Ricardo Energy & Environment

Pilot study on the air quality impacts from Combined Heat and Power in London

Report for Greater London Authority

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Combustion-based CHP plant gives rise to emissions to the atmosphere. The majority of CHP plants in London operate by burning fuels, and consequently generate oxides of nitrogen (referred to as NOx, and made up mainly of nitrogen dioxide and nitric oxide) as well as smaller amounts of fine particulate matter (PM_{10} and $PM_{2.5}$).

The findings from this study suggests that the CHP facilities proposed at the planning stage, if not effectively abated, could have a significant effect on air quality across the five boroughs studied in this project, which could offset the benefits gained from many of the transport-related air quality interventions currently being implemented by the Mayor. Impacts are more significant in the near vicinity of gas engine CHP facilities, which can often be located in residential areas or in close proximity to schools, hospitals or other sensitive sites.

Gas-engine CHP has in the past been an effective means of reducing carbon emissions. However, at a national level, the amount of greenhouse gases emitted per unit of electricity generated almost halved between 2012 and 2016, and is continuing to decrease. This means that CHP is now less effective in reducing carbon emissions.

Future GLA policy should consider the potential for significant local and cumulative air quality impacts of combustion-based CHP plant, while taking into account the contribution that CHP installations make to electricity generation and heat provision in London boroughs.

Summary

Combined Heat and Power (CHP) systems, also known as cogeneration, generate electricity and useful thermal energy in a single, integrated system. Combustion-based CHP plant gives rise to emissions to the atmosphere. The term “combustion-based CHP plant” in this study includes: natural gas-fired engine CHP, biogas-fired engine CHP, and bio-diesel CHP. Evidence is growing on the emissions to the atmosphere from some types of Combined Heat and Power (CHP) plant, and there are particular concerns about gas-engine CHP plant because of its widespread use in London. The main air pollutants of concern are oxides of nitrogen and fine particulate matter.

Combustion-based CHP has in the past been an effective means of reducing carbon emissions. However, at a national level, the amount of greenhouse gases emitted per unit of electricity generated almost halved between 2012 and 2016, and is continuing to decrease. This means that combustion-based CHP is now much less effective in reducing carbon emissions, and can also have adverse impacts on air pollution.

While combustion-based CHP has played a role in reducing emissions of greenhouse gases when compared to heat only gas combustion systems, it is important to ensure that existing and new CHP facilities do not have an adverse effect on air quality, particularly in London where air pollution remains a significant environmental and health issue. Under the current 2013 London Plan, the focus on implementation of combustion-based CHP may have contributed to conflicts with policies to improve air quality. The aim of this project is to help avoid ongoing air pollution issues with CHP, by providing an evidence base on CHP plant currently installed in London.

Gas-engine CHP is a significant air quality challenge, because of the prevalence of this technology, and the associated NO_x emissions. A significant improvement to air quality in London was achieved historically by relocating electricity generation outside of the city. Most of the power stations serving London are located away from densely populated areas, and discharge emissions through a tall stack. Additionally, most combustion-based electricity generating plant emit discharges to the atmosphere at a high temperature, which contributes to effective dispersion of emissions. In contrast, even though there is guidance on stack heights for combustion plant, emissions from combustion-based CHP plant in urban areas like London take place at a relatively low level (often below the height of nearby buildings), in close proximity to sensitive locations such as homes, schools and hospitals, and at low temperature (because heat is extracted from the flue gases to improve energy efficiency). This means that combustion-based CHP facilities can have a significant impact on local air quality.

Key findings from the study

The first stage in the study was to compile a database of CHP installations in five selected boroughs: Camden, Enfield, Kensington & Chelsea, Southwark and Westminster. A total of 376 CHP sites were identified in these boroughs. The information obtained in this study is considered to give a reasonably complete picture of CHP plant in the five boroughs. The numbers of facilities identified in each borough were as follows:

Borough	Number of facilities	Total identified CHP electrical capacity (kWe)
London Borough of Camden	63	22,853
London Borough of Enfield	19	14,489
Royal Borough of Kensington and Chelsea	34	16,932
London Borough of Southwark	103	25,336
London Borough of Westminster	157	31,743
Total for five boroughs	**376**	**111,353**

The database developed during this study draws mainly on records from the publicly available online planning portals, supplemented by data from GLA database records. The identified records were

checked through discussions with building owners and operators, where appropriate contacts could be identified. Additionally, a number of site visits to operational CHP facilities were carried out. Most CHP installations identified in this study use gas-fired engine technology. No Energy from Waste Plant with CHP were identified in the five boroughs which were the subject of this study.

Planning applications are designed to establish whether a proposed development is an appropriate use of the land. This means that planning decisions are often taken before detailed information is available on issues like CHP technology selection and plant design. It was found that there are often discrepancies between the plant identified in planning applications, and the plant that is installed in practice. There may be many reasons for this – for example, changes in building design or operation, or a change in plant contractor.

Published emissions factors indicate that emissions per unit of energy generated by CHP are typically higher from smaller plant (below 1 MW thermal input, MW_{th}) than from larger plant. This reflects the more extensive controls on emissions from larger plant.

Typically, the installed capacity of the CHP plant was found to be lower than envisaged in the planning application. This is a potential concern in view of the typically higher emissions per unit of energy produced for smaller facilities.

Currently, large combustion plant with capacity above 50 MW_{th} is regulated by the Environment Agency. Combustion plant with capacity between 20 and 50 MW_{th} is regulated by local authorities. Plant below 20 MW_{th} is not subject to formal regulation at present, although a regulatory regime under the Medium Combustion Plant (MCP) Directive is being introduced. For plant with a capacity below 1 MW_{th}, there is no regulatory requirement, although options for regulating this plant might be available under smoke control legislation, nuisance legislation, Local Air Quality Management or Ecodesign regulations. Consequently, while low-emissions CHP plant can be specified by conditions at the planning stage, there is currently no provision for ongoing regulation of CHP plant smaller than 20 MW thermal input (the majority of CHP installations) once it is installed, to ensure that the combustion component and any abatement systems are operating correctly.

It is important to ensure that where abatement technology is fitted, it is capable of achieving the required emission standards, (i.e. that the right technology is chosen) and that this is installed, operated and maintained correctly (see further discussion of abatement below).

Estimation of emissions potential of installed capacity

Emissions to air from the CHP plant identified in this study were estimated to be as follows:

Borough	Calculated emissions (Tonnes/year) of		
	Oxides of nitrogen	Particulate matter	Carbon dioxide
London Borough of Camden	563	3.29	46,174
London Borough of Enfield	203	1.66	34,365
Royal Borough of Kensington and Chelsea	168	1.08	17,568
London Borough of Southwark	638	4.69	88,436
London Borough of Westminster	959	5.22	64,212
Total for five boroughs	**2,532**	**15.95**	**250,755**

A sensitivity test was carried out to investigate emissions that would result if engines were assumed to emit at the median level identified in manufacturers' specifications for engines operating with and without catalytic convertor.

The results are presented in the table below:

Sensitivity tests	Oxides of nitrogen emissions (Tonnes per year)
Total for five boroughs – main study	2,539
Total if all plant assumed to emit at the same rate per unit of electricity generated as larger plant	597
Total if all plant assumed to emit at the rate provided by manufacturers for unabated CHP plant	5,963
Total if all plant assumed to emit at the rate provided by manufacturers for abated CHP plant (approximately equivalent to compliance with the GLA's Supplementary Planning Guidance on Sustainable Development)	371

Not all the facilities in the database are operational – indeed, fewer than half of the identified facilities may be operational. However, as part of the purpose of this report is to assess the *maximum potential* impact of the capacity allowed to be installed through the planning system (as there are no effective mechanism for regulating most CHP plant once agreed through the planning process) it is useful to understand the total possible emissions if all identified CHP facilities are assumed to be operational. On this basis, they would contribute around 6% of direct carbon dioxide emissions, and smaller percentages of PM_{10} and $PM_{2.5}$ emissions. The maximum potential contribution to NOx emissions is estimated to be around 32% of emissions averaged across the five boroughs, and over 50% of emissions from the London Borough of Southwark. The maximum contribution would be below 10% of other sources if all plant were fitted with operational abatement. This is not the case at present, but does highlight the potential for reductions in impacts due to emissions from CHP installations if abatement were more widely applied and if it is properly installed, maintained and operated. Separate work is underway to understand the 'real-world' emissions of gas-engine CHP plant installed in London.

As a rough estimate, if all the identified CHP facilities were operational, this could give rise to an average contribution to levels of oxides of nitrogen across the boroughs under consideration of approximately 5 $\mu g/m^3$ (the annual average legal limit for nitrogen dioxide is 40 $\mu g/m^3$). Again, because only 17% of identified CHP facilities (representing 43% of identified thermal capacity) could be confirmed as operational, the air quality impact at present is likely to be significantly lower than this upper estimate. If the heat provided by CHP installations were instead provided by low NOx boilers or zero emitting sources such as heat pumps, these installations would make a much lower contribution to levels of oxides of nitrogen.

As currently planned infrastructure is progressively implemented, impacts in the future may increase towards the upper estimates set out in this report. CHP facilities continue to be a feature of some planning applications, and without a change in policy to prioritise low emissions heat sources and take air quality into account, this can be expected to continue into the future.

This report suggests that ongoing implementation of the CHP facilities proposed at the planning stage, if not effectively abated, could have a significant effect on air quality across the five boroughs studied in this project, which would offset the benefits gained from many of the transport-related air quality interventions currently being implemented by the Mayor. Impacts would be more significant still in the near vicinity of gas engine CHP facilities, which can often be located in residential areas or in close proximity to schools, hospitals or other sensitive sites. This could be particularly important if the design or operation of the facility falls below best practice (for example, a poorly designed stack discharging close to or below the heights of neighbouring buildings).

Abatement of CHP emissions

The planning system does not allow for the controls that would be needed to consistently require and effectively ensure the ongoing use and maintenance of abatement equipment for combustion-based CHP. The planning system is not set up to address the details of specific plant installed, such details often develop following the grant of planning permission into the detailed design and construction process. Furthermore, the planning system is not intended to be an alternative to a proper ongoing permitting and inspection process. Even if accurate details of specific plant are available, planning conditions or Section 106 agreements are designed to ensure acceptable land uses, not to ensure ongoing standards of monitoring and maintenance to achieve emissions benchmarks. Accordingly, a planning-dependent solution which continues to support combustion-based CHP, even with the specification of abatement where needed, may not be effective. Stricter emission requirements than those in the GLA's current Supplementary Planning Guidance on Sustainable Development and other regulatory approaches (potentially supported by new legislation) may be appropriate to effectively address the risk of pollution from combustion-based CHP. Adherence to the SPG is determined by the relevant local authority, but approaches to securing compliance vary between authorities during and after planning determination. This partly reflects the lack of specificity about energy solutions included in planning applications. Such requirements may be outside the Mayor's current powers.

The above discussion indicates that gas-engine technology may not be the most appropriate technology choice for CHP in London in view of the potential air quality impacts. Introducing an additional unabated and/or unregulated NOx emission source to an area which already has poor air quality may significantly worsen the situation, and could potentially contribute to exceedances of the Air Quality Objectives. In the light of this, GLA may wish to consider restrictions on the use of combustion-based CHP technology. This suggests that project developers should consider alternative low carbon and low emissions heat sources at an early stage in project development. If combustion plant is required, this should be properly designed, and located as far away as possible from sensitive locations such as schools, hospital/medical facilities, and residential properties. However, there are limits on what can be achieved in this way for CHP facilities located in a densely populated city

Alternative low- or zero emission technology such as fuel cells or heat pumps may require market interventions to incentivise uptake.

In the case of gas-fired generating engines (the dominant technology identified in this study), project developers should consider procuring CHP plant which enables NO_x emissions to be minimised through control of combustion temperature. If required to achieve a more demanding performance standard, an appropriately designed catalytic system can be used to further reduce NO_x emissions. A three-way catalytic convertor can be used for some installations, but selective catalytic reduction (SCR) is more widely applicable and can be used for post-combustion emissions reduction, either as an inherent component of engine design, or as an add-on to an existing unabated engine. Additionally, a maintenance system/programme for the catalytic convertor and CHP plant operation, which provides for regular measurement and reporting of emissions, should be agreed at the planning stage, even though the planning system does not accommodate ongoing monitoring and enforcement.

Release concentrations below 100 mg/Nm^3 with catalytic systems are widely reported in manufacturer specifications however the performance of individual plant will depend on how it is designed, operated and maintained. Evidence from measurements of systems in the field confirms that the actual; real-world performance of plant can be variable, and optimum performance may not be achieved in practice as has been seen in the car industry. If installations do not achieve the expected performance, this could affect air quality in the immediate vicinity of a gas-fired CHP unit. Furthermore, if there were a widespread failure to achieve the performance required to comply with a policy such as the emission limits set in GLA's current 2014 Supplementary Planning Guidance on Sustainable Design and Construction, this could result in a more widespread air quality impact.

Study and data limitations

The database developed in this study is considered to be a reasonable starting point to describe CHP provision in the five boroughs under consideration. Further work and access to data across London would be required to improve this database and provide a full picture. For example, information was not available to enable the data obtained from the planning and GLA databases to be checked in every case. Consequently, while information from planning records may give a reasonable indication of the overall level of CHP provision in London, it should not be relied on to give an indication of specific local impacts resulting from individual facilities.

It was found that information in planning records often differs from the features of the CHP plant installed in practice.

Typically, installed capacity was found to be lower than envisaged in the planning application. While emissions per unit of energy produced are higher for smaller facilities, if the CHP facilities installed are smaller than envisaged at the planning stage, the potential extent of CHP implementation and associated air quality impacts have nevertheless been over-estimated in this study because of the study assumption that all proposed installations will be installed and operated in practice. The potential effect of uncertainty in emission factors was investigated by consideration of three sensitivity cases to reflect the range of potential emissions from CHP installations.

Recommendations

A range of policy options would be available to mitigate or eliminate the local air quality impacts of combustion-based CHP, and in particular gas-engine CHP. Gas-fired CHP plants fitted with catalytic convertors can be designed to achieve much lower NOx emissions if properly operated and maintained – although these still result in pollutant emissions and alternative technologies (e.g. heat pumps) should be considered, particularly in areas where air quality is poor. Possible policy approaches for combustion-based CHP could include:

For new developments

- A complete ban on combustion-based CHP provision for new development, either in specific geographical areas where air quality is a particular problem or there are sensitive communities or even across the entire city reflecting the potential scale of negative impacts and the way this could off-set other improvements, e.g. those delivered by reducing transport emissions.
- Where combustion-based CHP is used stricter limits on emissions of oxides of nitrogen should be applied by planning authorities, including through the use of abatement equipment; although the ability to effectively enforce these through the planning system and the lack of any comprehensive existing regulatory structure limits the potential effectiveness of these.
- Better enforcement of the requirement in the GLA Supplementary Planning Guidance on Sustainable Development for the assessment and mitigation of the air quality impacts of any development which includes a combustion-based CHP element. This should already take place: however, this study highlights that the existing planning system does not consistently ensure that these impacts are appropriately mitigated.
- A requirement on planning authorities to ensure that planning controls are in place to check the installation of appropriate abatement equipment in accordance with planning permissions.
- Regular real-world emission measurements should be carried out by the operator of any CHP facility which relies on mitigation.
- Specific provisions for enforcement, monitoring, auditing and maintenance of CHP equipment, systems and abatement technology installed in new developments, to be carried out by the planning authority or other relevant body. Such provisions are likely to require implementation through means other than the land-use planning system, although Section 106 agreements could provide a mechanism for delivery of some components of this. This could in principle be implemented through means such as an extension to the Environmental Permitting Regulations 2016 to include smaller CHP plants in the range of processes regulated as Part B activities by local authorities. This would enable specific statutory guidance to be produced, identifying appropriate emission benchmarks, together with monitoring and inspection requirements.

Any controls introduced on CHP installations at new developments would take some time to take effect, as existing permissions are implemented.

To address existing plant

- Specific provisions for enforcement, monitoring, auditing and maintenance of existing CHP equipment, systems and abatement technology. As with new plant, such provisions are likely to require implementation through means other than the land-use planning system, such as an extension to the range of Part B activities regulated by local authorities under the Environmental Permitting Regulations 2016, as described above.
- Additional abatement requirements for existing combustion-based CHP, or plant already approved through planning. This is especially important if the potential legacy impact of existing CHP equipment is to be addressed. This may require a new regulatory structure underpinned by new legislation.
- Provision of guidance/training for CHP facility operators.

It is recommended that the database developed under the current project should be extended to other London boroughs. A further study to investigate the actual local air pollution impacts of example CHP installations would also be valuable, and it is understood that two such studies are under way. This would provide an indication of the likely range of impacts of CHP plant in the immediate vicinity of the facility.

Future GLA policy should consider the potential for significant local and cumulative air quality impacts of CHP plant, while taking into account the contribution that CHP installations make to electricity generation and heat provision in London boroughs, and the associated potential carbon dioxide emissions savings in some circumstances.

Additionally, changes proposed to the national Standard Assessment Procedure would make gas-fired CHP unfavourable from a carbon mitigation perspective. In view of the potentially significant impact on local air quality, and question marks over future carbon savings, it is recommended that GLA policy in relation to combustion-based CHP technology which has associated emissions to air should be reviewed.

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1 Introduction

1.1 Combined Heat and Power

Combined Heat and Power (CHP) systems, also known as cogeneration, generate electricity and useful thermal energy in a single, integrated system. Combustion-based CHP plant give rise to emissions to the atmosphere. The term "combustion-based CHP plant" in this study includes: natural gas-fired engine CHP, biogas-fired engine CHP, and bio-diesel CHP.

The term "CHP" does not refer to a specific technology: it is an approach to applying a combination of technologies. Heat that is normally wasted in conventional power generation is recovered as useful energy, thereby avoiding the losses that would otherwise be incurred from separate generation of heat and power. While the conventional method of producing usable heat and power separately has a typical combined efficiency of 45%, CHP systems can operate at levels as high as 80%.[1]

CHP has in the past been an effective means of reducing carbon emissions. However, at a national level, the amount of greenhouse gases emitted per unit of electricity generated almost halved between 2012 and 2016, and is continuing to decrease.[2] This means that CHP is now much less effective in reducing carbon emissions, and also has adverse impacts on air pollution as described below.

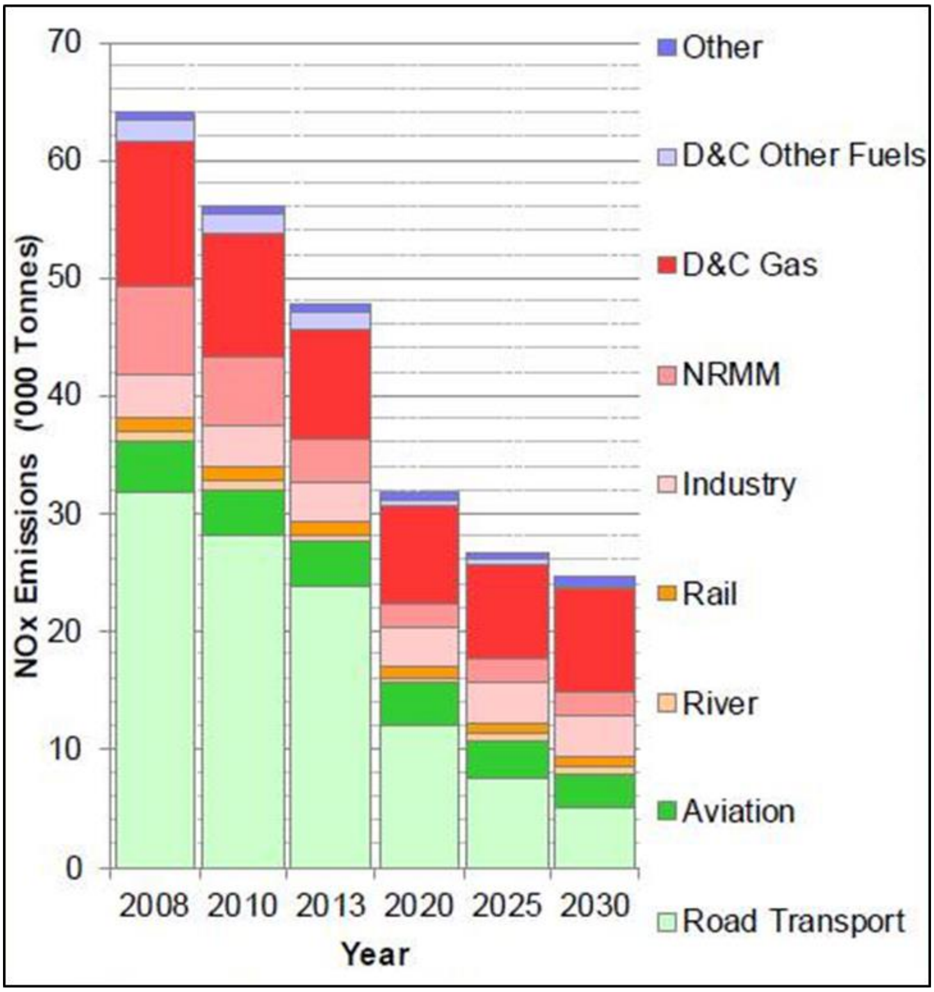
1.2 Context

1.2.1 Air quality in London

Air quality is one of the Mayor of London's strategic priorities. Air quality is the biggest environmental priority for the Greater London Authority (GLA), and has been made a personal priority for the Mayor. Consequently, the GLA is making significant investments in addressing air pollution. London's ambition is for its entire transport system to become zero emission, and for London to be a zero carbon city by 2050.[3] Transport emissions are well understood and there is a well-defined road map towards zero emissions.[4] The GLA is seeking additional powers to deal with emissions of air pollutants from construction activities . As a result, emissions of oxides of nitrogen from London as a whole are forecast to decrease towards 2030 and beyond. As a result of this, Domestic and Commercial combustion for energy production is forecast to become the largest source of oxides of nitrogen emissions in London from 2025 onwards.

[1] Description of CHP adapted from http://aceee.org/topics/combined-heat-and-power-chp
[2] https://eandt.theiet.org/content/articles/2017/11/carbon-emissions-associated-with-uk-s-electricity-generation-have-halved-since-2012/
[3] The Mayor of London, "London Environment Strategy," Draft for Public Consultation, August 2017. Available from: https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/draft-london-environment-strategy-have-your-say
[4] https://www.london.gov.uk/what-we-do/transport/our-vision-transport/draft-mayors-transport-strategy-2017

Figure 1: Total NOx emissions by source type for GLA, 2008 to 2030



By 2030, emissions of oxides of nitrogen from all sources in London are forecast to be about half the calculated emissions in 2013, with the majority of this reduction coming from reduced road transport emissions. By 2050, achieving the aspiration for a zero carbon city would eliminate many of the remaining sources, including Combined Heat and Power (CHP) as a component of domestic and commercial gas. However, there are concerns that ongoing investment in CHP in the short-to medium term could potentially compromise the improvement in air quality which will be secured from the move towards a zero emissions and zero carbon city. Airborne PM_{10} and $PM_{2.5}$ are also a concern in relation to air quality in London, but these pollutants are emitted in much lower quantities from combustion-based CHP, and consequently are less directly relevant to this study.

The GLA is keen to understand the potential impacts of existing and emerging planning policy to inform future approaches.

1.2.2 Effects of CHP on air quality

Under the current 2013 London Plan, there has been a policy focus encouraging low carbon energy provision through the use of Combined Heat and Power (CHP). The table below summarises the key features of CHP technologies which may be used in London.

Table 1: Summary of available CHP technologies

CHP Technology	Typical capacity kW	Local NOx emission factor (g/kWh gross heat input basis)	Abatement method?	Other characteristics
Gas reciprocating engine	25 to 4000 kW per engine	<1000 kW: 4.9 >1000 kW: 0.44	Inherent or end-of-pipe catalytic convertor	
Diesel reciprocating engine	25 to 4000 kW per engine	Stage IIIA 1.6-3 [HC+NOx] Stage V 0.27 (Ref. 5)	Inherent or end-of-pipe catalytic convertor	Higher emissions from smaller installations Emissions of PM are also significant
Gas microturbine	25 to 500 kW	0.023-0.051 (Ref. 6)		
Gas turbine	500 to 50,000 kW	0.009-0.14 (Ref. 7)		
Biogas reciprocating engine	25 to 4000 kW per engine	<1000 kW: 4.9 >1000 kW: 0.66	Inherent or end-of-pipe catalytic convertor	Zero fossil carbon dioxide emissions*
Biodiesel reciprocating engine	25 to 4000 kW per engine	<1000 kW: 6.8 >1000 kW: 3.2	Inherent or end-of-pipe catalytic convertor	Zero fossil carbon dioxide emissions*
Steam turbine	500 to 15000 kW	Coal 0.3-2.2 Wood 0.3-0.8 Oil 0.1-0.6 Natural gas 0.05-0.3 (Ref. 6)		
Fuel cell	5 to 3000 kW	0.002 (Ref. 7)	Not applicable	Hydrogen supply required, often derived from natural gas Zero direct carbon and PM emissions
Energy from waste	5,000 to 70,000 kW	0.7 to 1.35	SNCR or SCR can be used	Enables energy recovery from non-recyclable materials

Note: PM: particulate matter

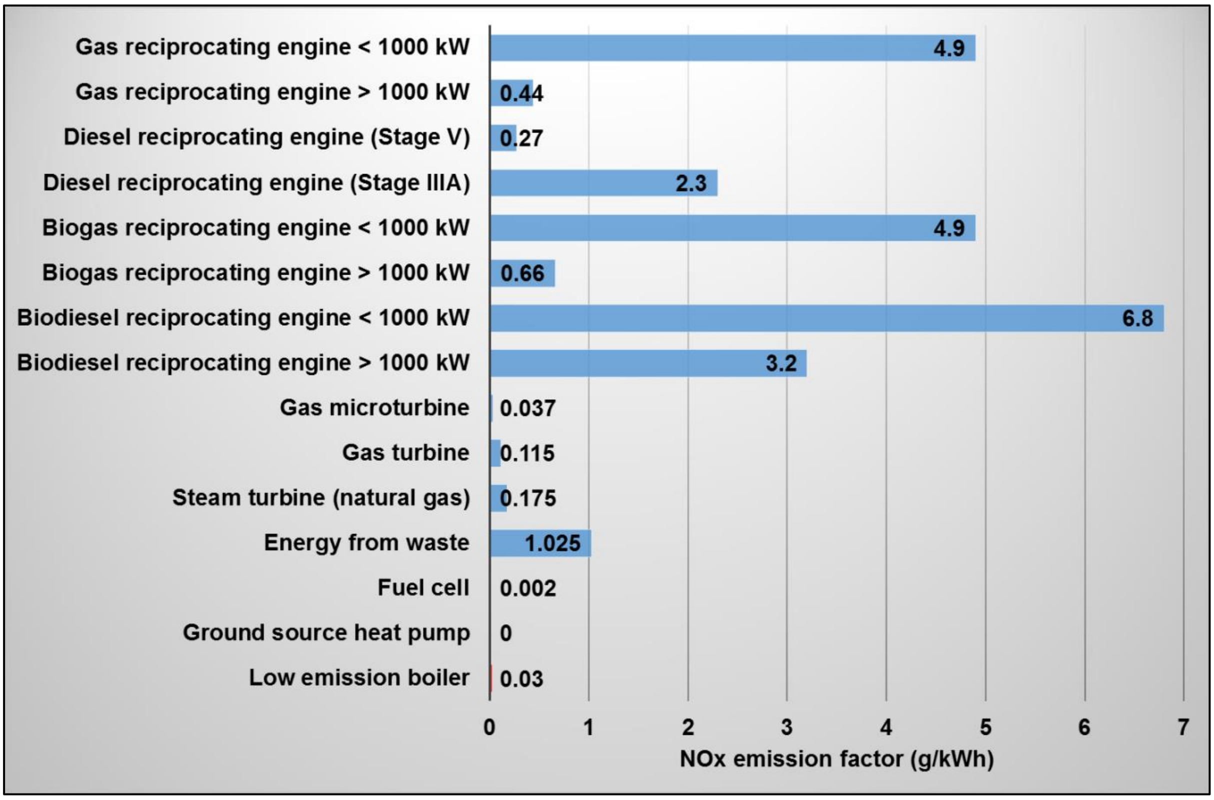
*Fossil CO_2 emissions contribute to levels of CO_2 in the atmosphere, whereas biogenic CO_2 emissions do not make a net contribution to atmospheric CO_2. Biogenic CO_2 emissions are defined as CO_2 emissions related to the natural carbon cycle, as well as those resulting from the combustion, harvest, combustion, digestion, fermentation, decomposition, or processing of biologically based materials.[8]

Evidence is growing on the emissions to the atmosphere from some types of Combined Heat and Power (CHP) plant, and there are particular concerns about gas-engine CHP plant because of its widespread use in London. The NO_x emissions performance of the technologies listed in Table 1 is illustrated in Figure 2. This figure also provides a comparison with NOx emissions from Ground Source Heat Pumps (a zero emitting heat technology), and low emission boilers. A study carried out in support of

[5] European emission standards for engines in new non-road mobile machinery (NRMM) specified by Directive 97/68/EC and amendments and Regulation (EU) 2016/1628 adjusted for notional 40% engine efficiency
[6] US EPA CHP Partnership, "Catalog of CHP Technologies," 2015
[7] US Department of Energy, "Combined Heat and Power Technology Fact Sheet Series," 2016
[8] https://19january2017snapshot.epa.gov/climatechange/carbon-dioxide-emissions-associated-bioenergy-and-other-biogenic-sources_.html

Westminster Council's Knightsbridge Neighbourhood Plan 2017-2037 indicated that low emission boilers emit less than 30 mg NO_x per kWh heat delivered are available.[9]

Figure 2: NOx emissions performance of CHP technologies



The results shown in Figure 2 confirm that CHP systems could have relatively high, relatively low or zero emissions of oxides of nitrogen. Emissions are determined by technology selection and abatement. The figure shows that generating engines, both gas and diesel fired, are relatively high emitting technologies compared to gas turbine, steam turbine or low emission boiler technologies. Much lower emissions can be achieved with these and other alternative technologies, although these may not be appropriate for individual developments, for technical, economic or other reasons.

A preliminary study carried out for GLA in 2016 showed that combustion-based CHP facilities make a small but potentially significant contribution to airborne levels of nitrogen dioxide in London.[15] This study included the identification of 148 CHP plants confirmed as operational across the GLA area – an average of fewer than five sites per borough, compared to the average of 80 sites per borough identified in this study (see Chapter 3). It was estimated that emissions from this incomplete database of CHP facilities would contribute approximately 0.3 µg/m^3 to annual average NOx concentrations averaged across London as a whole. While this would correspond to a relatively small average contribution of less than 1% of the air quality objective for nitrogen dioxide, it suggested that a more complete database of CHP would potentially highlight a higher impact. Furthermore, this suggests that in some local areas, combustion-based CHP facilities could have a more significant impact on local air quality, particularly in any cases where the discharge point is not well located, or the plant is not well operated and maintained.

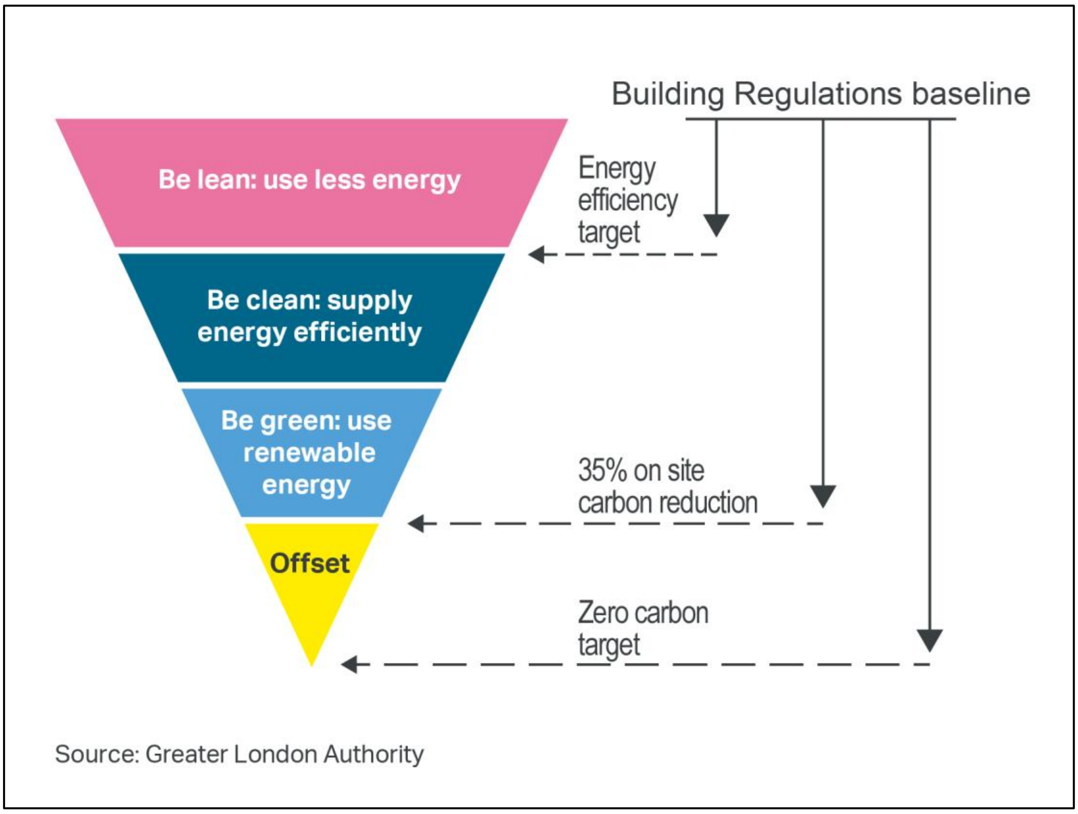
1.2.3 GLA Policy

District heating and creating heat networks are part of GLA policy under the London Environment Strategy and the London Plan. New planning applications have to look at heat network availability or for larger developments, act as the catalyst for investment in new heat infrastructure. The first principle for new developments is to connect to a heat network if one is available. Previous GLA policy promoted CHP as a key technology to support the development of heat networks. New draft London Plan policy

[9] Knightsbridge Neighbourhood Plan 2017 – 2037, "Part Three: Knightsbridge Evidence Base," November 2017

introduces a new heating hierarchy which promotes zero-emission technologies such as heat pumps above low emission CHP technology, which are for limited use in strategic area wide heat networks. Future policy due for implementation in 2019 following public consultation, is likely to incorporate a wider range of technologies and take greater consideration of air quality than previously, while still looking to meet carbon targets. The GLA's policy is summarised as "Be lean, be clean, be green", as shown in Figure 3.

Figure 3: GLA policy for energy provision in new buildings



Current air quality requirements for CHP are set through Supplementary Planning Guidance (SPG) on Sustainable Design and Construction.[10] This sets three requirements relevant to new combustion-based CHP facilities:

- Two sets of emission limits are specified, depending on ambient air quality. If background air quality levels are above 95% of the air quality objective for NOx, limits are applied which require abatement. Otherwise, emission limits are set at levels which can be achieved by engine management. These emission limits were derived from research carried out in relation to larger scale combustion plant. Emissions from smaller scale unabated CHP engines are likely to exceed the limits set in the SPG. For the purposes of this project, it has been assumed that smaller scale plant are more polluting. If developers have been obliged to install lower emitting smaller-scale plant as a result of the terms of the SPG, this would result in lower emissions than indicated in this study. GLA is currently looking to tighten the SPG requirements.
- "Air quality neutral" – developers are required to evaluate NOx emissions based on building type and footprint, and any new development is required not to increase NOx emissions above the benchmarked levels. These current benchmarks have been found not to represent a challenging target for new development and are being reviewed to base them on the energy requirements of new build rather than existing building stock. As well as reviewing Air Quality

[10] Mayor of London, "Supplementary Planning Guidance: Sustainable Development and Construction," March 2014

Neutral the GLA has introduced policies in the draft London Plan to promote a design led approach for managing air quality impacts and exposure associated with new development.

- A requirement for air quality impact assessments (AQIAs) for new developments. An AQIA is designed to assess the effects of a new development air quality due to emissions from sources such as road traffic and any heating plant. It is based on the information available during design of the development, which may not fully reflect the impacts of the development once constructed. Because of this, AQIAs are often carried out on a "worst case" basis, designed to ensure that any impacts are over-estimated – for example, by over-estimating the likely CHP capacity requirements. The plant installed may then be smaller scale than envisaged in the AQIA, without invalidating the conclusions of the AQIA. These impact assessment studies should include the impacts of heating technologies, but are very variable in quality and do not always address these issues. Anecdotal evidence suggests that planning approaches in different boroughs are not consistent. Some boroughs consider that a CHP which meets emissions limits does not require an AQIA, whereas this is not necessarily the case. This could potentially result in CHP plant being designed and installed in some cases which has a significant impact on air quality in the local area.

Notwithstanding these controls, the focus on implementation of CHP has led to conflicts with air quality policy. Widespread implementation of gas engine CHP has to date been driven by carbon reduction targets and cost savings from CHP, together with the cost-effectiveness and flexibility of gas engines. As a result, gas engine CHP is a significant air quality challenge, because of the prevalence of this technology, the associated NO_x emissions and characteristics of releases from CHP facilities. A significant improvement to air quality in London was achieved historically by relocating energy generation outside of the city. Most of the power stations serving London are located away from densely populated areas, and discharge emissions through a tall stack. Additionally, most combustion-based electricity generating plant emit discharges to the atmosphere at a high temperature, which contributes to effective dispersion of emissions. In contrast, even though there is guidance on stack heights for combustion plant, emissions from combustion-based CHP plant in urban areas like London take place at relatively low level (often below the height of nearby buildings), in close proximity to sensitive locations such as homes, schools and hospitals, and at low temperature (because heat is extracted from the flue gases to improve energy efficiency). This means that combustion-based CHP facilities can have a significant impact on local air quality.

This was only partially addressed under the previous administration, by issuing Supplementary Planning Guidance (SPG) which sets emission standards for combustion-based CHP. For the most commonly encountered CHP plant (gas fired spark ignition engine), the emission standards for NOx emissions are 95 mg/Nm^3 where levels of nitrogen dioxide are close to or above the air quality standard, and 250 mg/Nm^3 in other areas. Specific abatement may be needed to achieve these emission limits, particularly the more demanding standard. This may be provided as part of a "low emissions" package, or may require additional end-of-pipe abatement. Even with this SPG in place, achieving the GLA's previous target for decentralised energy provision mainly by combustion-based CHP would have risked eroding the air quality improvements being delivered by significant investments in transport improvements. There remains a risk that increased combustion-based CHP could compromise the ability to achieve air quality benefits. Additional evidence is needed to fully understand the potential significance of the risk that past and ongoing investment in combustion-based CHP poses to air quality.

The London Plan is currently being developed by GLA. The London Plan is the key opportunity for GLA to make a difference on the ground, and provides the opportunity to set policy priorities in relation to CHP, and thereby minimise the risk of significant pollution impacts being built in to London's infrastructure.

1.2.4 National policy developments

Changes are being proposed to the national Standard Assessment Procedure (SAP) used to evaluate the energy performance of residential properties. A study carried out for GLA[11] found that, if implemented as planned, these changes would make gas engine CHP unfavourable from a carbon mitigation perspective. Options such as direct electric heating and air source heat pumps would be

[11] Buro Happold Engineering, "The future role of the London Plan in the delivery of area wide district heating," June 2017 (executive summary available from: https://www.london.gov.uk/sites/default/files/the_future_role_of_the_london_plan_in_the_delivery_of_area-wide_district_heating_-_executive_summary_-_buro_happold.pdf

more favourable from this perspective. While the proposed changes to SAP could encourage a move away from gas-fired CHP in new development, at present there is no guarantee that this would occur in practice, and is in any case subject to the implementation of the proposed changes by BEIS. These proposed changes cannot be relied on to deliver reductions in the impact of combustion-based CHP emissions on air quality.

1.3 This project

The aim of this project is to help avoid new and ongoing air pollution issues with CHP, by providing an evidence base on CHP plant currently installed in London. The aim is to understand, as far as possible, what plant is currently installed, what combustion technology is used, what abatement is applied, how this is maintained and how frequently the plant is used. Anecdotal evidence suggests that there may be inconsistencies in approach between local authorities. Different authorities may have different approaches regarding the assessment of air quality impacts of development which includes CHP, and alongside this, different requirements for setting emission limits and requiring abatement of emissions from new CHP plant. Variations in maintenance and emissions monitoring requirements between authorities would also be also important in affecting emissions from individual installations.

This project is focused on:

- Identifying CHP facilities
- Investigating what requirements are being set through the planning system
- Investigating what happens on the ground. For new development, the following questions are relevant:
  - Was CHP installed as proposed?
  - Was abatement applied as required?
  - What maintenance is carried out?
  - Who is responsible for operating, maintaining and inspecting CHP plant?

The project investigates whether the current or future implementation of CHP could result in a local impact on air quality. However, this project does not include modelling of air quality impacts. A database of CHP facilities in five London boroughs is provided, which will form the basis for a CHP register in London.

1.4 Project outputs

This project provides the following information:

- Background information on CHP facilities and their potential air quality impacts (this chapter)
- A database of CHP facilities in five London boroughs
- A discussion of controls on air pollution impacts from CHP installations
- A discussion of potential air pollution impacts of CHP in London
- Case studies for a number of CHP facilities

2 Methodology

2.1 Identification of five London boroughs

At the project outset, five boroughs were identified to form the focus of this pilot project. The boroughs were identified based on the following criteria:

- Useful contacts with borough air quality and planning officers
- Availability of information on CHP facilities held by the borough
- Mix of central and outer authorities

Based on these criteria, the following five boroughs were selected:

- London Borough of Camden
- London Borough of Enfield
- Royal Borough of Kensington and Chelsea
- London Borough of Southwark
- London Borough of Westminster

2.2 Database development

Information on CHP facilities in the above five boroughs was drawn together from the following sources:

1. Every local planning authority (LPA) maintains a searchable database of planning applications. A detailed search of the planning database for each borough was carried out to identify developments which include a CHP element.
2. The GLA has maintained a database of CHP facilities. The completeness and accuracy of this database is not known, but it comprises a useful potential source of information, with approximately 400 records.
3. Each authority was contacted to investigate whether officers maintain a database of information on CHP facilities, and to request provision of any relevant data
4. The GLA maintains a database of called-in planning applications. As an additional cross-check on the data obtained from local authority records and the GLA's CHP database, this database was searched in relation to potential CHP facilities in Southwark. It was found that the called-in applications database did not contain information on additional facilities to those identified in the Southwark planning database.
5. The GLA's PAWS planning database was searched to investigate whether any further facilities were listed on this system.

Having identified CHP facilities within the five boroughs, an internet search was carried out to investigate whether the CHP facilities described in the planning application have been constructed in practice.

The database was then scrutinised to exclude facilities for which there was reasonable evidence that they do not exist in practice, and to identify and reconcile duplicate entries. Planning records were then scrutinised to identify relevant information on the proposed facilities for entry into the database. The following information was sought in respect of each identified CHP facility.

Table 2: Database entries

Database entry	Database entry
Planning application (id/number)	What catalytic converter or other abatement technology is installed? (emission reduction of air quality pollutants)
Borough	What scheme is in place to maintain the catalytic convertor
Site name	Energy manager/Site Manager email address

Database entry	Database entry
Easting (m)	Energy manager/Site Manager tel number
Northing (m)	Closed? (date)
Postcode	Type of back up boilers
Address	Number of back up boilers
Installed capacity (kW_{th})	Assumed emission factor/rate for boilers
Installed capacity (kWe)	Dispersion Modelling Included
Installation date	Search term
Operational hours 2016	Primary Source
Life time	LPA planning DB Record
Technology (engine type)	GLA planning DB record
How many engines are installed	Other (web search)
Engine make	GLA CHP london-wide dataset
Engine model	Duplicate record in different datasets?
Stack height (AOD) (m)	CHP included in application?
Stack Height (above building) (m)	URL (1) ref
Diameter (m)	URL (2) ref
Velocity (m/s)	URL (3) ref
Flow rate @ reference (Nm3/s)	Date CHP commissioned
Actual flow rate (m3/s)	CHP Operational?
Temp (°C)	Development Status / Other scheme details
NOx Concentration (mg/Nm3)	GLA case No.
NOx Release rate (g/s)	Planning App Year - latest
Fuel used	AQM plan?
Dom/Com/Other	Project calculated NOx emission

2.3 Search strategy

Each database was searched using a number of terms designed to identify the existence of centralised energy plant, and specifically CHP. The terms used were as follows:

Specific search terms:

1. Combined heat and power
2. CHP

Generalised search terms:

3. Energy centre
4. Energy plant
5. Heat recovery

6. Biomass
7. Reciprocating engine
8. Chimney
9. Stack
10. Exhaust

Using the Local Authority databases, it was only possible to apply these search terms to the facility name and overall description.

Every planning application or installation identified in this way was reviewed. Any application identified as including a CHP element was entered into a long list of identified developments for more detailed evaluation.

2.4 Combining datasets

The long list of developments was firstly audited to identify and eliminate duplicate entries. Duplicate entries arose in a number of cases from entries in more than one of the databases. These were identified and amalgamated into a single entry. Additionally, the planning databases frequently identified multiple records relating to a single development – for example, applications for discharge of reserved matters following granting of outline planning permission. Again, these were identified and a single entry identified.

The database was then set up with unique entries using the headings set out in Table 2. An appropriate planning reference number was used as the unique identifier for each installation.

2.5 Data extraction

All available sources of data were then used to complete the database so far as possible. The key documents which were found to provide useful data were:

- Energy statements submitted with planning applications
- Air quality impact assessments submitted with planning applications
- Overall development descriptions

2.6 Verification

The next step was to verify database records. A number of steps were taken to achieve this.

1. An internet search was carried out to investigate whether the development could be confirmed as having proceeded to construction and/or operation. Relevant information was provided by sources such as local media reports, developers' websites (e.g. advertising properties available for occupation), and local authority websites. In only 17% of cases, accounting for 43% of identified operational capacity, was it possible to identify whether the proposed CHP installation had been implemented as planned. In cases where there was doubt as to whether the development had proceeded, it was assumed that the development could have gone ahead, and the entry was retained in the database.
2. The developers and owners of developments thought to contain CHP were contacted to discuss whether the proposed development had gone ahead, and if so, whether CHP provision was as anticipated. Once a useful contact was identified, a request for further information was sent, using the database headings as a prompt for provision of additional information in relation to the CHP facility. This was particularly useful where the design of the CHP facility had changed from that anticipated at the time planning permission was granted, and also in securing data on the actual operating hours of CHP facilities.
3. Where appropriate, site visits were arranged to inspect CHP facilities. The aim of these site visits was to hold further discussions with the facility operators with the aim of gaining insights into real-world operation of these installations. Where possible, facility maintenance records and arrangements were discussed. Discharge points were inspected with the aim of identifying any potential air quality issues – in particular, installations with low discharge heights relative to nearby buildings and structures.

On completion of discussions with owners and developers, and following site visits, the CHP database was updated with new information.

It was found that none of the facilities identified were of sufficient scale to be regulated as Part A or Part B processes in their own right, so it was not possible to cross-check facility data and calculated emissions against reports to the Environment Agency's Pollution Inventory. The South-East London Combined Heat and Power (SELCHP) plant is an Environment Agency regulated waste to energy facility which provides some heat to users in the borough of Southwark: however, the plant itself is located in the borough of Lewisham.

2.7 Emissions estimation

Based on the information assembled in the CHP database as described in Sections 2.1 to 2.6 above, emissions of oxides of nitrogen, PM_{10} and carbon dioxide from CHP facilities in the five boroughs were estimated.

2.7.1 Emission factors

Emissions from large point sources regulated by the Environment Agency could be taken from data reported to the Environment Agency's Pollution Inventory and Pollutant Release and Transfer Registry. However, no such facilities were identified in the five boroughs under consideration in this study.

Emissions from the identified CHP installations were estimated by identifying appropriate emission factors for each relevant technology and fuel type. The relevant emission factor was multiplied by an index of activity for each facility to provide an estimated emission rate.

Technology-specific emission factors are published in emission inventory guidance (for example the European Environment Agency[12] and the US Environment Protection Agency[13]). Some published emission factors are quite dated, or based on a limited set of references, and a short literature review was undertaken to find other technology emission factors. Manufacturers' data is available for some installation types, but this tends to refer to measurements carried out under optimum conditions, and represents the manufacturer's view of what constitutes achievable emissions, rather than typical in-service emissions. Manufacturers' data was therefore not relied on in this study.

The EEA database provides emission factors which are applicable to facilities with capacity between 1 MW and approximately 25 MW. The EEA factors are based on a survey of CHP engines with capacity up to 25MW in Denmark, and the engines surveyed are all relatively large units and are likely to be subject to emission controls. However, smaller gas engines are unlikely to have NOx controls applied (for example, the Gothenburg Convention threshold for NOx control on stationary gas engines is 1MWth). In the current study, further evaluation identified that emission factors developed by the US EPA are applicable to smaller facilities with a capacity below 1MW. In this study, therefore, the EEA emission factor were used for facilities greater than 1 MW, and the USEPA factors were used for facilities with capacities below 1 MW.

Activity data in relation to CHP facilities is typically based on fuel consumed or energy generated. Some site-specific data on facility utilisation were available from the preceding tasks, and this was used where available. However, such data were not available for all CHP plant. In the absence of installation-specific data, fuel consumption was estimated on the basis of the plant capacity, the average CHP load factor for London published in the DUKES Energy Trends publications,[14] and knowledge of the fuel type and technology efficiency. Facilities for which fuel type was not known were assumed to be gas fired, as this is by far the most common fuel for CHP facilities in London.

Emissions were then estimated from estimates of fuel used (activity data) and pollutant emission factors.

Annual emission = Electrical generation capacity × annual hours × Efficiency factor × emission factor

This calculation was repeated for each pollutant and plant to provide the total emission for each pollutant.

[12] TFEIP emission inventory guidance: https://www.eea.europa.eu/publications/emep-eea-guidebook-2016
[13] USEPA AP42 emission inventory guidance:https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors
[14] Energy trends special report https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/556273/CHP.pdf

Emission factors and activity data were calculated as follows:

- Operating hours per year
  - Waste to energy and CCGT: GLA 2016 report[15]
  - Other installations: BEIS Energy Trends report[14]. This gives a relatively low figure for utilisation. This reflects that a high proportion of London's CHP is used to provide space heating, and hence does not operate all the time.
- Energy efficiency
  - Waste to energy and CCGT: DECC 2014 report[16]
  - Other installations: DECC 2014 report with data broken down separately for plant <100 kWe, 100-200 kWe, 200-1000 kWe, and >1000 kWe
- Emission factors
  - All technologies: Carbon dioxide: UK Government conversion factors for company reporting[17]
  - Medium gas engines (>= 1 MW): EEA/EMEP factor[18]
  - Small gas engines (<1 MW) USEPA AP-42 factor (if higher) [13]
  - Medium biogas engines (>= 1 MW): Danish CHP study for NOx, EEA/EMEP factor for PM[18]
  - Small biogas engines (<1 MW): USEPA AP-42 factor (if higher) [13]
  - Medium compression ignition engines using gas oil (>= 1 MW): EEA/EMEP factor[18]
  - Small compression ignition engines using gas oil (<1 MW): USEPA AP-42 factor (if higher) [13]
  - Medium compression ignition engines using biodiesel (>= 1 MW): EEA/EMEP factor[18]
  - Small compression ignition engines using biodiesel (<1 MW): USEPA AP-42 factor (if higher)[13]
  - Fuel cells: zero emissions

This process resulted in the following emission factors and supporting data:

Table 3: Emission factors and supporting data

Facility type	Definition	Operating hours per year	Electrical efficiency	Emission factors (g/kWh thermal input)			
				CO2	NOx	PM10	PM2.5
Energy from waste - incineration		5957	n/a	n/a	n/a	n/a	n/a
Gas Engine - Small, natural gas	200 - 1000 kWe	3446	0.380	184	4.868	0.0227	0.0227
	100 - 200 kWe	3446	0.338	184	4.868	0.0227	0.0227
	<100 kWe	3446	0.317	184	4.868	0.0227	0.0227
Gas Engine - Medium (including multi-engine), natural gas	>=1000 kWe	3446	0.380	184	0.438	0.0065	0.0065
Renewable Energy Gas Engine - Small, biofuel	200 - 1000 kWe	3446	0.380	0	4.868	0.0227	0.0227
	100 - 200 kWe	3446	0.338	0	4.868	0.0227	0.0227
	<100 kWe	3446	0.317	0	4.868	0.0227	0.0227
Renewable Energy Gas Engine - Medium (including multi-engine), biofuel	>=1000 kWe	3446	0.380	0	0.656	0.0065	0.0065
Fuel Cell CHP		5957	0.420	0	0	0	0
RE (diesel) - small, biodiesel	200 - 1000 kWe	3446	0.380	0	6.826	0.480	0.480

[15] Ricardo Energy & Environment for GLA, "Air quality impacts of the London heat plan", 2016
[16] DECC (2014), Ricardo AEA , Bespoke Gas CHP Policy– Cost curves and Analysis of Impacts on Deployment
[17] https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting#conversion-factors-2017
[18] European Monitoring and Evaluation Programme /European Environment Agency, "Air pollutant emission inventory guidebook," 2016

Facility type	Definition	Operating hours per year	Electrical efficiency	Emission factors (g/kWh thermal input)			
				CO2	NOx	PM10	PM2.5
	100 - 200 kWe	3446	0.338	0	6.826	0.480	0.480
	<100 kWe	3446	0.317	0	6.826	0.480	0.480
RE (diesel - large, biodiesel	>=1000 kWe	3446	0.380	0	3.189	0.102	0.102

It was found that the dominant CHP technology was natural gas-fired generating engines, with most plant in the higher-emitting category below 1 MWe. Consequently, a sensitivity analysis was carried out to investigate the potential effects on estimated emissions if all engines were assumed to have the lower emissions factor applied to engines in the 1 MWe and above category.

2.7.2 Comparison with manufacturer/supplier data

These emission factors were compared with information obtained from a search of supplier and manufacturer specifications for gas-fired CHP engines. Some manufacturers provided emissions factors referenced to electrical output; in other cases, emission factors were deduced from emission concentration and fuel usage data. Because of the focus on natural gas-fired plant, no specification was identified which provided emissions data for particulate matter.

Table 4: Comparison of emission factors with supplier/manufacturer information

Facility type/Manufacturer	Model	Electrical output (kWe)	Emission factors (g/kWh electrical output)			
			CO_2	NOx	PM_{10}	$PM_{2.5}$
Emission factors used in this study						
Gas Engine – Small, natural gas		<1000 kWe	184	4.868	0.0227	0.0227
Gas Engine – Medium, natural gas		>=1000 kWe	184	0.438	0.0065	0.0065
Supplier/manufacturer information: without catalyst						
Newenco	CG50S-NG	50	200	11.38		
Newenco	CG70S-NG	70	190	11.67		
EnerG	E210			2.50		
EnerG	E230			11.74		
Waukesha	VGF F18G	149	671	21.46		
Minimum (plant without catalyst)			190	2.50		
Median (plant without catalyst)			200	11.67		
Maximum (plant without catalyst)			671	21.46		
Supplier/manufacturer information: with catalyst						
EnerG		770-2535		0.69 – 1.39		
EnerG	E210 Low NOx			0.146		
EnerG	E230 Low NOx			0.69		
SAV Systems		3-20	222	0.04		
SAV Systems		3-20	222	0.62		
Remeha	Dachs G5.5	5.5	255	0.21		
Remeha	R-Gen 20/44 NG	20	198	0.06		
Remeha	R-Gen 100/50 NG	49.5	184	0.07		

Facility type/Manufacturer	Model	Electrical output (kWe)	Emission factors (g/kWh electrical output)			
			CO_2	NO_x	PM_{10}	$PM_{2.5}$
Newenco	CG100S-NG	100	187	0.82		
Newenco	CG200S-NG	200	170	0.74		
Newenco	CG250S-NG	250	173	0.76		
Newenco	CG400S-NG	400	165	0.72		
Newenco	CG520S-NG	520	164	0.72		
Newenco	CG875S-NG	875	181	0.73		
Newenco	CG1000S-NG	1000	179	0.75		
Newenco (“Budget” plant)	GXC50S-NG	50	187	0.82		
Newenco (“Budget” plant)	GXC100S-NG	100	187	0.82		
Jenbacher	J208	294-335		1.0 approx		
Jenbacher	J3xx	390-1067		1.0 approx		
Jenbacher	J4xx	634-1500		1.0 approx		
MWM	TCG 3016	400-800		1.0 approx		
Waukesha	VHP F3514GSI	460-550		0.67		
Waukesha	275GLplus	3625-5000		0.67		
Finning	G35xx	485-2039		1.34		
Minimum (plant with catalyst)			**164**	**0.035**		
Median (plant with catalyst)			**185**	**0.73**		
Maximum (plant with catalyst)			**255**	**1.39**		

The NO_x emissions factor used in this project for plant above 1 MWe, after accounting for electrical efficiency, is within the range of manufacturer data for plant fitted with a catalyst (either a three-way catalyst, or SCR). Similarly, the NO_x emissions factor used in this project for plant below 1 MWe is within the range of manufacturer data for plant without specific abatement. This reflects the approach taken in the identification of emission factors for this project: as noted in 2.7.1, smaller gas engines are unlikely to have NO_x controls applied, so it is appropriate to use a higher emission factor for these smaller, unregulated installations.

Two further sensitivity cases were carried out to investigate the potential effects on estimated emissions if (a) all engines were assumed to have the median manufacturer reported NO_x emissions factor for engines with no catalyst; and (b) all engines were assumed to have the median manufacturer reported NO_x emissions factor for engines fitted with a catalyst. The NO_x emissions factor for engines fitted with a catalyst corresponds approximately to compliance with the emissions requirement set in GLA's Supplementary Planning Guidance on Sustainable Design and Construction,[10] for development in areas where levels of nitrogen dioxide are more than 5% below the national air quality objective.

2.7.3 Integration into LAEI

Within the LAEI, smaller combustion activities (including smaller CHP) are currently treated as part of an area source. CHP facilities are included in the category of smaller industrial, commercial and residential activities. To avoid double-counting of emissions in the LAEI the fuel used by CHP plant should be subtracted from the fuel assigned to the LAEI area sources. This will allow removal of CHP plant emissions from the LAEI 1 x 1 km grid squares. The geographic data can be used to identify the most appropriate 1 x 1 km grid square for each CHP plant.

2.8 Mapping

The database of CHP plant included geographic (mapping) data suitable for generating maps of CHP using ArcGIS or MapInfo. Geographical plant locations were based on postcodes or spatial coordinates identified from planning applications. Based on this information, MapInfo multipart files were developed for the CHP facilities identified in each of the five boroughs, including facility identified, capacity and estimated emissions.

3 Results

3.1 Full dataset

The full database is provided as a spreadsheet and GIS database under separate cover to Greater London Authority.

Maps of identified facilities are provided in Figure 4 to Figure 8, and in Appendix 1.

Figure 4: CHP facilities identified in London Borough of Camden

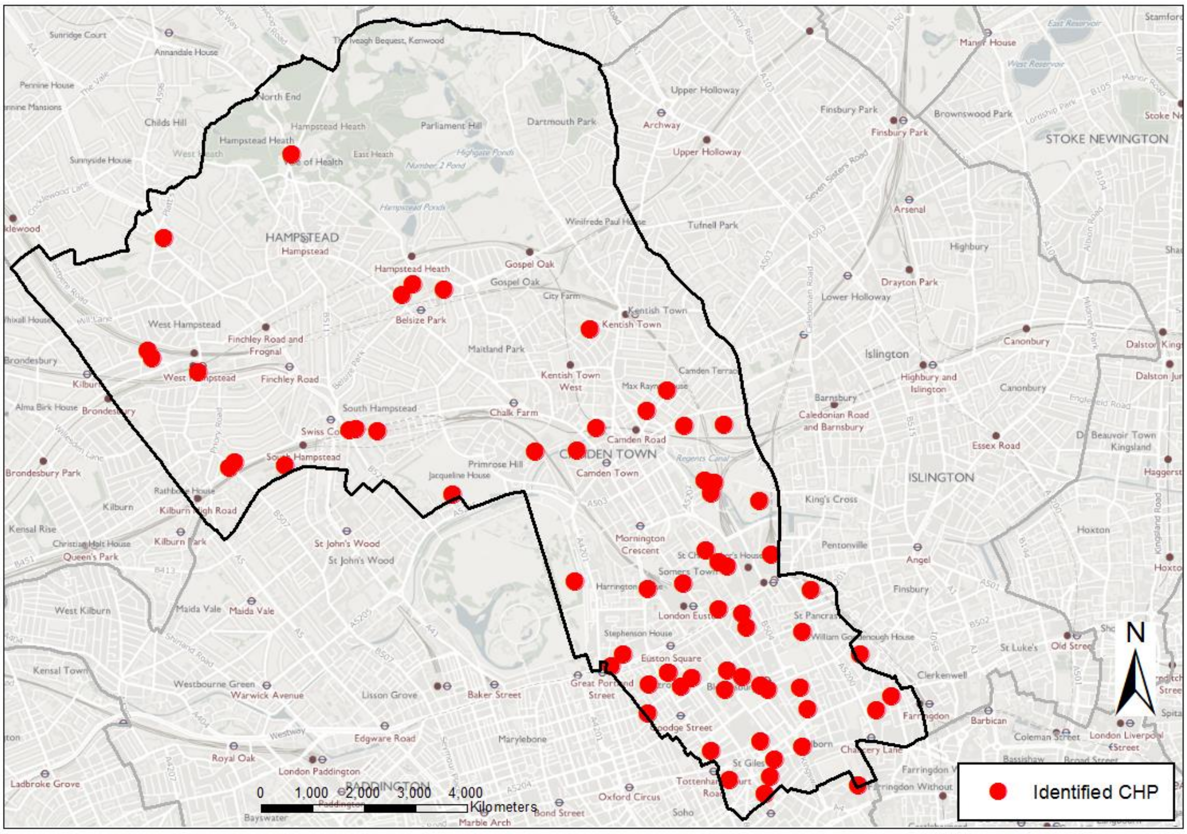


Figure 5: CHP facilities identified in London Borough of Enfield

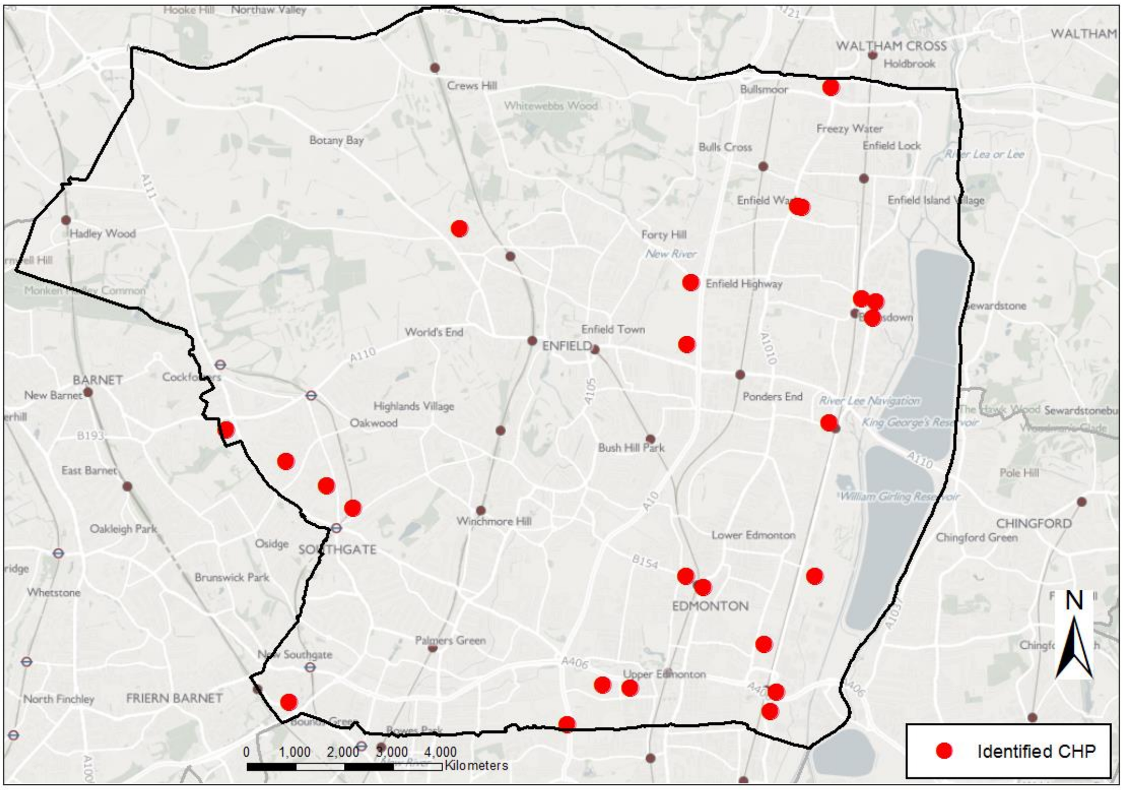


Figure 6: CHP facilities identified in Royal Borough of Kensington and Chelsea

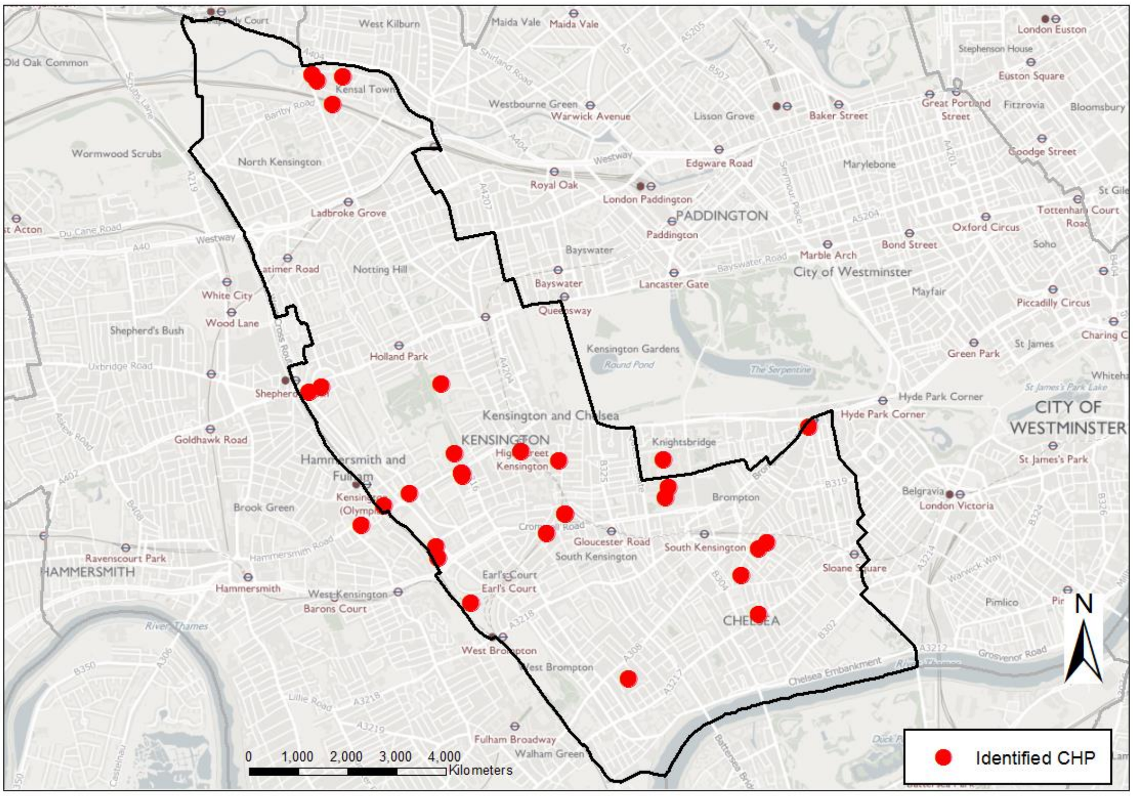


Figure 7: CHP facilities identified in London Borough of Southwark

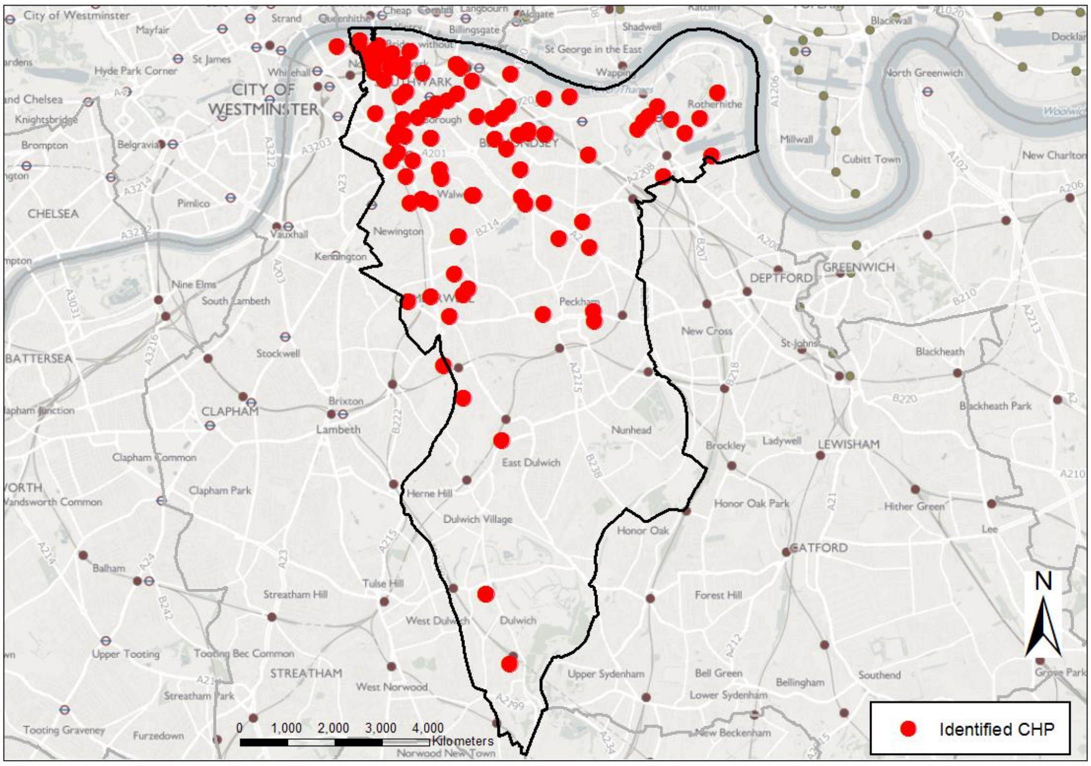
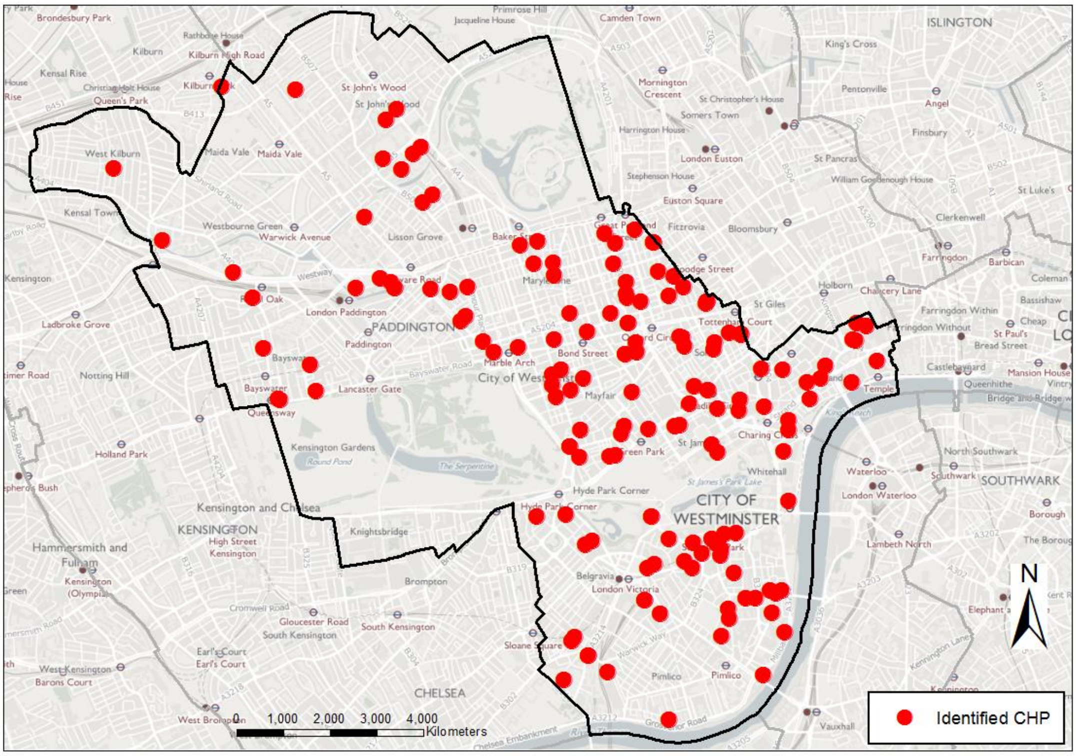


Figure 8: CHP facilities identified in London Borough of Westminster



3.2 Summary data

The number of facilities and their aggregated capacity in each borough was as follows. This table includes identified sites (operational and non-operational: facilities planned, proposed and/or under construction):

Table 5: Numbers of identified sites and their capacity

Borough	Number of facilities	Number of sites with information on electrical output capacity	Total CHP electrical capacity for sites with available data (kWe)
London Borough of Camden	63	36	22,853
London Borough of Enfield	19	12	14,489
Royal Borough of Kensington and Chelsea	34	24	16,932
London Borough of Southwark	103	63	25,336
London Borough of Westminster	157	79	31,743
Total for five boroughs	**376**	**214**	**111,353**

Data on thermal capacity was less widely available. While electrical capacity data was available for 57% of identified facilities, thermal capacity data was available for 156 facilities, 41% of the total number identified. Total reported thermal capacity was 73592 kW_{th}.

Data on operating hours was available only for a relatively small number of facilities:

Table 6: Numbers of identified sites and operating hours

Borough	Number of facilities	Number of sites with information on operating hours	Average operating hours for sites with available data (hours per year)
London Borough of Camden	63	11	4,761
London Borough of Enfield	19	8	5,727
Royal Borough of Kensington and Chelsea	34	10	3,796
London Borough of Southwark	103	10	4,301
London Borough of Westminster	157	38	4,577
Total for five boroughs	**376**	**77**	**4,586**

Most CHP installations identified in this study use gas-fired engine technology. No Energy from Waste Plant with CHP were identified in the five boroughs which were the subject of this study.

Emissions from identified sites with known capacity were calculated as set out in Table 7 below. Facilities for which the technology type was not known were assumed to be natural gas engines, as this was identified as the predominant technology. Additionally, this table provides a preliminary estimate of total CHP emissions for each borough, and for the five boroughs as a whole, scaling up by the total number of identified sites divided by the number of sites with information on electrical output capacity.

The data in Table 7 represents the total emissions that would occur if all the identified sites were operational, including sites which are currently at the planning and/or construction stage, sites which are not currently being operated, and sites for which the operational parameters could not be identified.

Table 7: Calculated emissions to air of oxides of nitrogen, particulate matter and carbon dioxide

Borough	Number of identified CHP sites with information on electrical output capacity	Calculated emissions from identified CHP sites with information on electrical output capacity (T/year) of			
		CO_2	NO_x	PM_{10}	$PM_{2.5}$
London Borough of Camden	36	46174	563	3.29	3.29
London Borough of Enfield	12	34365	203	1.66	1.66
Royal Borough of Kensington and Chelsea	24	17568	168	1.08	1.08
London Borough of Southwark	63	88436	638	4.69	4.69
London Borough of Westminster	79	64212	959	5.22	5.22
Total for five boroughs	**216**	**250755**	**2532**	**15.95**	**15.95**
Borough	**Total number of identified CHP sites**	**Preliminary estimate of emissions from all CHP facilities (T/year) of**			
		CO_2	NO_x	PM_{10}	$PM_{2.5}$
London Borough of Camden	63	80804	985	5.8	5.8
London Borough of Enfield	19	54411	322	2.6	2.6
Royal Borough of Kensington and Chelsea	34	24887	239	1.5	1.5
London Borough of Southwark	103	144587	1044	7.7	7.7
London Borough of Westminster	157	127611	1905	10.4	10.4
Total for five boroughs	**376**	**440578**	**4448**	**28.0**	**28.0**

3.3 Sensitivity tests

3.3.1 Sensitivity test 1: lower emissions from smaller engines

As described in Section 2.7.1, a sensitivity test was carried out to investigate emissions that would result if engines with a capacity below 1 MWe were assumed to emit less NOx, using the emission factor applied to engines with a capacity of 1 MWe and above.

Table 8: Sensitivity analysis 1: lower NOx emissions from plant below 1 MWe

Borough	Calculated NOx (T/year)			
	Calculated for sites with capacity data		Estimated for all sites	
	Main study	Sensitivity test 1	Main study	Sensitivity test 1
London Borough of Camden	563	110	985	192
London Borough of Enfield	203	82	322	130
Royal Borough of Kensington and Chelsea	168	42	239	59
London Borough of Southwark	638	211	1044	344
London Borough of Westminster	965	153	1918	304
Total for five boroughs	**2532**	**597**	**4448**	**1049**

3.3.2 Sensitivity test 2: manufacturer's specification, without catalytic convertor

As described in Section 2.7.2, a sensitivity test was carried out to investigate emissions that would result if engines were assumed to emit at the median level identified in manufacturers' specifications for engines operating with no catalytic convertor.

Table 9: Sensitivity analysis 2: manufacturer's specification without catalytic convertor

Borough	Calculated NOx (T/year)			
	Calculated for sites with capacity data		Estimated for all sites	
	Main study	Sensitivity test 2	Main study	Sensitivity test 2
London Borough of Camden	563	1,098	985	1,922
London Borough of Enfield	203	827	322	1,309
Royal Borough of Kensington and Chelsea	168	415	239	588
London Borough of Southwark	638	2,104	1,044	3,440
London Borough of Westminster	965	1,519	1,918	3,018
Total for five boroughs	**2,532**	**5,963**	**4,448**	**10,477**

3.3.3 Sensitivity test 3: manufacturer's specification, with catalytic convertor

As described in Section 2.7.2, a sensitivity test was carried out to investigate emissions that would result if engines were assumed to emit at the median level identified in manufacturers' specifications for engines operating with a catalytic convertor.

Table 10: Sensitivity analysis 3: manufacturer's specification with catalytic convertor

Borough	Calculated NOx (T/year)			
	Calculated for sites with capacity data		Estimated for all sites	
	Main study	Sensitivity test 3	Main study	Sensitivity test 3
London Borough of Camden	563	68	985	120
London Borough of Enfield	203	52	322	82
Royal Borough of Kensington and Chelsea	168	26	239	37
London Borough of Southwark	638	131	1,044	214
London Borough of Westminster	965	95	1,918	188
Total for five boroughs	**2,532**	**371**	**4,448**	**653**

3.4 Context

The London Atmospheric Emission Inventory 2013 was published in April 2016.[19] The overall LAEI emissions for London are set out in Table 11 below, alongside the data for CHP facilities in London identified in the present study.

Table 11: Emissions to air of oxides of nitrogen, particulate matter and carbon dioxide from all sources

Borough	Calculated CHP emissions (T/year)			
	CO_2	NO_x	PM_{10}	$PM_{2.5}$
Calculated emissions (T/year) from identified CHP sites				
London Borough of Camden	46,174	563	3.29	3.29
London Borough of Enfield	34,365	203	1.66	1.66
Royal Borough of Kensington and Chelsea	17,568	168	1.08	1.08
London Borough of Southwark	88,436	638	4.69	4.69
London Borough of Westminster	64,212	959	5.22	5.22
Total CHP for five boroughs	**250,755**	**2,532**	**15.95**	**15.95**
Total CHP for five boroughs (Sensitivity case 1)		**597**		
Total CHP for five boroughs (Sensitivity case 2)		**5,963**		
Total CHP for five boroughs (Sensitivity case 3)		**371**		
Total emissions (T/year) from all sources (2013)				
London Borough of Camden	655,957	1,282.7	104.5	57
London Borough of Enfield	1,632,801	2,692.4	224.7	100.5
Royal Borough of Kensington and Chelsea	451,070	856.8	72.4	38.7
London Borough of Southwark	591,070	1,199.9	109.6	56.2

[19] Data downloaded from http://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory-2013, October 2017

Borough	Calculated CHP emissions (T/year)			
	CO_2	NO_x	PM_{10}	$PM_{2.5}$
London Borough of Westminster	977,775	1,960	154	80
Total all sources for five boroughs	**4,308,673**	**7,992**	**665**	**332**
Identified CHP sites as a proportion of total emissions				
London Borough of Camden	7.0%	43.9%	3.1%	5.8%
London Borough of Enfield	2.1%	7.6%	0.7%	1.7%
Royal Borough of Kensington and Chelsea	3.9%	19.7%	1.5%	2.8%
London Borough of Southwark	15.0%	53.2%	4.3%	8.3%
London Borough of Westminster	6.6%	48.9%	3.4%	6.5%
Total for five boroughs	**5.8%**	**31.7%**	**2.4%**	**4.8%**
Total for five boroughs (Sensitivity case 1)		7.5%		
Total for five boroughs (Sensitivity case 2)		74.6%		
Total for five boroughs (Sensitivity case 3)		4.6%		

Part of the purpose of this report is to assess the *maximum potential* impact of the capacity allowed to be installed through the planning system. Consequently, it is useful to understand the total possible emissions if all identified CHP facilities are assumed to be operational. The information in Table 11 indicates that, if all current and permitted CHP facilities identified in this study are assumed to be operational, these would make a significant contribution to borough-wide emissions. The maximum potential contribution would be around 6% of carbon dioxide emissions, and smaller percentages of borough-wide PM_{10} and $PM_{2.5}$ emissions. The maximum potential contribution to NOx emissions is estimated to be around 32% of emissions averaged across the five boroughs, and over 50% of emissions from the London Borough of Southwark. This reflects the larger number of CHP sites identified in Southwark. If all CHP installations are assumed to operate at the lower end of quoted emission factors, representative of plant fitted with a catalytic convertor (Sensitivity Cases 1 and 3), NO_x emissions are estimated to be 5% to 8% of the total for all five boroughs. This is not the case at present, but does highlight the potential for reductions in impacts due to emissions from CHP installations if abatement were more widely applied. Conversely, if all CHP installations are assumed to operate without a catalytic convertor (either because no catalyst is fitted, or a fitted catalyst is not operational), NO_x emissions from the identified CHP facilities could be as high as 75% of the total for all five boroughs.

Estimated NOx emissions from CHP installations if all plant are assumed to be operational are approximately equivalent to the LAEI estimate for domestic and commercial gas combustion for the five boroughs. By 2030, emissions from domestic and commercial gas combustion are forecast to reduce by about a quarter from the 2013 LAEI estimate. Under these circumstances, the estimated NOx emissions from currently installed and proposed CHP would equate to 170% of the forecast emissions from the domestic and commercial gas combustion sector in 2030.

3.5 Database issues

Obtaining relevant information from planning databases is a time-consuming process which requires understanding of a number of key issues on the part of researchers. These issues include:

- Differences between thermal and electrical capacity
- Identifying CHP plant which may not be described in these terms. For example, CHP plant may be described as “co-generation plant” or “energy centre”

- Reconciling contradictory information between different data sources, or between different documents. This often requires a judgment to be taken on the most likely characteristics of a CHP plant, based on the nature of the documents (e.g. general description of a development versus a detailed description of energy provision) or the timing of documentation (a later document is more likely to give accurate information, other factors being equal).

Relevant information often needs to be drawn together from a range of different documents. The most relevant documentation is typically found in the Energy Statement for a development. If an air quality impact assessment study has been produced, this can also often provide useful information, although the majority of air quality studies focus on traffic impacts.

Comparison of information in planning applications with data identified from further investigations indicates that information in planning records often differs from the features of CHP plant installed in practice. Examples of this are discussed further in Section 5.1 below. Typically, installed capacity was found to be lower than envisaged in the planning application. While emissions per unit of energy produced are higher for smaller facilities, if the CHP facilities installed are smaller than envisaged at the planning stage, the potential extent of CHP implementation and associated air quality impacts have nevertheless been over-estimated in this study. While information from planning records may give a reasonable indication of the overall level of CHP provision in London, it should not be relied on to give an indication of specific local impacts resulting from individual facilities. Detailed investigation of each record would be needed to verify and update the records for individual facilities.

It was found that CHP facilities, even when fully installed, often do not operate to the extent envisaged in the planning application. In some cases, this reflected a lower need for energy provision than envisaged at the planning stage. In other cases, it was found that the CHP was uneconomic to run, and it made better sense for operators to use other sources of heat and power – typically, mains electricity and standalone boiler provision for heat. In some cases, it was found that facilities required maintenance and repair, and facility operators did not have the expertise or funds available to carry out the works required. This can lead to facilities being out of commission for extended periods. This is illustrated in Section 5.2 below.

The database developed in this study is considered to be a reasonable starting point to describe CHP provision in the five boroughs under consideration. With additional resource, more could be done to improve this database. For example, it was not possible to check the data obtained from the planning and GLA databases in every case. Further work could therefore focus on ongoing investigation of CHP provision at the identified installations. A law of diminishing returns applies: some information can be obtained relatively rapidly (e.g. from internet searches and phone calls to active businesses and users), after which further refinements to the database requires more time and persistence.

A search of the remaining 27 London boroughs, together with the City of London Corporation, would be a valuable means of securing further information on CHP provision in London. Work to carry out this analysis is now under way. The accuracy of a complete database would depend on the level of resource allocated to the development of a full database. Where possible, planning records need to be followed up and, where possible, checked or updated with current information on CHP provision.

3.5.1 Completeness

It is considered that taking account of the range of data sources used in the study, the database provides a reasonably complete inventory of CHP facilities installed in the five boroughs over the past ten years. It is estimated that 80% to 90% of recently installed facilities may have been identified. The inventory may not contain complete information on older CHP facilities which were installed before the widespread availability of online planning databases.

3.5.2 Accuracy

The database is considered to be reasonably accurate where information has been checked and updated independently. In cases where this has not been possible, the database should not be considered as reliable in respect of data on individual facilities or the associated local impacts on air quality.

At a borough or city-wide level, the database provides a reasonable indication of the overall level of CHP provision: however, it should not be relied on to give an indication of specific local impacts resulting from individual facilities.

3.6 Key findings

Of the five boroughs under consideration in this study, it was found that the most facilities, and the highest aggregate installed capacity, was in the City of Westminster.

The median installation capacity (where data were available) was 112 kWe. By contrast, the mean installation capacity was 520 kWe. This indicates that there are a number of large installations which result in a higher mean value than the median. This is referred to as a skewed distribution, and suggests that the mean capacity is not a reliable descriptor of the dataset. The following statistics provide a description of installed capacities:

Table 12: Statistical distribution of installed capacity

Percentile	Capacity (kWe)
5th percentile	15
50th percentile	112
75th percentile	308
90th percentile	1179
95th percentile	2974
98th percentile	4822
100th (maximum)	9000

The largest individual installation was at City and Guilds College, Kensington and Chelsea. Facilities with a capacity over 4000 kWe were identified at the following locations:

- Building T1 King Cross Central York Way London	Camden	5580 kWe
- Royal Free Hospital Pond Street London	Camden	4600 kWe
- College Farm, 515 Hertford Road, Enfield,	Enfield	6510 kWe
- Guy's and St Thomas' NHS Foundation Trust	Southwark	6058 kWe
- King's College Hospital, Denmark Hill, London	Southwark	4200 kWe
- Ministry of Defence, 57 Whitehall	Westminster	4900 kWe
- City and Guilds College, Kensington and Chelsea	Kensington & Chelsea	9000 kWe

Figure 4 to Figure 8 show the pattern of CHP installations in the five boroughs under consideration in this study. While the extent of CHP installations varied from place to place, no areas of unusually intense CHP activity were identified. CHP installations were more intense in the inner London boroughs than in the London Borough of Enfield.

It was found that existing and forthcoming CHP installations in the five boroughs could meet a significant proportion of each borough's electrical energy needs. Table 13 provides a comparison of CHP electrical capacity in each borough with electricity usage in 2012, the latest year for which data are available.[20]

Table 13: CHP capacity and electricity usage

Borough	Total CHP electrical capacity for facilities with available data (kWe)	Borough electricity usage (2012) GWh	CHP electrical capacity as % of usage
London Borough of Camden	22,853	1,784	4.4%
London Borough of Enfield	14,489	1,052	4.7%
Royal Borough of Kensington and Chelsea	16,932	1,502	3.9%
London Borough of Southwark	25,336	1,658	5.3%

[20] https://data.london.gov.uk/dataset/total-energy-consumption-borough

Borough	Total CHP electrical capacity for facilities with available data (kWe)	Borough electricity usage (2012) GWh	CHP electrical capacity as % of usage
London Borough of Westminster	31,743	3,993	2.7%
Total for five boroughs	**111,353**	**9,988**	**3.8%**

3.7 Abatement

Introducing an additional unabated and/or unregulated NO_x emission source to an area which already has poor air quality may significantly worsen the situation, and could potentially contribute to exceedances of the Air Quality Objectives. In the light of this, GLA may wish to consider restrictions on the use of combustion-based CHP technology. This suggests that project developers should consider alternative low carbon and low emission heat sources to combustion-based CHP solutions at an early stage in project development. If combustion plant is required, this should be properly designed, and located as far away as possible from sensitive locations such as schools, hospital/medical facilities, and residential properties. However, there are limits on what can be achieved in this way for CHP facilities located in a densely populated city.

The dominant technology for CHP plant is natural gas fired generating engines. In view of the potential air quality impact of CHP emissions, gas engine technology may not be the most appropriate technology choice for future CHP provision in London in view of the potential air quality impacts. Introducing an additional unabated and/or unregulated NO_x emission source to an area which already has poor air quality may significantly worsen the situation, and could potentially contribute to exceedances of the Air Quality Objectives. However, if combustion based CHP plant is to be used, a range of abatement technologies are available. Abatement techniques available for reducing emissions of NOx from generating engines generally focus on reducing combustion temperature by means of the following:[6]

- Delayed fuel injection
- Exhaust gas recirculation
- Water injection
- Fuel-water emulsification (applicable to diesel fired engines only)
- Inlet air cooling
- Intake air humidification
- Compression ratio and/or turbocharger modifications

Additionally, selective catalytic reduction (SCR) can be used for post-combustion emissions reduction, either as an inherent component of engine design, or as an add-on to an existing unabated engine. This requires the injection of a fluid containing urea which reacts with oxides of nitrogen to form nitrogen and carbon dioxide. A three-way catalyst can also be used in gas-fired engines with low oxygen levels in exhaust gases (that is, a fuel rich configuration). A three-way catalyst converts oxides of nitrogen, carbon monoxide and non-methane hydrocarbons in the flue gases to nitrogen, carbon dioxide and water. In practice, most large gas engines are set up to run lean in the interests of fuel economy, and hence a three-way catalyst would not be appropriate. However, on small and medium sized engines (<250 kWe), an engine can be set to run with a stoichiometric mixture so that it can be fitted with an effective three-way catalytic converter. Larger gas engines (250 kWe and above) which require abatement are normally run in a lean fuel configuration, with the use of SCR to reduce NO_x emissions.[21]

The most common abatement technology identified in CHP installations in London was the use of selective catalytic reduction. As described above, SCR can be effective across the air-fuel ratio range. Gas fired CHP plant without a catalytic convertor typically emits 500 to 5000 mg/Nm^3 of oxides of nitrogen at 5% oxygen. A catalytic convertor can be part of the inherent design of a gas engine, in which case it is likely to be referred to as “low NOx” emitting plant. Alternatively, end of pipe units can be fitted to pre-existing CHP plant, although space and technical considerations mean that this is not

[21] https://www.blackthorn.net/gas-engines/

always possible in practice. Catalytic convertors can only be applied to naturally aspirated engines, not to turbocharged engines, because the discharge temperature from a turbocharged engine is too low for the catalyst to operate effectively. The use of a catalytic convertor can be expected to place an additional capital and running cost on CHP plant, but gas engines with integral catalysts, and end of pipe catalytic convertor units, are widely available on the market.

Gas fired CHP plants fitted with catalytic convertors can be designed to achieve much lower NOx emissions if properly operated and maintained. Release concentrations below 100 mg/Nm^3 with catalytic systems are widely reported in manufacturer specifications.[22] A number of technology providers suggest that emissions can be below 50 mg/Nm^3, with some claiming a discharge concentration as low as 10 mg/Nm^3 at 5% oxygen. Hence, if these claims are borne out in practice, catalytic convertors could be effective in reducing emissions of oxides of nitrogen by 90% or more. However, a study commissioned by GLA in relation to abatement of emissions from bus engines[23] suggests that optimum performance of emissions abatement is often not achieved in practice. For example, the study found that 40% of bus abatement systems were not functioning at one point in 2013. Similar experience with the car industry has resulted in significant negative impacts in terms of emissions. Furthermore, data held by GLA which was recorded at three operational 3.3 MW CHP units indicated that the catalytic convertor was effective in reducing emissions of carbon monoxide by 85%, but did not have any significant benefit in reducing NO_x emissions. The performance of individual plant will depend on how it is designed, operated and maintained.

It is therefore important to ensure that where abatement technology is relied on, this is installed, operated and maintained correctly. These examples demonstrate that it is particularly important to ensure that attention is paid to ongoing maintenance and monitoring of plant which relies on the use of catalytic convertor technology to achieve an expected performance level in terms of emissions of NO_x.

Currently, large combustion plant with capacity above 50 MW_{th} is regulated by the Environment Agency. Combustion plant with capacity between 20 and 50 MW_{th} is regulated by local authorities. Plant below 20 MW_{th} is not subject to formal regulation at present, although a regulatory regime under the Medium Combustion Plant (MCP) Directive is being introduced. For plant with a capacity below 1 MW_{th}, there is no regulatory requirement, although options for regulating this plant might be available under smoke control legislation, nuisance legislation, Local Air Quality Management or Ecodesign regulations. Consequently, while low-emissions CHP plant can be specified by conditions at the planning stage, there is currently no provision for ongoing regulation of CHP plant smaller than 20 MW thermal input (the majority of CHP installations) once it is installed, to ensure that the combustion component and any abatement systems are operating correctly.

If installations do not achieve the expected performance, this could affect air quality in the immediate vicinity of a gas fired CHP unit. Furthermore, if there were a widespread failure to achieve the performance required to confirm with a policy such as the GLA's current 2014 Supplementary Planning Guidance on Sustainable Design and Construction, this could result in a more widespread air quality impact.

The planning system does not allow for the controls that would be needed to require and effectively ensure the ongoing use and maintenance of abatement equipment such as that set out above. Accordingly a planning-dependent solution which continues to support combustion CHP, even with the specification of abatement where needed, may not be effective. Stricter requirements than those in the GLA's current Supplementary Planning Guidance on Sustainable Development and other regulatory approaches (potentially supported by new legislation) may be appropriate to effectively address the risk of pollution from combustion-based CHP. Adherence to the SPG is determined by the relevant local authority, but approaches to securing compliance vary between authorities during and after planning determination.

Fuel cell technology has minimal emissions at the point of use but is not widely used for CHP at present, mainly because of the relatively high installation cost, and need for supplementary heat and power provision. Wider scale implementation may require market interventions to incentivise uptake.

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[22] E.g. SAV Systems, "LoadTracker Combined Heat and Power Technical Specifications"
[23] King's College London, "*Analysis of the 2013 vehicle emission remote sensing campaigns data,"* David Carslaw and Max Priestman: final report February 2015

Limited information was identified on the abatement of emissions from identified CHP sites, as set out in Table 14. Where information was available on abatement plant, this referred either to "Low NOx" engines, or to the use of three-way catalysts for abatement of NO_x emissions.

Table 14: Abatement plant at Identified CHP sites

Borough	Number of identified sites	Confirmed with abatement	Confirmed with no abatement	With maintenance	No confirmed information
London Borough of Camden	63	5	2	2	56
London Borough of Enfield	19	0	2	1	17
Royal Borough of Kensington and Chelsea	34	5	0	1	29
London Borough of Southwark	103	4	1	3	98
London Borough of Westminster	157	6	1	0	150
Total for five boroughs	**376**	**20**	**6**	**7**	**350**

In cases where abatement of CHP emissions is required, the installation of appropriate technology should be checked through the planning system. Regulation of the operation and maintenance of abatement plant through the planning system by means of planning conditions is not typically practical. The most effective approach is likely to be through a unilateral or bilateral agreement secured through the planning process.

Identification of appropriate abatement technology should be the responsibility of a project developer. However, well established principles of air pollution abatement should apply to mitigating the impacts of CHP plant, as with any other installation:

- **Principle 1:** Avoidance or prevention is preferable to treatment/abatement. Avoidance and prevention of pollution can often be more efficient than treatment and abatement, and is also often low cost or even cost beneficial. There may also be other co-benefits with avoiding air pollution, such as avoidance of greenhouse gas emissions. Implementing measures for avoiding or preventing pollution at source requires air pollution and other environmental aspects to be considered from the outset of a project and throughout the scheme design.
- **Principle 2:** When designing mitigation measures, consider:
  (a) mitigation measures that act on the source; before
  (b) mitigation measures that act on the pathway; which in turn should take precedence over
  (c) mitigation measures at or close to the point of receptor exposure

This suggests that project developers should consider alternative low carbon and low emission heat sources to combustion-based CHP solutions at an early stage in project development. If combustion plant is required, this should be located as far away as possible from sensitive locations such as schools, hospital/medical facilities, and residential properties. Discharge points should be appropriately designed to minimise the impacts of emissions to air. However, there are limits on what can be achieved in this way for CHP facilities located in a densely populated city

In the case of gas-fired generating engines (the dominant technology identified in this study), project developers should consider procuring CHP plant which enables NO_x emissions to be minimised through control of combustion temperature. If required to achieve a required performance standard, an appropriately designed catalytic system can be used to further reduce NO_x emissions. A three-way catalytic convertor can be used for some installations, but selective catalytic reduction (SCR) is more widely applicable and can be used for post-combustion emissions reduction, either as an inherent component of engine design, or as an add-on to an existing unabated engine. Additionally, a maintenance system/programme for the catalytic convertor and CHP plant operation, which provides for regular measurement and reporting of emissions, should be agreed at the planning stage.

4 Potential air quality implications

Combustion-based CHP facilities give rise to emissions of air pollutants which could potentially represent a significant proportion of overall emissions and sector-specific emissions, in each borough. Taking into account those that are operational suggests that CHP facilities could be giving rise to a significant contribution to current levels of oxides of nitrogen in the five boroughs under consideration.

A preliminary study carried out for the GLA in 2016[15] found that a set of heating technologies classified as “point sources” could give rise to an average increment of 0.52 µg/m^3 of oxides of nitrogen, averaged across London. This included a contribution from 148 CHP sites which were confirmed as operational across the GLA area at that time – an average of fewer than five CHP sites per borough, compared to the average of 80 sites per borough identified in this study. It was estimated that emissions from this incomplete database of CHP facilities would contribute 0.31 µg/m^3 to annual average NO_x concentrations, spread across the 33 London boroughs (including the City of London). It was known at the time that this database was incomplete, and emissions from CHP facilities not specifically identified were allocated within a more general sector reflecting natural gas combustion sources. This suggested that a more complete database of CHP would potentially highlight a higher impact.

The present study has identified a total of 382 facilities, spread across five London boroughs. Hence, the density of facilities identified in this focused study is approximately 17 times higher than in the 2016 study. Consequently, it can be estimated very crudely that, if all the identified CHP facilities were operational, this could give rise to an average increase in baseline levels of oxides of nitrogen of approximately 5 µg/m^3. Away from the immediate vicinity of a source of NO_x, the majority of NO_x is likely to be present in the form of nitrogen dioxide, and the annual average legal limit for nitrogen dioxide is 40 µg/m^3. This would be sufficient to have a significant effect on air quality across London. Furthermore, this suggests that in some local areas, combustion-based CHP facilities could have a more significant impact on local air quality, particularly in any cases where the discharge point is not well located, or the plant is not well operated and maintained. If the heat provided by CHP installations were instead provided by low NOx boilers or zero emitting sources such as heat pumps, the information in Table 1 indicates that low emission boilers would make a much lower contribution to levels of oxides of nitrogen.

Published emissions factors indicate that emissions per unit of energy generated are typically higher from smaller plant than from larger plant. This reflects the more extensive controls on emissions which are normally applied to larger plant. The sensitivity analysis results set out in Table 8 indicate that, if emissions from smaller scale combustion-based CHP plant are at the lower rate identified for larger plant, the impact of NO_x from CHP plant across the five boroughs could be approximately 25% of that identified in this study. That would correspond to an increase in levels of oxides of nitrogen across London of approximately 1.25 µg/m^3. While this would still be of concern, it is considered that the higher figure of 5 µg/m^3 is a better representation of the potential impact of identified CHP installations on air quality. This is because smaller plant are less likely to have specific abatement of NO_x emissions applied, resulting in the higher emission factor used in the study as a whole.

The contribution from CHP facilities to airborne NOx concentrations is relatively high, because emissions from combustion-based CHP plant take place at relatively low level (often below the height of nearby buildings), in close proximity to sensitive locations such as homes, schools and hospitals, and at low temperature (because heat is extracted from the flue gases to improve energy efficiency). In contrast, other point sources such as power stations and biogas combustion plant at wastewater facilities are normally located away from densely populated areas, and typically discharge emissions through a tall stack. This means that CHP facilities can have a relatively more significant impact on local air quality than other point sources.

At present, only 17% of the facilities in the CHP database have been confirmed as operational, representing 43% of identified thermal capacity). 29% of facilities have been confirmed as not operational. As described in Section 3.5, this could be for a number of reasons, including: (a) development did not proceed; (b) CHP was not installed in the development as originally planned; (c) CHP has been found to be impractical or not economic to operate; (d) CHP has broken down with no prospect of repair. The operational status of 54% of facilities could not be confirmed. This indicates that the air quality impact at present is significantly lower than suggested by the estimated contributions to emissions and ambient concentrations set out in Table 7 and in the above discussion. However, the potential exists for CHP to make a significant and growing contribution to airborne levels of oxides of nitrogen, and, to a lesser extent, PM_{10} and $PM_{2.5}$ in London.

Combustion-based CHP installations are of particular concern from two perspectives:

(a) Combustion-based CHP facilities could potentially have a detectable or significant impact on air quality in their immediate vicinity. Where this is potentially an issue for a new CHP installation, it should be identified and addressed at the planning stage. CHP facilities could be a particular concern for local air quality if the design or operation of the facility falls below best practice. For example:

  i. local air quality issues can result from poorly designed stacks discharging close to or below the heights of neighbouring buildings.

  ii. If combustion or abatement plant is not operating correctly, emissions could be significantly higher than anticipated

(b) CHP facilities could potentially have an ongoing influence on local air quality if the provision of combustion-based CHP were to benefit from strategic policy support in the future.

Addressing the local air quality impacts of combustion-based CHP associated with new development could be achieved by policy requirements on the assessment and installation of CHP under certain circumstances. Examples of possible policy approaches could include:

- A requirement for assessment and mitigation of the air quality impacts of any development which includes a combustion-based CHP element
- Stricter emission limits on emissions from CHP installations consistent with currently achievable good practice or best practice (see Section 3.7). Emissions limits requiring catalytic convertors to be used on gas fired CHP engines are already part of GLA policy, but may not be consistently applied throughout all London boroughs.. The results for Sensitivity Cases 1 and 3 indicate that even if all existing and proposed plant complied with the GLA SPG on Sustainable Development, there could still be an important contribution from CHP plant to NOx levels in London.
- Geographical restrictions on where combustion-based CHP can be installed – e.g. based on existing or forecast levels of air pollution
- A requirement on planning authorities to ensure that planning controls are in place to check the installation of appropriate abatement equipment in accordance with planning permissions
- Specific provisions for enforcement, monitoring, auditing and maintenance of the installed combustion-based CHP equipment, systems and abatement technology. Such provisions are likely to require implementation through means other than the land-use planning system.
- Provision of guidance/training for combustion-based CHP facility operators
- A ban on non-zero emitting CHP provision going forward.

A policy approach which restricts combustion-based CHP provision could result CHP not being available for developments which would otherwise benefit from CHP. Such developments would continue to have heat and electricity requirements which would need to be met by other means. This is likely to include the use of boilers and other technologies such as Ground Source Heat Pumps for heat provision, and the use of mains electricity. Restricting combustion-based CHP provision would reduce the production of air pollution from electricity generation in London. This would be beneficial for air quality in London boroughs, although electricity requirements would still need to be met through other means.

CHP installation dates were recorded for some installations, as set out in Table 15. The recorded data suggest that there was an increase in CHP installations in 2013 and 2014, but this has not been sustained since that point. This may reflect a move away from CHP and towards other technologies for heat provision since 2014.

Table 15: CHP facility installation dates

Year	Number of new installations	Year	Number of new installations
2000 or earlier	16	2009	2
2001	2	2010	4
2002	0	2011	2
2003	2	2012	4
2004	1	2013	6
2005	0	2014	8
2006	1	2015	2
2007	0	2016	3
2008	0		

5 Case studies

Examples of CHP installations illustrate some common features of data availability and operational aspects, in practice.

5.1 Data availability

In cases where facility operators could be contacted, it was often found that the CHP facility installed did not correspond with the information provided at the planning application stage. A small number of sites were verified during this pilot study through a combination of site visits, telephone conversations and email exchanges. Even though a small number of sites were verified during this Pilot study all of the sites listed below did not match the planning permission of the approved planning applications

As a result of this verification process, some examples were identified of sites where the installed facilities did not match the planning permission of the approved planning applications:

Table 16: Discrepancy between planning application information and operational information

Planning application (id/number)	Development /Property name - if applicable	Installed capacity (kW_{th})	Installed capacity (kWe)	Notes
14/AP/2169 & 13/AP/0239 & 09/AP/1917	The Arc	64.5	30	Installed one larger unit rather than two smaller units, following a change in expected contractor. Installed thermal capacity was slightly higher than planning application figure (2 x 30.6kW_{th})
10-AP-1935; 10-AP-1923; 10-AP-1933; 10-AP-1934	One Tower Bridge	109	70	Installed a unit with half the electrical capacity indicated in the planning application (140kWe); no information on thermal capacity included in the planning application
11-AP-2565	Quebec Way (Canada Water)	160	80	Installed four units with aggregated electrical capacity 60% of the single unit capacity indicated in the planning application (140kWe); no information on thermal capacity included in the planning application

Planning application (id/number)	Development /Property name - if applicable	Installed capacity (kW_{th})	Installed capacity (kWe)	Notes
	Old Kent Road Fire Station (E35)	28	12	No information on capacity included with planning application
15/AP/4072	The Taper Building	70	50	No information on capacity included with the planning application
2006/3387/P	Kings Cross Station redevelopment			It was decided not to install CHP at the station. This was because the development primarily had a cooling load, and there was consequently little use for the Heat part of the CHP.
LBE/11/0008/DP2	Albany swimming pool	70	35	The installed electrical and thermal capacity was about 25% lower than indicated in the planning application

Discrepancies between the planning application and installed plant may arise for a number of reasons, including the following:

- For a new development, the heat load calculations for sizing the CHP may change in the timeframe between planning approval and building completion – see example from King's Cross above. Other reasons why the predicted heat load used for sizing the CHP may change, potentially resulting in a change in installed capacity, could include more/fewer flats, different hours of occupancy for commercial development, etc.
- A developer may install multiple smaller engines rather than a single unit to provide back-up, e.g. so that heat can continue to be provided during maintenance or breakdown
- The location of CHP may act as a constraint. For example, if a plant is located on the building roof, there may be plenty of room; however, an engine located in a plant room may be more space constrained. In this case, a developer might opt for multiple small engines rather than a single larger engine (can more easily remove if they want to).
- The cost of a larger engine vs a smaller engine may be a factor.
- The CHP supplier / operator may supply a particular engine make. At the planning stage, the developer may not have selected the contractor who will provide the CHP plant – see The Arc example above.

Typically, installed capacity of the CHP plant was found to be lower than envisaged in the planning application. Emissions per unit of energy produced are typically higher for smaller facilities. Also, there is currently no provision to regulate most CHP plant once it is installed, to ensure that the combustion component and any abatement systems are operating correctly. It is important to ensure that where abatement technology is relied on that it is capable of achieving required emission standards, that the right technology is chosen and that this is installed, operated and maintained correctly (see further discussion of abatement above). Based on the evidence collected through this report it appears that the planning system is not an appropriate mechanism for ensuring that this is done. Instead, new regulatory approaches (which may need to be supported by legislative changes) may be more appropriate.

5.2 Operating patterns

CHP facilities were found to have a wide range of variability in operating patterns. Examples of CHP plant with low utilisation included the following:

- University of Westminster
- Albany swimming pool, Enfield: the facility is currently not operational awaiting repair.

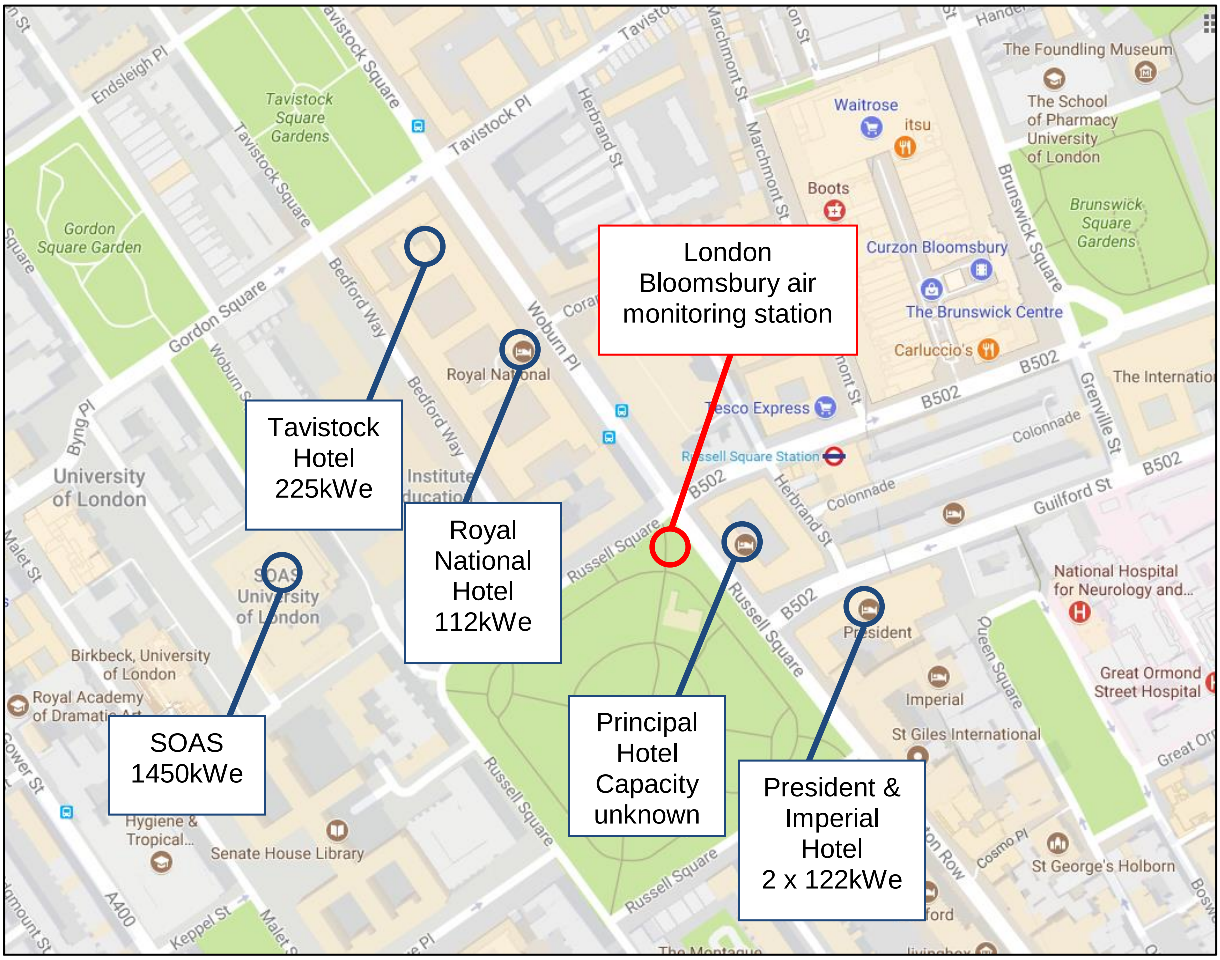
More generally, the reasons why CHP engines may run infrequently could include:

- Older engines may break down frequently, requiring maintenance and repair. There may be no budget available for investment in replacement plant.
- An engine may be oversized for the current heat load at site, and consequently it becomes uneconomic to run as the operator is obliged to dump most of the heat generated.
- CHP facilities may be uneconomic to run – it may be preferable for an operator to obtain electricity from the grid and use standard boiler plant to meet heat demand.
- Some facilities operate during working hours only – e.g. Dean Abbot House in Westminster (12/03794/FULL) was intended to operate from 7 am to 7 pm, giving 4,380 annual operating hours per year.

5.3 Measured impacts

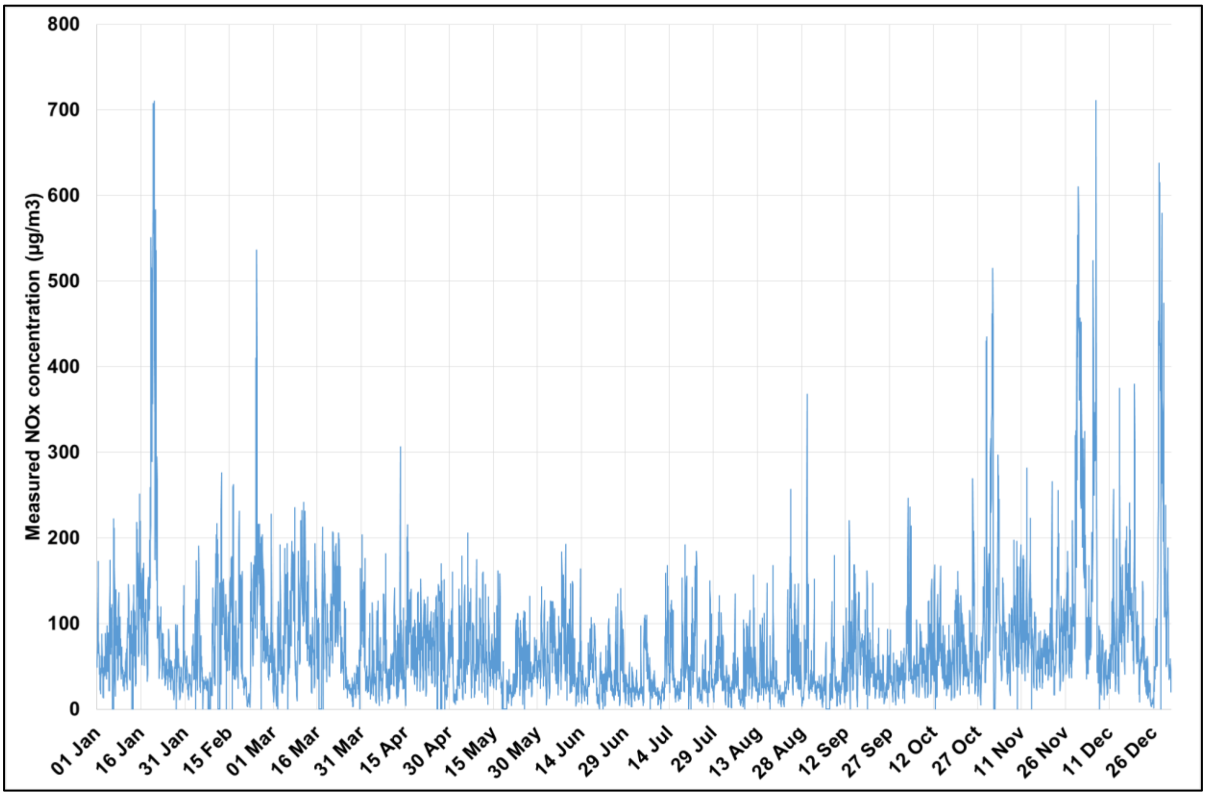
The London Bloomsbury air quality monitoring station at Russell Square is located close to CHP facilities in five nearby hotels, as well as a larger CHP facility in the nearby School of Oriental and African Studies (SOAS).

Figure 9: CHP facilities close to London Bloomsbury air monitoring station



The levels of oxides of nitrogen measured at this location during 2016 are shown in Figure 10.

Figure 10: Oxides of nitrogen levels measured at London Bloomsbury during 2016



The highest levels of oxides of nitrogen were found to occur during the winter months, with episodes above 500 µg/m^3 occurring on the following dates:

- 19-21 January 2016
- 24 February 2016
- 1 November 2016
- 30 November 2016
- 5-6 December 2016
- 27-28 December 2016

Each of these episodes corresponded to periods when high levels of NOx were observed at the nearby Marylebone Road air quality monitoring station. This suggests that these episodes were largely influenced by weather conditions affecting wider areas of central London. In order to investigate whether measured levels of oxides of nitrogen at the London Bloomsbury air monitoring station are influenced by the CHP plant installed at the nearby hotels and at SOAS, a more detailed analysis is needed. To do this, measured levels of oxides of nitrogen were plotted against wind speed and direction, to show the weather conditions giving rise to relatively high and relatively low levels of oxides of nitrogen, as shown in Figure 11.

Figure 11: Measured levels of oxides of nitrogen at the London Bloomsbury air monitoring station in 2016

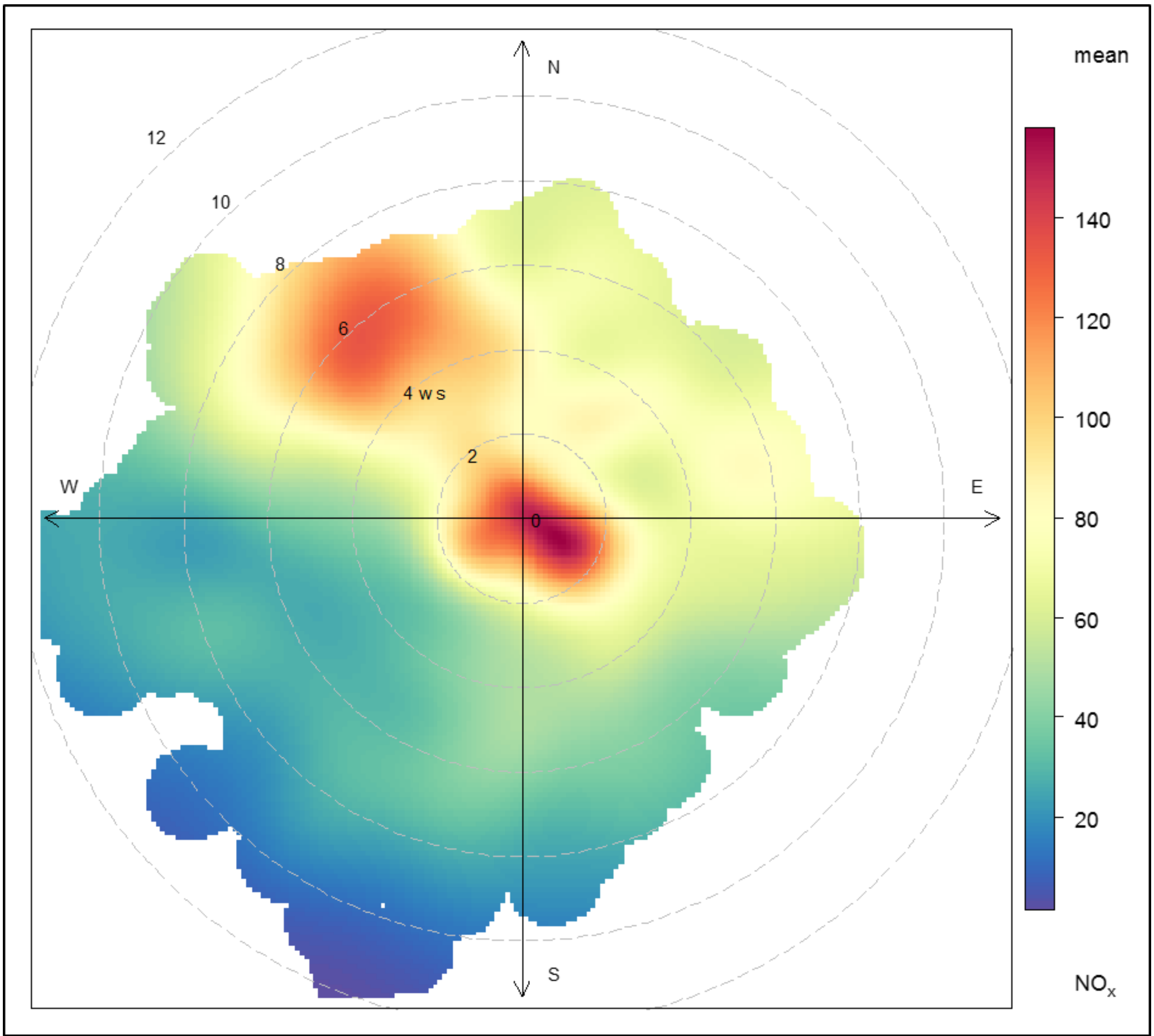


Figure 11 shows two distinct contributors to measured levels of oxides of nitrogen at the Bloomsbury monitoring station:

(a) The orange area in the top left quadrant of the graph indicates a relatively high contribution to measured NOx levels when wind speeds are 4 to 8 metres per second, and the wind is blowing from the north-west.

(b) The dark orange area in the centre of the graph indicates a relatively high contribution to measured NOx levels when wind speeds are lower than 2 metres per second, which occurs with all wind directions, and is particularly strong when winds are from the south-east. This is indicative of a nearby source of pollution close to ground level.

The orange area in the top left quadrant is evidence of a source of oxides of nitrogen located above ground level, to the north-west of the monitoring station. This could possibly be due to the CHP installations at the two hotels located to the north-west, within 300 metres of the monitoring station in this direction. The darker orange area in the centre of the graph is evidence for a source of NOx located close to the monitoring station, which results in higher levels of NOx when the wind speed is less than 2 metres per second. This might potentially correspond to the CHP facility at the other hotels, but the correlation with low wind speed suggests that this is likely to be a source located close to ground level. Local traffic emissions would typically exhibit this pattern. It is concluded that both road traffic and nearby CHP installations make a detectable contribution to measured levels of oxides of nitrogen at the Bloomsbury monitoring station.

This analysis does not provide any evidence for a significant influence on air quality at the facility due to emissions from the facility installed at SOAS, which has a capacity more than twice that of the combined CHP capacity at the four hotels for which the capacity is known. This may reflect lower emissions from the SOAS facility due to higher operational and maintenance standards, or it may reflect the relatively high release point of the SOAS facility, at 42 metres above ground level. The hotel facilities typically have lower discharge points. A discharge point at an elevation above 40 metres would result in significant dispersion in the atmosphere before released substances reached ground level, which could be sufficient to avoid detectable impacts on air quality at the Russell Square monitoring station. A more detailed evaluation of measured levels of NOx and nitrogen dioxide may enable the contribution of the larger CHP unit to be detected, but this analysis indicates that it is likely to be smaller than the contribution from other local sources.

6 Conclusions and recommendations

6.1 The CHP database

It is concluded that a reasonably complete database of CHP installations in local authorities can be developed by combining planning data held by local authorities with information in the GLA's own records. This approach will not identify every CHP facility in a local authority, with the main omissions resulting from:

- Older infrastructure installed before online planning databases became well established.
- The limited search capabilities of planning databases, which may not identify every new development which includes a CHP component.

A total of 376 CHP installations were identified in the five local authorities which were the subject of this study. The lowest number of CHP installations was identified in Enfield, the only Outer London borough included in the study. This may reflect the greater prevalence of office and commercial buildings in inner London.

There are 20 outer London boroughs, and 13 inner London boroughs (including the City of London). If the 19 facilities identified in Enfield are representative of all outer London boroughs, and the 357 facilities identified in the other four boroughs are representative of all inner London boroughs, it is estimated that if the study were extended to London as a whole, there would be approximately 400 facilities in outer London and 1150 facilities in inner London. If the study as a whole is representative of all London boroughs, this suggests an average of approximately 75 CHP sites per borough, giving a total number in London as a whole of approximately 2,500.

The database could be improved if the following steps were taken under the planning process:

- Enabling planning applications to be searched more extensively. Current searches are limited to short application descriptions, which may not highlight the existence of a CHP facility
- The provision and use of a standard form for data collection in cases where a planning application will include a CHP component. An alternative approach would be to ensure that the Energy Statement includes the relevant information. An Energy Statement is a requirement of the London Plan. It makes most sense for this information to be provided as part of an Energy Statement, as any application which includes a CHP facility will submit an Energy Statement as part of the planning application. The GLA's guidance on preparing energy assessments[24] sets out the information required in relation to CHPs in sections 11.34 to 11.38. In practice, it is unusual to find the full range of information specified in these paragraphs in an Energy Statement for a development with a CHP component. These requirements could potentially be reinforced by means of a standard form for data collection on CHP. Additional useful information/clarification to that already provided in the GLA guidance would include:
    - Confirmation that an Energy Statement should provide data on both thermal capacity and electrical capacity of total CHP provision.

[24] GLA, "Energy Planning: Guidance on preparing energy assessments," March 2016

  - Expected operational lifetime
  - The number of individual units to be installed, and their individual thermal and electrical capacity
  - The expected NOx emission concentration (mg/Nm^3) and release rate (g/s) from combustion-based CHP
  - The fuel used for combustion-based CHP
  - Expected operational hours per year
  - Details of any back-up boiler provision
- In common with many other aspects of development, there is no systematic means of tracking changes to a development once planning permission is granted. Implementing a system for tracking the installation, operation and monitoring of CHP plants would be valuable, but would have an implementation and resource cost. This would be valuable if combustion-based CHP installations are found to have local air quality impacts. Ideally an automated web-based system would be used, but it would rely on local authority officers following up with developers and maintaining the information held on the system.

6.2 Potential air pollution impacts

If all current and permitted CHP facilities identified in this study are assumed to be operational, these would make a significant contribution to borough-wide emissions. The contribution would be around 6% of carbon dioxide emissions, and smaller percentages of borough-wide PM_{10} and $PM_{2.5}$ emissions. The potential contribution to NOx emissions is estimated to be around 32% of emissions averaged over the five boroughs, up to over 50% of emissions from the London Borough of Southwark. This reflects the larger number of CHP facilities identified in Southwark. At present, not all the facilities in the database are operational – indeed, fewer than half of the identified facilities may be operational. In view of this, the contribution at present is likely to be lower than these upper bound estimates. If all CHP installations were to operate with operational abatement plant, the contribution to NOx emissions could be less than 10% of total emissions from the five boroughs. However, if all installations were to operate without abatement, the CHP contribution to NOx emissions could amount to as much as 75% of total emissions. If the heat provided by CHP were delivered by low NOx boilers or zero emitting sources such as heat pumps, this would be expected to result in lower overall emissions, as illustrated in Figure 2.

Estimated NOx emissions from CHP installations if all plant are assumed to be operational are approximately equivalent to the LAEI estimate for domestic and commercial gas combustion for the five boroughs. By 2030, emissions from domestic and commercial gas combustion are forecast to reduce by about a quarter from the 2013 LAEI estimate. Under these circumstances, the estimated NOx emissions from currently installed and proposed CHP would equate to over 170% of the forecast emissions from the domestic and commercial gas combustion sector in 2030.

It was estimated very crudely that, if all the identified CHP facilities were operational, this could give rise to an average increase in baseline levels of oxides of nitrogen of approximately 5 $\mu g/m^3$ (the annual average legal limit for nitrogen dioxide is 40 $\mu g/m^3$). Again, because only 17% of identified sites representing 43% of installed capacity could be confirmed as operational, the air quality impact at present is likely to be significantly lower than this upper estimate.

Published emissions factors indicate that emissions per unit of energy generated are typically higher from smaller plant than from larger plant. This reflects the more extensive controls on emissions which are normally applied to larger plant in order to comply with applicable emissions limits and benchmarks. If smaller CHP plant actually had similar emissions to larger installations, the potential impact of CHP emissions on air quality would be lower than identified in this study. However, it is considered that emissions from smaller plant are in fact higher than the data used to represent emissions from larger installations, and so the results above are more likely to be reliable.

It is concluded that ongoing implementation as planned of combustion-based CHP facilities, if not effectively abated, could have a significant effect on air quality across the five boroughs studied in this project, which would offset the benefits gained from many of the transport-related air quality interventions currently being implemented by the Mayor. Impacts would be more significant still in the near vicinity of combustion-based CHP facilities. This could be particularly important if the design or operation of the facility falls below best practice (for example, a poorly designed stack discharging close to or below the heights of neighbouring buildings). This would be a particular concern if CHP facilities were to benefit from strategic policy support in the future. The GLA has commissioned further work to better understand the real-world impact of CHP plant installed in London and this should provide further evidence on this point.

A range of policy options would be available to mitigate or eliminate the local air quality impacts of combustion-based CHP, and in particular gas-engine CHP. Gas-fired CHP plants fitted with catalytic convertors can be designed to achieve much lower NOx emissions if properly operated and maintained – although these still result in pollutant emissions and alternative technologies (e.g. heat pumps) should be considered, particularly in areas where air quality is poor. Possible policy approaches for combustion-based CHP could include:

For new developments

- A complete ban on combustion-based CHP provision for new development, either in specific geographical areas where air quality is a particular problem or there are sensitive communities or even across the entire city reflecting the potential scale of negative impacts and the way this could off-set other improvements, e.g. those delivered by reducing transport emissions.
- Where combustion-based CHP is used stricter limits on emissions of oxides of nitrogen should be applied by planning authorities, including through the use of abatement equipment; although the ability to effectively enforce these through the planning system and the lack of any comprehensive existing regulatory structure limits the potential effectiveness of these.
- Better enforcement of the requirement in the GLA Supplementary Planning Guidance on Sustainable Development for the assessment and mitigation of the air quality impacts of any development which includes a combustion-based CHP element. This should already take place: however, this study highlights that the existing planning system does not consistently ensure that these impacts are appropriately mitigated.
- A requirement on planning authorities to ensure that planning controls are in place to check the installation of appropriate abatement equipment in accordance with planning permissions.
- Regular real-world emission measurements should be carried out by the operator of any CHP facility which relies on mitigation.
- Specific provisions for enforcement, monitoring, auditing and maintenance of CHP equipment, systems and abatement technology installed in new developments, to be carried out by the planning authority or other relevant body. Such provisions are likely to require implementation through means other than the land-use planning system, although Section 106 agreements could provide a mechanism for delivery of some components of this. This could in principle be implemented through means such as an extension to the Environmental Permitting Regulations 2016 to include smaller CHP plants in the range of processes regulated as Part B activities by local authorities. This would enable specific statutory guidance to be produced, identifying appropriate emission benchmarks, together with monitoring and inspection requirements.

Any controls introduced on CHP installations at new developments would take some time to take effect, as existing permissions are implemented.

To address existing plant

- Specific provisions for enforcement, monitoring, auditing and maintenance of existing CHP equipment, systems and abatement technology. As with new plant, such provisions are likely to require implementation through means other than the land-use planning system, such as an extension to the range of Part B activities regulated by local authorities under the Environmental Permitting Regulations 2016, as described above.
- Additional abatement requirements for existing combustion-based CHP, or plant already approved through planning. This is especially important if the potential legacy impact of existing CHP equipment is to be addressed. This may require a new regulatory structure underpinned by new legislation.
- Provision of guidance/training for CHP facility operators.

6.3 Recommendations and next steps

It is recommended that the database developed under the current project should be extended to other London boroughs. Compilation of the database should take account of the learning from the present project.

It is recommended that a further study to investigate the local air pollution impacts of example CHP installations would also be valuable, and it is understood that two such studies are under way. This would provide an indication of the likely range of impacts of CHP plant in the immediate vicinity of the facility.

It is recommended that GLA policy with regard to combustion-based CHP should consider the potential for significant local and cumulative air quality impacts of CHP plant, while taking into account the contribution that CHP installations make to electricity generation and heat provision in London boroughs, and the associated potential carbon dioxide emissions savings in some circumstances. A range of options are open to the GLA and London Boroughs, as set out in Sections 3.7 and 6.2.

Additionally, as discussed in Section 1.2.4, changes proposed to the national Standard Assessment Procedure would make gas-fired CHP unfavourable from a carbon mitigation perspective. In view of the potentially significant impact on local air quality, and question marks over future carbon savings, it is recommended that GLA policy in relation to combustion-based CHP technology which has associated emissions to air should be reviewed.

Appendices

Appendix 1: Maps of CHP facilities showing locations of schools

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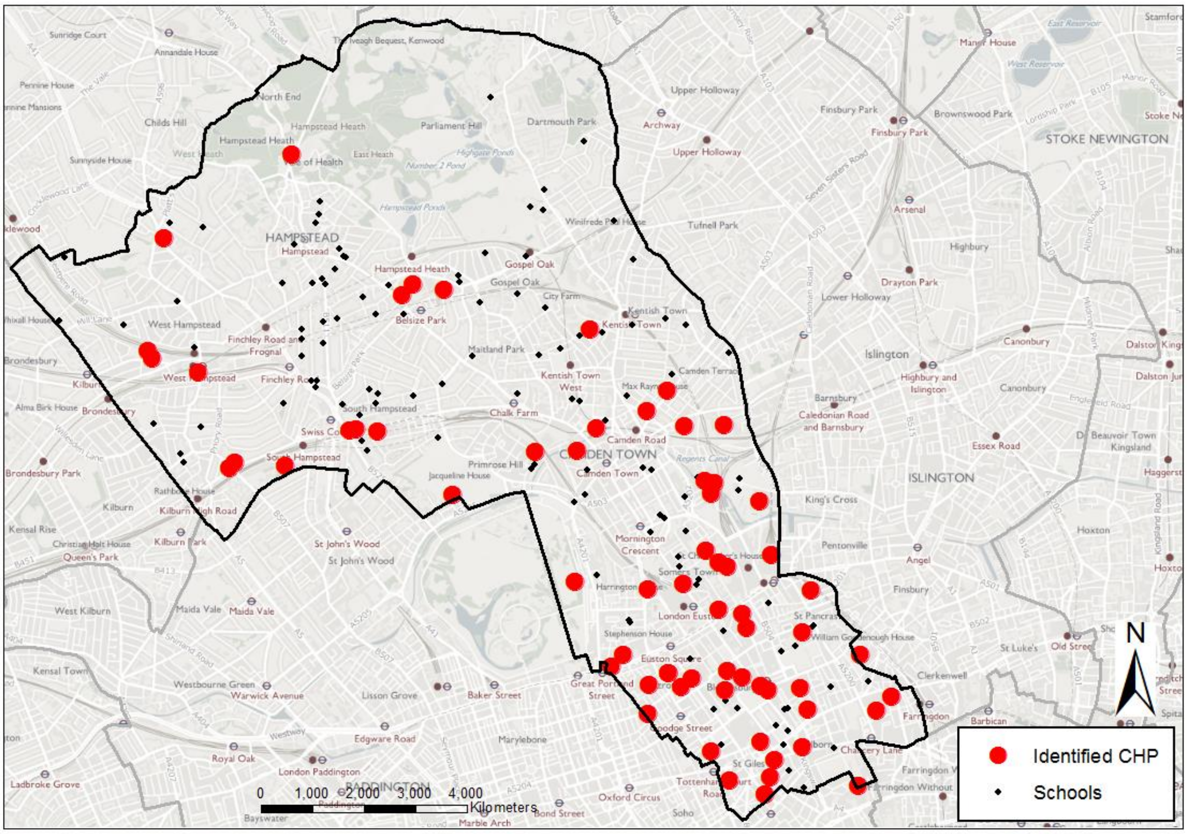

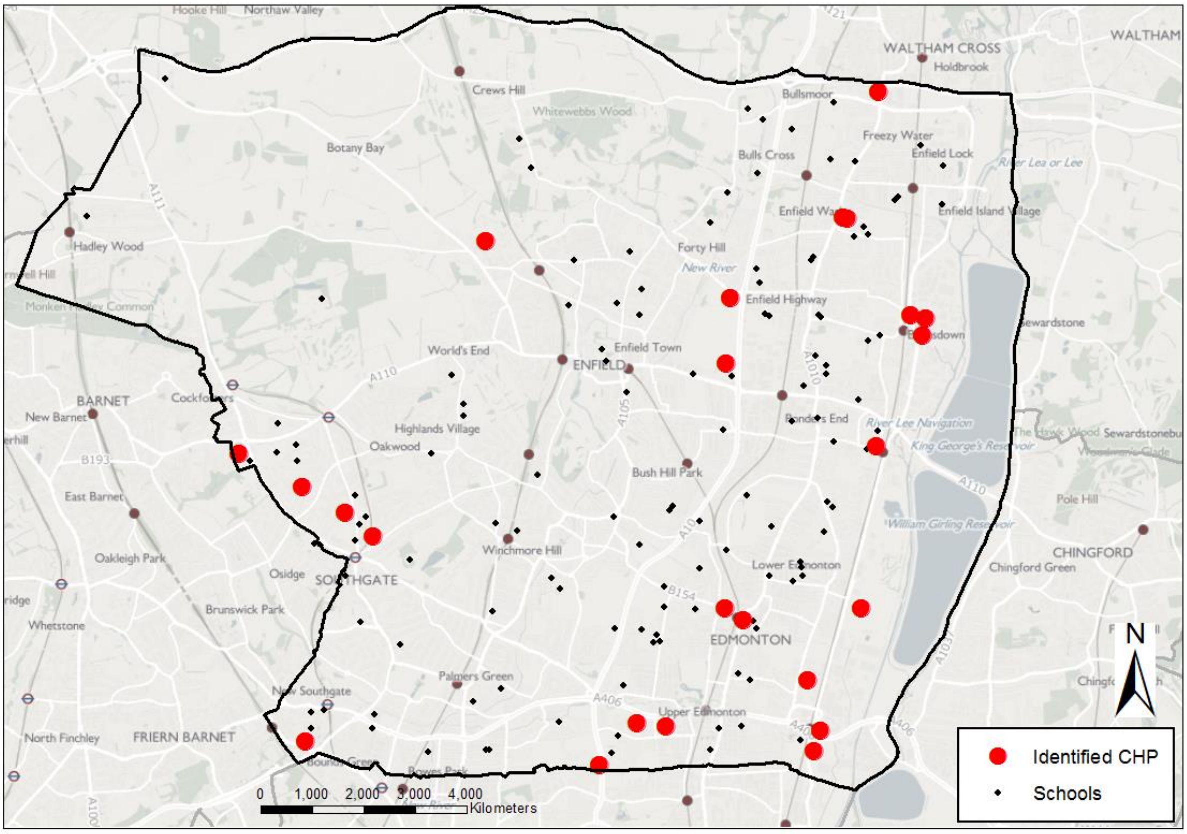
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Holdbrook
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Crews Hill
Whitewebbs Wood
Botany Bay
Bullsmoor
Freezy Water
Enfield Lock
Bulls Cross
Enfield Wash
Enfield Island Village
Hadley Wood
Forty Hill
New River
Enfield Highway
Monken Hadley Common
World's End
Enfield Town
ENFIELD
BARNET
Cockfosters
New Barnet
Highlands Village
Oakwood
Ponders End
River Lee Navigation
King George's Reservoir
Sewardstone
East Barnet
Bush Hill Park
Pole Hill
William Girling Reservoir
Oakleigh Park
Winchmore Hill
Lower Edmonton
CHINGFORD
Chingford Green
Osidge
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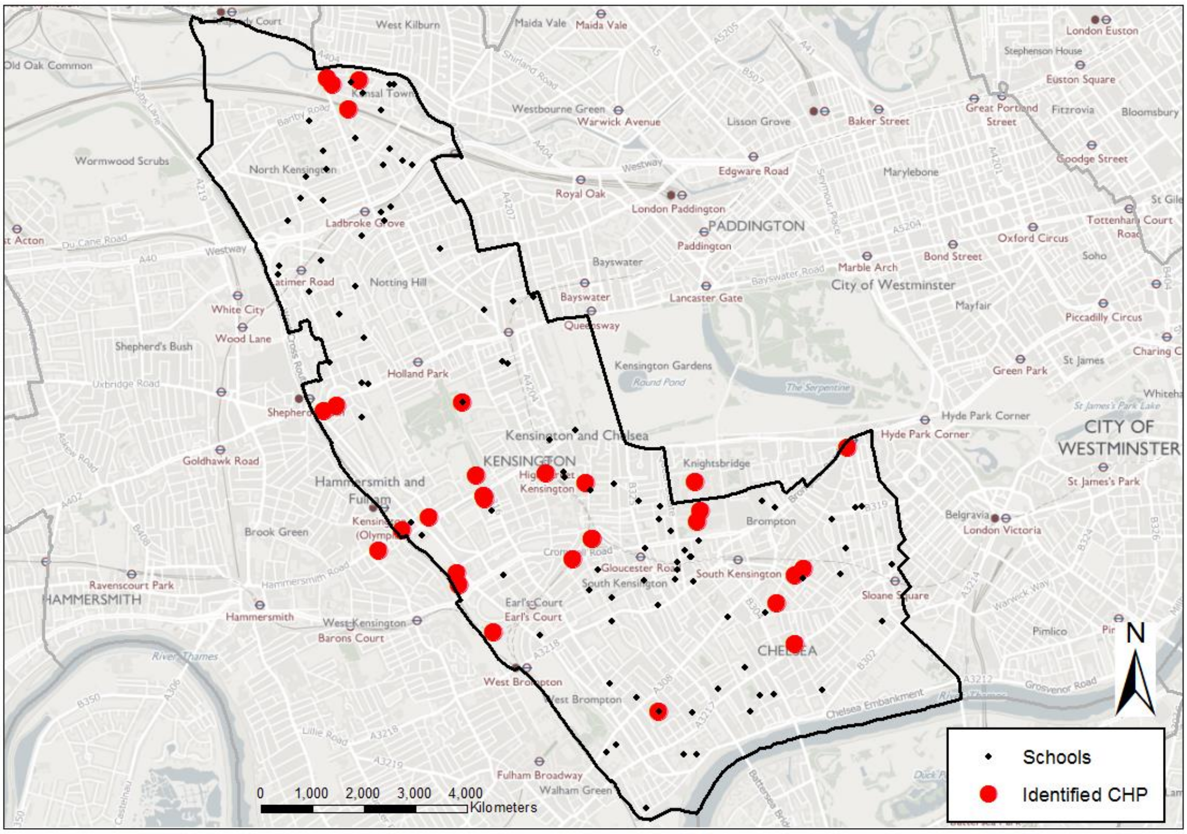
Bounds Green
Bowes Park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Warwick Avenue
Lisson Grove
Baker Street
Great Portland Street
Fitzrovia
Bloomsbury
Euston Square
Wormwood Scrubs
North Kensington
Westway
Edgware Road
Marylebone
Goodge Street
Royal Oak
London Paddington
PADDINGTON
Ladbroke Grove
Paddington
Oxford Circus
Tottenham Court Road
East Acton
Bayswater
Marble Arch
Bond Street
City of Westminster
Soho
Latimer Road
Notting Hill
White City
Lancaster Gate
Mayfair
Wood Lane
Queensway
Piccadilly Circus
Shepherd's Bush
Kensington Gardens
Round Pond
St James
Holland Park
The Serpentine
Green Park
Hyde Park Corner
CITY OF WESTMINSTER
Kensington and Chelsea
KENSINGTON
High Street Kensington
Knightsbridge
St James's Park
Goldhawk Road
Hammersmith and Fulham
Belgravia
London Victoria
Brompton
Brook Green
Kensington (Olympia)
Cromwell Road
Gloucester Road
South Kensington
Sloane Square
Ravenscourt Park
HAMMERSMITH
Hammersmith
West Kensington
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West Brompton
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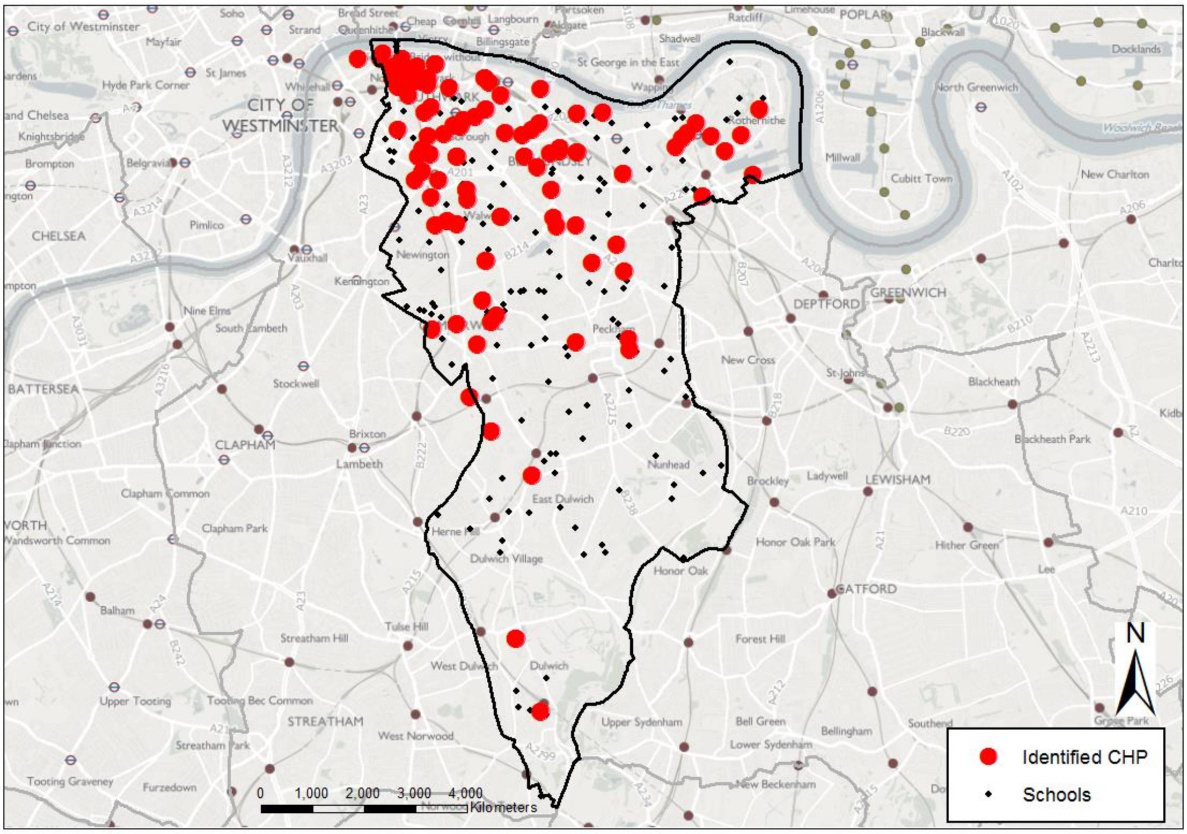
Fulham Broadway
Walham Green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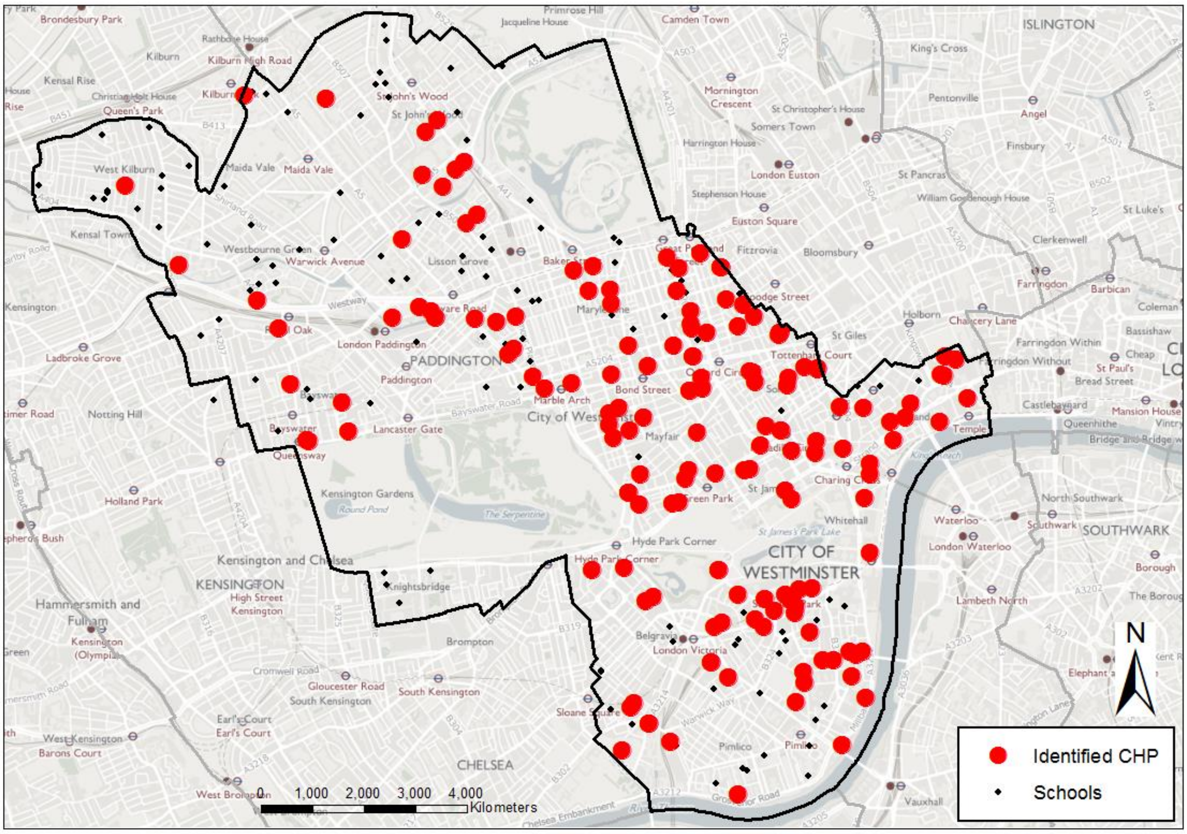
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