(Library Central Library Elec BV)
Central Library BV Day	ED(Library Central Library Elec BV;Day) / UnitOfDemand(Library Central Library Elec BV)
B33N BV Night	ED(Office B33N Elec BV;Night) / UnitOfDemand(Office B33N Elec BV)
B33N BV Day	ED(Office B33N Elec BV;Day) / UnitOfDemand(Office B33N Elec BV)
North Ninth Street Flats	ED(Res North 9th St Flats Elec;All Periods) / UnitOfDemand(Res North 9th St Flats Elec)
CBXIII 1200 Site BV Night	ED(Hotel CBXIII 1200 Site Elec;Night) / UnitOfDemand(Hotel CBXIII 1200 Site Elec)
CBXIII 1200 Site BV Day	ED(Hotel CBXIII 1200 Site Elec;Day) / UnitOfDemand(Hotel CBXIII 1200 Site Elec)
C312 BV Night	ED(Office C312 Elec BV;Night) / UnitOfDemand(Office C312 Elec BV)
C312 BV Day	ED(Office C312 Elec BV;Day) / UnitOfDemand(Office C312 Elec BV)
B4143 BV Night	ED(Office B4143 Elec BV;Night) / UnitOfDemand(Office B4143 Elec BV)
B4143 BV Day	ED(Office B4143 Elec BV;Day) / UnitOfDemand(Office B4143 Elec BV)
Magistrates Court BV Night	ED(Office Magistrates Court Elec BV;Night) / UnitOfDemand(Office Magistrates Court Elec BV)
Magistrates Court BV Day	ED(Office Magistrates Court Elec BV;Day) / UnitOfDemand(Office Magistrates Court Elec BV)
County Court BV Night	ED(Office County Court Elec BV;Night) / UnitOfDemand(Office County Court Elec BV)
County Court BV Day	ED(Office County Court Elec BV;Day) / UnitOfDemand(Office County Court Elec BV)
Santander House BV Night	ED(Office Santander Elec BV;Night) / UnitOfDemand(Office Santander Elec BV)
Santander House BV Day	ED(Office Santander Elec BV;Day) / UnitOfDemand(Office Santander Elec BV)
Witan Gate BV Night	ED(Office Witan Gate Elec BV;Night) / UnitOfDemand(Office Witan Gate Elec BV)
Witan Gate BV Day	ED(Office Witan Gate Elec BV;Day) / UnitOfDemand(Office Witan Gate Elec BV)
Central Business Ex BV Night	ED(Office Central Business Ex Elec BV;Night) / UnitOfDemand(Office Central Business Ex Elec BV)
Central Business Ex BV Day	ED(Office Central Business Ex Elec BV;Day) / UnitOfDemand(Office Central Business Ex Elec BV)
Midsummer Court BV Night	ED(Office Midsummer Court Elec BV;Night) / UnitOfDemand(Office Midsummer Court Elec BV)
Midsummer Court BV Day	ED(Office Midsummer Court Elec BV;Day) / UnitOfDemand(Office Midsummer Court Elec BV)
Exchange House BV Night	ED(Office Exchange House Elec BV;Night) / UnitOfDemand(Office Exchange House Elec BV)
Exchange House BV Day	ED(Office Exchange House Elec BV;Day) / UnitOfDemand(Office Exchange House Elec BV)
Grafton Gate BV Night	ED(Office 401 Grafton Gate Elec BV;Night) / UnitOfDemand(Office 401 Grafton Gate Elec BV)
Grafton Gate BV Day	ED(Office 401 Grafton Gate Elec BV;Day) / UnitOfDemand(Office 401 Grafton Gate Elec BV)
Jurys Inn BV Night	ED(Hotel Jurys Inn Elec BV;Night) / UnitOfDemand(Hotel Jurys Inn Elec BV)
Jurys Inn BV Day	ED(Hotel Jurys Inn Elec BV;Day) / UnitOfDemand(Hotel Jurys Inn Elec BV)
Avebury House BV Night	ED(Office Avebury House Elec BV;Night) / UnitOfDemand(Office Avebury House Elec BV)
Avebury House BV Day	ED(Office Avebury House Elec BV;Day) / UnitOfDemand(Office Avebury House Elec BV)
Home Retail Group BV Night	ED(Office Home Retail Group Elec BV;Night) / UnitOfDemand(Office Home Retail Group Elec BV)
Home Retail Group BV Day	ED(Office Home Retail Group Elec BV;Day) / UnitOfDemand(Office Home Retail Group Elec BV)
Ramada Encore BV Night	ED(Hotel Ramada Encore Elec BV;Night) / UnitOfDemand(Hotel Ramada Encore Elec BV)
Ramada Encore BV Day	ED(Hotel Ramada Encore Elec BV;Day) / UnitOfDemand(Hotel Ramada Encore Elec BV)
Holiday Inn BV Night	ED(Hotel Holiday Inn Elec BV;Night) / UnitOfDemand(Hotel Holiday Inn Elec BV)
Holiday Inn BV Day	ED(Hotel Holiday Inn Elec BV;Day) / UnitOfDemand(Hotel Holiday Inn Elec BV)
Westminster House BV Night	ED(Office Westminster House Elec BV;Night) / UnitOfDemand(Office Westminster House Elec BV)
Westminster House BV Day	ED(Office Westminster House Elec BV;Day) / UnitOfDemand(Office Westminster House Elec BV)
Travelodge BV Night	ED(Travelodge Elec BV;Night) / UnitOfDemand(Travelodge Elec BV)
Travelodge BV Day	ED(Travelodge Elec BV;Day) / UnitOfDemand(Travelodge Elec BV)
Sovereign Court BV Night	ED(Office Sovereign Court Elec BV;Night) / UnitOfDemand(Office Sovereign Court Elec BV)
Sovereign Court BV Day	ED(Office Sovereign Court Elec BV;Day) / UnitOfDemand(Office Sovereign Court Elec BV)
Silbury Court BV Night	ED(Office Silbury Court Elec BV;Night) / UnitOfDemand(Office Silbury Court Elec BV)

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Catalogue of Economic Assumptions

Silbury Court BV Day	ED(Office Silbury Court Elec BV;Day) / UnitOfDemand(Office Silbury Court Elec BV)
Ashton House BV Night	ED(Office Ashton House Elec BV;Night) / UnitOfDemand(Office Ashton House Elec BV)
Ashton House BV Day	ED(Office Ashton House Elec BV;Day) / UnitOfDemand(Office Ashton House Elec BV)
Norfolk House BV Night	ED(Office Norfolk House Elec BV;Night) / UnitOfDemand(Office Norfolk House Elec BV)
Norfolk House BV Day	ED(Office Norfolk House Elec BV;Day) / UnitOfDemand(Office Norfolk House Elec BV)
Lloyds Court BV Night	ED(Office Lloyds Court Elec BV;Night) / UnitOfDemand(Office Lloyds Court Elec BV)
Lloyds Court BV Day	ED(Office Lloyds Court Elec BV;Day) / UnitOfDemand(Office Lloyds Court Elec BV)
Heat Sales	
Existing Commercial	HD(Existing Comm Heat demand) / UnitOfDemand(Existing Comm Heat demand)
Existing Residential	HD(Existing Res Heat demand) / UnitOfDemand(Existing Res Heat demand)
YMCA SH	HD(Res YMCA SH) / UnitOfDemand(Res YMCA SH)
YMCA DHW	HD(Res YMCA DHW) / UnitOfDemand(Res YMCA DHW)
Police HQ SH	HD(EPH Police HQ SH) / UnitOfDemand(EPH Police HQ SH)
Police HQ DHW	HD(EPH Police HQ DHW) / UnitOfDemand(EPH Police HQ DHW)
Civic Offices SH	HD(Office Civic Offices SH) / UnitOfDemand(Office Civic Offices SH)
Civic Offices DHW	HD(Office Civic Offices DHW) / UnitOfDemand(Office Civic Offices DHW)
Central Library SH	HD(Library Central Library SH) / UnitOfDemand(Library Central Library SH)
Central Library DHW	HD(Library Central Library DHW) / UnitOfDemand(Library Central Library DHW)
Res B33N SH	HD(Res B33N SH) / UnitOfDemand(Res B33N SH)
Res B33N DHW	HD(Res B33N DHW) / UnitOfDemand(Res B33N DHW)
B33N SH	HD(Office B33N SH) / UnitOfDemand(Office B33N SH)
B33N DHW	HD(Office B33N DHW) / UnitOfDemand(Office B33N DHW)
North 9th St Flats SH	HD(Res North 9th St Flats SH) / UnitOfDemand(Res North 9th St Flats SH)
North 9th St Flats DHW	HD(Res North 9th St Flats DHW) / UnitOfDemand(Res North 9th St Flats DHW)
CBXIII 1200 Site SH	HD(Hotel CBXIII 1200 Site SH) / UnitOfDemand(Hotel CBXIII 1200 Site SH)
CBXIII 1200 Site DHW	HD(Hotel CBXIII 1200 Site DHW) / UnitOfDemand(Hotel CBXIII 1200 Site DHW)
Res C312 SH	HD(Office C312 SH) / UnitOfDemand(Office C312 SH)
Res C312 DHW	HD(Office C312 DHW) / UnitOfDemand(Office C312 DHW)
C312 SH	HD(Office C312 SH) / UnitOfDemand(Office C312 SH)
C312 DHW	HD(Office C312 DHW) / UnitOfDemand(Office C312 DHW)
Res B4143 SH	HD(Office B4143 SH) / UnitOfDemand(Office B4143 SH)
Res B4143 DHW	HD(Office B4143 DHW) / UnitOfDemand(Office B4143 DHW)
B4143 SH	HD(Office B4143 SH) / UnitOfDemand(Office B4143 SH)
B4143 DHW	HD(Office B4143 DHW) / UnitOfDemand(Office B4143 DHW)
Magistrates Court SH	HD(Office Magistrates Court SH) / UnitOfDemand(Office Magistrates Court SH)
Magistrates Court DHW	HD(Office Magistrates Court DHW) / UnitOfDemand(Office Magistrates Court DHW)
County Court SH	HD(Office County Court SH) / UnitOfDemand(Office County Court SH)
County Court DHW	HD(Office County Court DHW) / UnitOfDemand(Office County Court DHW)
Santander House SH	HD(Office Santander SH) / UnitOfDemand(Office Santander SH)
Santander House DHW	HD(Office Santander DHW) / UnitOfDemand(Office Santander DHW)
Witan Gate SH	HD(Office Witan Gate SH) / UnitOfDemand(Office Witan Gate SH)
Witan Gate DHW	HD(Office Witan Gate DHW) / UnitOfDemand(Office Witan Gate DHW)
Central Business Ex SH	HD(Office Central Business Ex SH) / UnitOfDemand(Office Central Business Ex SH)
Central Business Ex DHW	HD(Office Central Business Ex DHW) / UnitOfDemand(Office Central Business Ex DHW)
Midsummer Court SH	HD(Office Midsummer Court SH) / UnitOfDemand(Office Midsummer Court SH)
Midsummer Court DHW	HD(Office Midsummer Court DHW) / UnitOfDemand(Office Midsummer Court DHW)
Exchange House SH	HD(Office Exchange House SH) / UnitOfDemand(Office Exchange House SH)
Exchange House DHW	HD(Office Exchange House DHW) / UnitOfDemand(Office Exchange House DHW)
Grafton Gate SH	HD(Office 401 Grafton Gate SH) / UnitOfDemand(Office 401 Grafton Gate SH)
Grafton Gate DHW	HD(Office 401 Grafton Gate DHW) / UnitOfDemand(Office 401 Grafton Gate DHW)
Jurys Inn SH	HD(Hotel Jurys Inn SH) / UnitOfDemand(Hotel Jurys Inn SH)
Jurys Inn DHW	HD(Hotel Jurys Inn DHW) / UnitOfDemand(Hotel Jurys Inn DHW)
Avebury House SH	HD(Office Avebury House SH) / UnitOfDemand(Office Avebury House SH)
Avebury House DHW	HD(Office Avebury House DHW) / UnitOfDemand(Office Avebury House DHW)
Home Retail Group SH	HD(Office Home Retail Group SH) / UnitOfDemand(Office Home Retail Group SH)
Home Retail Group DHW	HD(Office Home Retail Group DHW) / UnitOfDemand(Office Home Retail Group DHW)
Ramada Encore SH	HD(Hotel Ramada Encore SH) / UnitOfDemand(Hotel Ramada Encore SH)
Ramada Encore DHW	HD(Hotel Ramada Encore DHW) / UnitOfDemand(Hotel Ramada Encore DHW)
Holiday Inn SH	HD(Hotel Holiday Inn SH) / UnitOfDemand(Hotel Holiday Inn SH)
Holiday Inn DHW	HD(Hotel Holiday Inn DHW) / UnitOfDemand(Hotel Holiday Inn DHW)
Westminster House SH	HD(Office Westminster House SH) / UnitOfDemand(Office Westminster House SH)
Westminster House DHW	HD(Office Westminster House DHW) / UnitOfDemand(Office Westminster House DHW)
Travelodge SH	HD(Hotel Travelodge SH) / UnitOfDemand(Hotel Travelodge SH)

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Catalogue of Economic Assumptions

Travelodge DHW	HD(Hotel Travelodge DHW) / UnitOfDemand(Hotel Travelodge DHW)
Sovereign Court SH	HD(Office Sovereign Court SH) / UnitOfDemand(Office Sovereign Court SH)
Sovereign Court DHW	HD(Office Sovereign Court DHW) / UnitOfDemand(Office Sovereign Court DHW)
Silbury Court SH	HD(Office Silbury Court SH) / UnitOfDemand(Office Silbury Court SH)
Silbury Court DHW	HD(Office Silbury Court DHW) / UnitOfDemand(Office Silbury Court DHW)
Ashton House SH	HD(Office Ashton House SH) / UnitOfDemand(Office Ashton House SH)
Ashton House DHW	HD(Office Ashton House DHW) / UnitOfDemand(Office Ashton House DHW)
Norfolk House SH	HD(Office Norfolk House SH) / UnitOfDemand(Office Norfolk House SH)
Norfolk House DHW	HD(Office Norfolk House DHW) / UnitOfDemand(Office Norfolk House DHW)
Lloyds Court SH	HD(Office Lloyds Court SH) / UnitOfDemand(Office Lloyds Court SH)
Lloyds Court DHW	HD(Office Lloyds Court DHW) / UnitOfDemand(Office Lloyds Court DHW)
Standing Charges	
Elec Comm Standing Charges	1 / 12
Heat Comm Standing Charge	1 / 12
Elec Res Standing Charges	ResCusE(_) / 12
Heat Res Standing Charges	ResCusH(_) / 12
Res Maintenance Charges	ResCusH(_) / 12
Electricity	
Elec Import	ImportedElectricity(Electricity Market;All Periods)
Elec Import Duos	ImportedElectricity(Electricity Market;All Periods)
Elec CCL	ImportedElectricity(Electricity Market;All Periods)
Triads	ImportedElectricity(Electricity Market;All Periods)
Standing Charges	1 / 12
Gas	
Gas	ImportedFuel(Natural Gas) / HeatValue(Natural Gas)
Gas CCL	FC(Gas Boiler Plant 2) + FC(Gas Boiler Plant 1) + FC(EC2 Gas Boiler Plant 2) + FC(EC2 Gas Boiler Plant 1) / HeatValue(Natural Gas)
Gas CCL Removed	FC(Gas Boiler Plant 2) + FC(Gas Boiler Plant 1) + FC(EC2 Gas Boiler Plant 2) + FC(EC2 Gas Boiler Plant 1) / HeatValue(Natural Gas)
Standing Charges	1 / 12
EU ETS	ImportedFuel(Natural Gas) / HeatValue(Natural Gas) * .216
CHP CCL	(accImportedFuel(Natural Gas) / HeatValue(Natural Gas)) * (Max(0;((100 - (QI(195;115))) / 100))) * month(12)
Maintenance	
Energy Centre	1 / 12
Heat Network etc maintenance	1 / 12
Elec Network etc maintenance	1 / 12

Formulas for annual key figures

QI	QI(195;115)