Thurrock Flexible Generation Plant

Environmental Statement Volume 6
Appendix 14.1: GHG Calculations

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Environmental Impact Assessment

Environmental Statement

Volume 6

Appendix 14.1

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Summary

This appendix reports the approach, data inputs, assumptions and boundaries of the calculation of greenhouse gas emissions due to the proposed development and other electricity generation sources displaced by it.

Qualifications

This document has been prepared by Tom Dearing, a Chartered Environmentalist and full Member of the Institute of Environmental Management and Assessment, who has nine years' experience of carbon footprint and climate change assessment for developments in the energy, waste, renewables, transport and major infrastructure sectors.

1. Calculation Approach

1.1 Introduction

1.1.1 This appendix provides additional details of the calculation of greenhouse gas (GHG) emission impacts reported in Volume 3, Chapter 14: Climate Change of the ES. It sets out the boundary of the assessment, data inputs or assumptions, and the output of the calculations.

1.1.2 The appendix should be read together with Chapter 14, which provides the policy context and characterises the significance of effects due to the net change in GHG emissions attributed to the proposed development.

1.2 Assessment boundary

1.2.1 The assessment boundary encompasses the construction, operational and decommissioning life-cycle stages of the proposed development.

1.2.2 It includes scope 1 (direct) emissions from the proposed development and scope 3 (indirect) emissions from the supply chain of its gas fuel, which are considered to be the most significant scope 3 source. The proposed development has no scope 2 (purchased electricity, heat or cooling) emissions as it supplies its own power load in normal operation.

1.2.3 The boundary also includes the GHG emissions of marginal baseline electricity generation sources that would be displaced by the proposed development, with equivalent boundary for their scope 1, 2 and 3 emissions.

1.2.4 Potential GHG emission sources of the proposed development that have been considered are:

- natural gas supply and combustion;
- fugitive emissions of natural gas fuel, insulating gas used in substation components, and/or working fluid of organic Rankine cycle (ORC) type exhaust gas energy recovery system;
- transport vehicles;
- construction materials' supply chain, construction activity and waste;
- operational consumables' supply chain and waste; and
- waste or recycling at decommissioning stage.

Allocation and attribution

1.2.5 All calculated net GHG emissions within the assessment boundary are allocated and attributed to the proposed development, for the purpose of assessing its net impacts. No differential allocation or attribution based on operational control, ownership or equity share has been required.

1.3 Emission source screening

1.3.1 The assessment focuses on the main sources of GHG emissions, i.e. those that would significantly contribute to the net total, in order to provide a proportionate level of detail relative to the information available about the design, construction, operation and decommissioning of the flexible generation plant[1].

1.3.2 Potential emissions sources have therefore been screened using conservative estimates to identify those that are expected to be *de minimis*[2] and do not require further detailed assessment. The *de minimis* threshold has been defined as emissions sources that are individually no more than 1% and collectively no more than 5% of lifetime total gross emissions from fuel combustion in the gas engines, as the dominant emissions source.

1.3.3 Gross emissions from the gas engines' operation for up to 4,000 hours per year over 35 years would be 45,596 $ktCO_2e$ total (see Table 1.1 for emissions factors and efficiency used). One percent and 5% of this would be 456 $ktCO_2e$ and 2,280 $ktCO_2e$, respectively.

Construction phase

1.3.4 At this early stage of design, before construction contractor involvement, it is not possible to estimate construction materials and plant requirements in detail.

[1] as a number of technology providers and options for the gas engines, batteries, substation designs and exhaust gas energy recovery system are under consideration by the applicant, no detailed information such as construction plant and materials estimates or lifecycle analysis Environmental Product Declarations are available at this stage

[2] a term often used in greenhouse gas accounting for very minor emission sources, either not appreciably affecting the total or likely to be within its uncertainty range

1.3.5 Using a general emissions factor for 'average construction' materials (BEIS and Defra, 2019), the 1% *de minimis* threshold would be equivalent to several million tonnes of materials, clearly far in excess of any reasonable construction estimate. Using the carbon intensity of general aluminium products (Hammond and Jones, 2011) as a proxy for higher carbon intensity materials that may be used in manufacturing of gas engines, substation components and similar, it is possible that the embodied carbon of construction materials could amount to a few tenths of 1% of the gross operational phase emissions total.

1.3.6 Published life-cycle analysis studies of gas-fired power stations reviewed by Ricardo-AEA for the Committee on Climate Change in 2013 (Odeh *et al*, 2013) suggest that the construction stage typically accounts for a minor proportion – around 1% – of total life-cycle GHG emissions.

1.3.7 As discussed in Section 0, the proposed development would displace marginal generation capacity that is likely to include gas-fired generators with a similar construction-phase contribution to their lifecycle emissions total. It is therefore very unlikely that the net difference in construction phase emissions would exceed the *de minimis* threshold or be significant to net total GHG emissions from the proposed development.

1.3.8 The 1% *de minimis* threshold would be equivalent to transporting several million tonnes of freight by road or sea to the site and it is clear that construction-phase traffic cannot contribute appreciably to the total GHG emissions of the proposed development.

Fugitive emissions

1.3.9 The 1% threshold would be equivalent to fugitive emissions of c. 18,000 tonnes of natural gas[3], 443 tonnes of R245fa (as one possible working fluid with a high global warming potential, GWP, for an ORC-type exhaust gas recovery system) or 20 tonnes of sulphur hexafluoride (SF_6, a potential substation insulator)[4, 5].

1.3.10 The developer would comply with the F-gas Regulations[6] (Regulation EU 517/2014) and good practice for installation, operation and end of life disposal of any components containing these gases, which would be undertaken by licensed contractors. The proposed development would also be operated in accordance with requirements for natural gas safety. There is considered to be no reasonable possibility of significant fugitive emissions in this order of magnitude and these sources are considered to be *de minimis*.

Operational consumables

1.3.11 The main operational consumables would be coolant (glycol), lubricating oil and ammonia solution or urea for emissions control, in quantities specified in Volume 2, Chapter 2: Project Description. Of these, the quantity of urea or ammonia solution is by far the greatest, estimated at up to 6,000 m^3 per annum (at operational dilution). The reference document on Best Available Techniques (BAT) for inorganic chemical production (EC, 2007) suggests carbon intensity of <2 tCO_2/t of ammonia or urea production, so the scope 3 supply chain emissions for this operational consumable would be below the 1% *de minimis* threshold.

1.3.12 The proposed development will use selective catalytic reduction (SCR) rather than selective non-catalytic reduction (SNCR) to reduce emissions of oxides of nitrogen (NO_x). Unlike SNCR, SCR does not typically lead to significant nitrous oxide (N_2O) formation as a byproduct (Lecomte *et al*, 2017).

Decommissioning phase and waste

1.3.13 Decommissioning phase emissions including generation of waste are not expected to exceed the *de minimis* threshold for the following reasons:

- decommissioning-stage GHG impacts are very unlikely to be greater than construction-stage impacts, given national trends in decarbonisation over time;
- it is likely that much of the proposed development's structure and energy generation components will be constructed of materials metals with good potential for recycling, in which case the benefits of recycling are attributed to the new material user in BEIS GHG reporting guidance (i.e. not attributed to the proposed development); and

[3] for simplicity, assumed to be all CH_4
[4] using global warming potentials (GWPs) specified in BEIS and Defra (2019)
[5] SF_6 use in high-voltage substation components is typically in the order of hundreds of kilograms rather than tonnes https://www.gov.uk/guidance/how-to-operate-or-service-high-voltage-switchgear-containing-sf6
[6] or domestic equivalent after the Brexit transition period

- if disposed of and not recycled, the proposed development's construction materials are likely to be mainly inert waste (e.g. metals, concrete), not of a nature to generate GHG emissions from decomposition or incineration.

Summary

1.3.14 GHG emissions arising from activity and supply chains for construction phase, transport, operational consumables (other than gas fuel), decommissioning phase and fugitive emissions have been screened out of further assessment as *de minimis* and non-material to the lifecycle total for the flexible generation plant.

1.3.15 Direct scope 1 combustion emissions and scope 3 supply chain emissions for the natural gas fuel have been screened in.

1.4 Displaced emissions

Gas engines

1.4.1 Electricity generated by the proposed gas engines would displace an equivalent amount of electricity generation from other sources in a business-as-usual future baseline without the proposed development. To assess the net effect on GHG emissions, the marginal source of electricity generation displaced must be identified.

1.4.2 The operating margin source displaced may in practice vary from moment to moment depending on the operation of the capacity market, i.e. led by commercial considerations and National Grid's needs at any given time. For the purpose of this assessment, longer-term trends (annual averages) have been used as it is not possible to predict shorter-term variations with confidence.

1.4.3 BEIS publishes projections of the carbon intensity of long-run build margin electricity generation and supply that would be affected by small (on a national scale) sustained changes in generation or demand (BEIS, 2019). BEIS's projections over the proposed development's operating lifetime (2022 to 2056) are based on an interpolation from 2010's assumed marginal generator (a combined cycle gas turbine [CCGT] power station) to a modelled energy mix in 2030 consistent with energy and climate policy and predicted demand reduction scenarios by that point.

1.4.4 A grid-average emissions factor is projected by BEIS for 2040 and the marginal factor is assumed to converge with it by that date, interpolated between 2030 and 2040; both factors are then interpolated from 2040 to a national goal for carbon intensity of electricity generation in 2050.

1.4.5 However, as the proposed development is a flexible generation plant that may be used intermittently (primarily to meet peak loads) rather than continuously as a baseload supplier, it is relevant also to consider more specifically other current and future peaking generation sources that could be displaced, particularly in the nearer-term before renewable or other low/zero-carbon supplies might come to constitute the majority of both the grid-average and marginal generation sources as implied in the converging BEIS projection.

1.4.6 In the absence of a dedicated flexible generation plant, peaking capacity can be provided by operating one (larger) or multiple conventional CCGT generators at part-load (rather than one at full load for the capacity required), allowing headroom for a short-term increase in generation to meet a peak demand, that can be achieved much more rapidly than starting a CCGT from cold. As set out in the BAT assessment submitted at EIA scoping stage, the thermal efficiency of a CCGT operated at part load in this way can fall to below 50%.

1.4.7 In addition, an open cycle gas turbine (OCGT) generator can provide an alternative to reciprocating engines for fast start-up to meet peak demand or a CCGT can in some cases be operated in OCGT mode. As set out in the BAT report, efficiencies can be lower again, at 39-43%.

1.4.8 A key factor in the national need for flexible generation capacity such as that provided by the proposed development is the increasing use of renewable generation sources such as wind power, whose output cannot be guaranteed at a particular time. Without sufficient backup or peaking capacity (and/or energy storage), deployment of renewable generation at the scale envisaged in energy and climate policy will not be possible. The proposed development can therefore be viewed as *enabling* a matching 600 MW (or more) of intermittent renewable capacity to be added to the energy supply mix, by providing the confidence that equivalent back-up capacity is available.

1.4.9 In that case, one effect of the proposed development is to enable the displacement of marginal baseload generation by renewable generation with lower carbon intensity during the (minimum) 4,760 hours of the year when the flexible generation plant is *not* required.

1.4.10 Three scenarios for GHG emissions displaced due to operation of the gas engines have therefore been defined for assessment.

- Scenario 1: displacement of average marginal source (BEIS projection).
- Scenarios 2a and 2b: displacement of a CCGT or OCGT.
- Scenario 3: additional displacement of average marginal source by enabled renewable capacity.

Batteries

1.4.11 The proposed batteries would provide up to 600 MWh storage and 150 MW output, i.e. up to four hours' discharge at the maximum output level. Volume 2, Chapter 2: Project Description sets out the various purposes that this battery storage capacity can provide for National Grid and hence ways in which the batteries may be used. For the purpose of this assessment, one complete charge and discharge cycle each 24 hours has been assumed.

1.4.12 The energy market function of the batteries, storing excess generation until it is needed, effectively displaces the need for equivalent peaking generation capacity. This has been represented for emissions calculation by the proposed development's own gas engines, as a conservative assumption (given their high efficiency and low carbon intensity relative to other peaking generation sources).

1.4.13 The electricity stored by the batteries could be considered to come preferentially from renewable generation, as excess renewable generation (from sources that cannot be controlled, like wind availability) will increase with greater renewables deployment. Alternatively, as a more conservative assumption, the projected grid-average carbon intensity of (non-marginal) generation can be assumed. These form scenarios 4 and 5 in the assessment, respectively.

1.4.14 For scenario 4, the lifecycle carbon intensity of mid-scale onshore wind generation has been assumed as representative.

1.4.15 For scenario 5, the BEIS grid-average projection for electricity generation has been used. National Grid also publishes 'Future Energy Scenario' projections (National Grid, 2019) of grid-average carbon intensity under several possible evolutions of the UK energy market, which have been reviewed. The BEIS projection sits broadly in the middle of the National Grid range so has been considered representative.

1.4.16 Displaced or avoided emissions if battery storage is used for frequency management or transmission balancing would be specific to the individual circumstances, such as reactive power losses avoided or industrial load and other generation source affected, and cannot be assessed.

1.5 Alternative fuels

1.5.1 Alternatives to the use of natural gas in the UK are being considered, which would allow the value of the national gas network and the energy storage buffer it provides to be retained while reducing GHG emissions at the point of combustion. Steam reformation of natural gas (methane) into hydrogen or ammonia produces a relatively pure CO_2 stream suited for pre-combustion capture and storage; this could be done at the supply or major offtake points (such as for power stations) of the gas grid. Electrolysis powered by renewables may also become a more viable method of producing hydrogen as power costs fall significantly in times of renewable surplus generation. Greater injection of biomethane to the grid from sources such as anaerobic digestion has also been proposed though this will never make a material contribution at a national level.

1.5.2 While a wholesale switch to hydrogen, ammonia and/or biogas in the national gas network in the immediate future is unlikely, it is possible that the national gas grid will come to provide a blend of natural gas and hydrogen within the next 5 years. For example, it has been suggested that around 20-30% of natural gas could feasibly be replaced by hydrogen, and around 5-20% could be replaced by biomethane (Groth, 2019) (although the latter would be difficult to supply in that quantity at a national level).

1.5.3 The proposed development has safeguarded space for the purpose of carbon capture readiness (CCR), i.e. to allow for potential installation of carbon capture and storage (CCS) equipment were that to become feasible in future. However, this space could also be viewed as providing for hydrogen/ammonia/biogas readiness, allowing space for additional equipment that may be necessary to be installed.

1.5.4 The intermittent nature of a peaking plant potentially favours pre-combustion decarbonisation and particularly use of hydrogen rather than post-combustion CCS. The applicant has a high level of confidence that the gas reciprocating engines could be adapted to run on a blend of natural gas and hydrogen, and in the medium term potentially pure hydrogen.

1.6 Emissions factors and data sources

1.6.1 Table 1.1 lists the emission factors, other data inputs and their sources used in the calculations. Figure 1.1 illustrates the carbon intensity of the sources discussed in Section 0.

Table 1.1: Emissions factors and other data inputs.

Parameter	Factor	Unit	Source or notes
Natural gas combustion (CO_2)	0.2030	tCO_2/MWh	Calculated from Ricardo Energy and Environment (2019), North Thames region
Natural gas combustion (other GHGs)	0.0004	tCO_2e/MWh	BEIS and Defra (2019)
Natural gas supply chain	0.0266	tCO_2e/MWh	BEIS and Defra (2019)
Natural gas total	0.2299	tCO_2e/MWh	Sum of rows 1-3
Marginal displaced electricity generation: 2022	0.246	tCO_2e/MWh	BEIS, 2018. Intervening years shown in Figure 1.1.
Marginal displaced electricity generation: 2056	0.025	tCO_2e/MWh	BEIS, 2017. Intervening years shown in Figure 1.1.
Grid average electricity generation: 2022	0.098	tCO_2e/MWh	BEIS, 2019. Intervening years shown in Figure 1.1.
Grid average electricity generation: 2056	0.025	tCO_2e/MWh	BEIS, 2019. Intervening years shown in Figure 1.1.
Renewable electricity generation (onshore wind)	0.010	tCO_2e/MWh	Siemens (not dated); Razdan and Garrett (2015, 2017) showing <0.010 for onshore models
CCGT efficiency (full load)	60.5	%	BAT report; H-class
CCGT efficiency (part load)	50	%	BAT report
OCGT efficiency	39.5	%	BAT report
Battery efficiency	90	%	Hiremath *et al* (2015)
Reciprocating gas engine operating hours	4,000	hrs/annum	Thurrock Power Ltd
Reciprocating gas engine generation (net)	600	MW	Thurrock Power Ltd
Reciprocating gas engine efficiency (net)	52	%	Thurrock Power Ltd
Reciprocating gas engine methane slippage in exhaust	667	$mgCH_4/Nm^3$	High end of BAT range

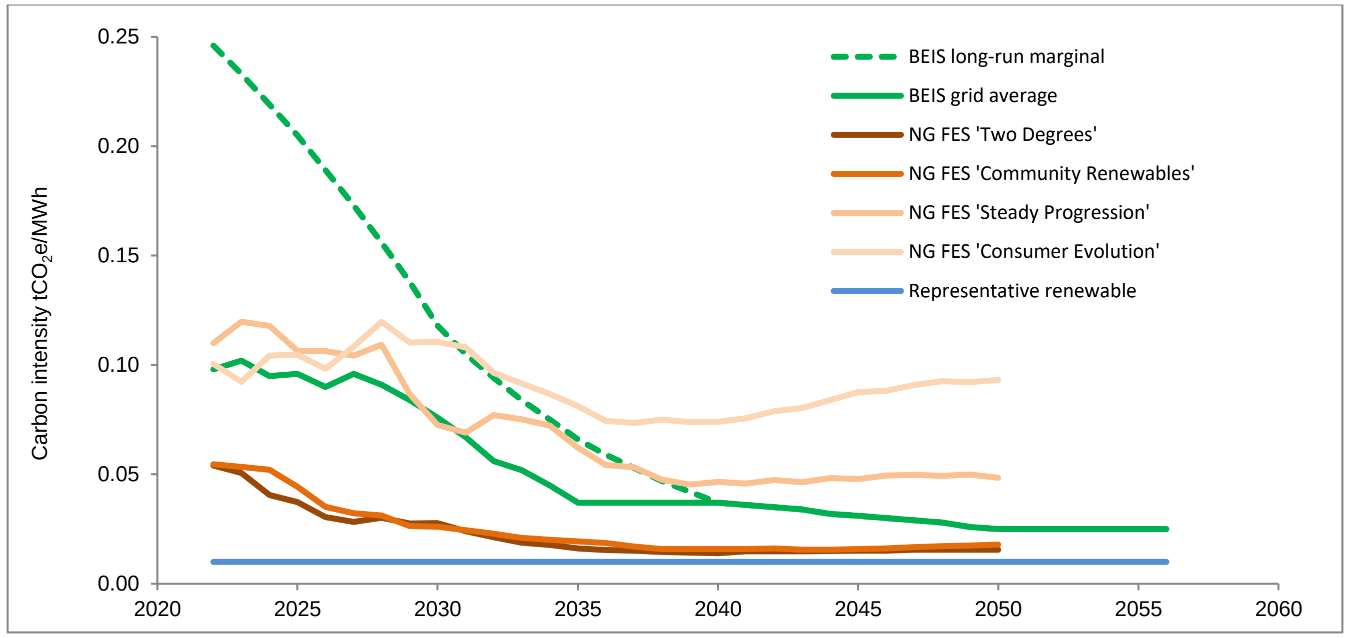

Figure 1.1: Carbon intensity of generation sources.

2. Calculation Outputs

2.1 Gross GHG emissions

2.1.1 The gross total GHG emissions from operation of the proposed development's gas engines would be up to 1,303 ktCO_2e/annum at 4,000 operating hours and cumulatively 45,596 ktCO_2e over an operating lifetime of 35 years.

2.1.2 The operation of battery storage would not cause direct GHG emissions from the proposed development. Indirect emissions arising from storage losses (i.e. emissions from generating that electricity) would be 2,433 tCO_2e/annum in scenario 4, cumulatively 85,167 tCO_2e. In scenario 5, emissions would be 23,792 tCO_2e/annum in 2022, falling to 6,133 tCO_2e/annum by 2056, and cumulatively 421 ktCO_2e.

2.2 Net GHG emissions

2.2.1 Table 2.1 overleaf shows gross GHG emissions (see Section 2.1), displaced emissions (see Section 0) and resulting net emissions in the scenarios assessed. Where scenarios are affected by projected changing carbon intensities of marginal and grid-average generation over time, GHG emissions in selected years between 2022 and 2056 are shown; see Figure 1.1 for a full time-series of the projections.

2.2.2 As a fossil-fuelled flexible generation plant with capacity to meet intermittent, peak demands, the proposed development naturally has higher carbon intensity than the projected marginal sources in the future under a national scenario of decarbonisation. Net scenario 1 emissions are around 700 ktCO_2e/annum in initial operation, increasing to around 1.2 MtCO_2e/annum by the end of its lifetime when other marginal sources are projected to have a very low carbon intensity.

2.2.3 Considering more specifically displacement of other gas-fired flexible generators (using different technologies) in scenarios 2a and 2b, the difference lies in the greater efficiency achieved by the proposed development. In scenario 2a, the net reduction achieved is -126 ktCO_2e/annum in initial operation, increasing to -230 ktCO_2e/annum by the end of its lifetime. In scenario 2b, the net reduction is -94 ktCO_2e/annum.

2.2.4 Taking the additional avoided GHG emissions through enabling renewable generation capacity in scenario 3 into account, a further reduction in emissions of around 673 ktCO_2e/annum in initial operation, falling to 43 ktCO_2e/annum by the end of its lifetime, could be facilitated.

2.2.5 The battery storage element of the proposed development would provide further GHG emission reductions in both scenarios 4 and 5, of between 73 ktCO_2e/annum and 94 ktCO_2e/annum.

2.2.6 Were lower-carbon fuels to become available and be used in the proposed development in future as discussed in Section 1.5, this would reduce the carbon intensity and gross emissions of the flexible generation plant. If similarly adopted it may also reduce the carbon intensity of other generation sources used in the comparison with the proposed development to estimate net emissions.

Table 2.1: Net GHG emissions results.

Operating year	Calendar year	tCO_2e/annum												
		Gross GHG emissions	Displaced GHG emissions – gas engines				Gross GHG emissions – batteries		Net GHG emissions					
		Gas engines	Scenario 1	Scenario 2a	Scenario 2b	Scenario 3	Scenario 4	Scenario 5	Scenario 1	Scenario 2a	Scenario 2b	Scenario 3	Scenario 4	Scenario 5
1	2022	1,302,734	590,171	1,429,036	1,396,920	673,743	2,433	23,792	712,563	-126,302	-94,186	628,991	-94,394	-73,035
5	2026	1,302,734	453,982	1,439,951	1,396,920	511,679	2,433	21,932	848,752	-137,217	-94,186	791,055	-94,394	-74,895
10	2031	1,302,734	253,175	1,473,683	1,396,920	272,718	2,433	16,184	1,049,559	-170,949	-94,186	1,030,016	-94,394	-80,643
15	2036	1,302,734	142,189	1,515,335	1,396,920	140,645	2,433	9,087	1,160,545	-212,601	-94,186	1,162,089	-94,394	-87,741
20	2041	1,302,734	86,710	1,517,068	1,396,920	74,625	2,433	8,791	1,216,024	-214,334	-94,186	1,228,109	-94,394	-88,036
25	2046	1,302,734	72,142	1,525,736	1,396,920	57,289	2,433	7,314	1,230,592	-223,002	-94,186	1,245,445	-94,394	-89,513
30	2051	1,302,734	60,487	1,532,671	1,396,920	43,420	2,433	6,133	1,242,247	-229,937	-94,186	1,259,315	-94,394	-90,695
35	2056	1,302,734	60,487	1,532,671	1,396,920	43,420	2,433	6,133	1,242,247	-229,937	-94,186	1,259,315	-94,394	-90,695
Cumulative totals		**45,595,692**	**6,712,129**	**52,433,402**	**48,892,194**	**6,987,834**	**85,167**	**420,845**	**38,883,563**	**-6,837,710**	**-3,296,502**	**38,607,859**	**-3,303,791**	**-2,968,113**

Note: totals may not equal sums of parts due to rounding

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