



## **Thurrock Flexible Generation Plant**

**Preliminary Environmental Information Report  
Appendix 14.1: GHG Calculations**

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**Environmental Impact Assessment**  
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**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 eight 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 PEIR. 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, explains the with- and without-development scenarios assessed, 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.

1.2.3 The assessment 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) 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<sup>1</sup>.

1.3.2 Potential emissions sources have therefore been screened using conservative estimates to identify those that are expected to be *de minimis*<sup>2</sup> 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 37,561 ktCO<sub>2</sub>e total (see Table 1.1 for emissions factors and efficiency used). One percent and 5% of this would be 376 ktCO<sub>2</sub>e and 1,878 ktCO<sub>2</sub>e, 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.

<sup>1</sup> as a number of technology providers and options for the gas engines, batteries, substation designs and ORC 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

<sup>2</sup> 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 (Department of Business, Energy and Industrial Strategy (BEIS) and Department for Environment, Food and Rural Affairs (Defra), 2018), 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 relatively high 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% 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 1.4, 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 15,000 tonnes of natural gas<sup>3</sup>, 356 tonnes of R245fa (potential ORC system working fluid) or 16 tonnes of sulphur hexafluoride (SF<sub>6</sub>, a potential substation insulator)<sup>4</sup>.

- 1.3.10 The developer would comply with the F-gas Regulations<sup>5</sup> (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<sup>6</sup> 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<sup>3</sup> per annum (at operational dilution). The reference document on Best Available Technology (BAT) for inorganic chemical production (European Commission, 2007) suggests carbon intensity of <2 tCO<sub>2</sub>/t of ammonia or urea production, so the scope 3 supply chain emissions for this operational consumable would be well 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<sub>x</sub>). Unlike SNCR, SCR does not typically lead to significant nitrous oxide (N<sub>2</sub>O) 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 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
  - 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.

<sup>3</sup> for simplicity, assumed to be all CH<sub>4</sub>

<sup>4</sup> using global warming potentials (GWPs) specified in BEIS and Defra (2018)

<sup>5</sup> or domestic equivalent after Brexit

<sup>6</sup> SF<sub>6</sub> 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>

## 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 marginal 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 marginal electricity generation and supply that would be affected by small (on a national scale) sustained changes in generation or demand (BEIS, 2017). 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. 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.
- 1.4.4 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.
- 1.4.5 In the absence of a dedicated flexible generation plant, peaking capacity can be provided by operating 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. As set out in the BAT assessment submitted at EIA scoping stage, the thermal efficiency of a CCGT operated in this way can fall to below 50%.
- 1.4.6 Alternatively, 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%.
- 1.4.7 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 of renewable capacity to be added to the energy supply mix, by providing the confidence that equivalent back-up capacity is available.
- 1.4.8 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.
- 1.4.9 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
- 1.4.10 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.
- 1.4.11 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).

- 1.4.12 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.
- 1.4.13 For scenario 4, the lifecycle carbon intensity of mid-scale onshore wind generation has been assumed as representative.
- 1.4.14 For scenario 5, the BEIS grid-average projection for electricity generation has been used. National Grid also publishes 'Future Energy Scenario' projections (National Grid, 2018) 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.
- 1.4.15 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 Emissions factors and data sources

- 1.5.1 Table 1.1 lists the emission factors, other data inputs and their sources used in the calculations.
- 1.5.2 Figure 1.1 illustrates the carbon intensity of the sources discussed in Section 1.4 and also the gross carbon intensity of the proposed development's gas engines.

Table 1.1: Emissions factors and other data inputs.

Parameter	Factor	Unit	Source or notes
Natural gas combustion (CO <sub>2</sub> )	0.2037	tCO <sub>2</sub> /MWh	Ricardo Energy and Environment (2017), North Thames region
Natural gas combustion (other GHGs)	0.0004	tCO <sub>2</sub> e/MWh	BEIS and Defra (2018)
Natural gas supply chain	0.0284	tCO <sub>2</sub> e/MWh	BEIS and Defra (2018)
Natural gas total	0.2325	tCO <sub>2</sub> e/MWh	BEIS and Defra (2018)
Marginal displaced electricity generation: 2022	0.246	tCO <sub>2</sub> e/MWh	BEIS, 2017. Intervening years shown in Figure 1.1.
Marginal displaced electricity generation: 2056	0.025	tCO <sub>2</sub> e/MWh	BEIS, 2017. Intervening years shown in Figure 1.1.

Parameter	Factor	Unit	Source or notes
Grid average electricity generation: 2022	0.148	tCO <sub>2</sub> e/MWh	BEIS, 2017. Intervening years shown in Figure 1.1.
Grid average electricity generation: 2056	0.025	tCO <sub>2</sub> e/MWh	BEIS, 2017. Intervening years shown in Figure 1.1.
Renewable electricity generation (onshore wind)	0.010	tCO <sub>2</sub> e/MWh	Siemens (not dated); Razdan and Garrett (2015, 2017) showing <0.010 for onshore models
CCGT efficiency (part load)	50	%	BAT report
OCGT efficiency	39.5	%	BAT report
Reciprocating gas engine efficiency	52	%	Thurrock Power Ltd
Flexible generation plant parasitic load	1.5	%	Thurrock Power Ltd
Battery efficiency	90	%	Hiremath <i>et al</i> (2015)

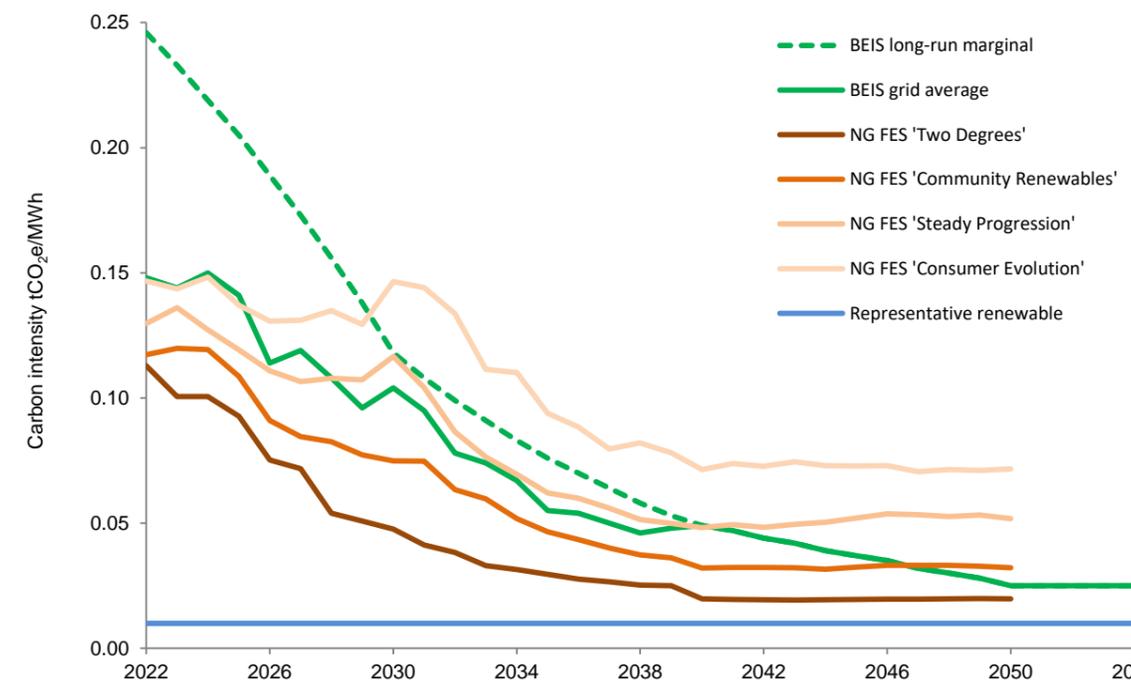


Figure 1.1: Carbon intensity of generation sources.

## 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 1,074 ktCO<sub>2</sub>e/annum at 4,000 operating hours and cumulatively 37,561 ktCO<sub>2</sub>e 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<sub>2</sub>e/annum in scenario 4, cumulatively 85,167 tCO<sub>2</sub>e. In scenario 5, emissions would be 36,013 tCO<sub>2</sub>e/annum in 2022, falling to 6,083 tCO<sub>2</sub>e/annum by 2056, and cumulatively 547 ktCO<sub>2</sub>e.

### 2.2 Net GHG emissions

- 2.2.1 Table 2.1 overleaf shows gross GHG emissions (see Section 2.1), displaced emissions (see Section 1.4) 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 500 ktCO<sub>2</sub>e/annum in initial operation, increasing to around 1 mtCO<sub>2</sub>e/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, leading to net GHG emissions reductions of between around 26 ktCO<sub>2</sub>e/annum to 318 ktCO<sub>2</sub>e/annum.
- 2.2.4 Taking the additional avoided GHG emissions through enabling renewable generation capacity in scenario 3 into account, a further reduction in net emissions of around 664 ktCO<sub>2</sub>e/annum in initial operation, falling to 42 ktCO<sub>2</sub>e/annum by the end of its lifetime, could be facilitated.

- 2.2.5 The battery storage element of the proposed development would provide further net GHG emission reductions in both scenarios 4 and 5, of between 63 ktCO<sub>2</sub>e/annum and 97 ktCO<sub>2</sub>e/annum.

Table 2.1: Net GHG emissions results.

Operating year	Calendar year	tCO <sub>2</sub> e												
		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	1,073,159	581,544	1,099,344	1,391,575	663,906	2,433	36,013	491,615	-26,185	-318,416	409,253	-96,984	-63,404
5	2026	1,073,159	446,796	1,099,344	1,391,575	503,556	2,433	27,740	626,363	-26,185	-318,416	569,603	-96,984	-71,677
10	2031	1,073,159	255,312	1,099,344	1,391,575	275,690	2,433	23,117	817,847	-26,185	-318,416	797,469	-96,984	-76,300
15	2036	1,073,159	165,780	1,099,344	1,391,575	168,790	2,433	13,140	907,679	-26,185	-318,416	904,369	-96,984	-86,277
20	2041	1,073,159	111,108	1,099,344	1,391,575	104,087	2,433	11,437	962,051	-26,185	-318,416	969,072	-96,984	-87,980
25	2046	1,073,159	82,740	1,099,344	1,391,575	70,329	2,433	8,517	990,419	-26,185	-318,416	1,002,830	-96,984	-90,900
30	2051	1,073,159	59,100	1,099,344	1,391,575	42,197	2,433	6,083	1,014,059	-26,185	-318,416	1,030,962	-96,984	-93,334
35	2065	1,073,159	59,100	1,099,344	1,391,575	42,197	2,433	6,083	1,014,059	-26,185	-318,416	1,030,962	-96,984	-93,334
<b>Cumulative totals</b>		<b>37,560,563</b>	<b>6,943,068</b>	<b>38,477,041</b>	<b>48,705,115</b>	<b>-7,277,645</b>	<b>85,167</b>	<b>547,257</b>	<b>30,617,495</b>	<b>-916,478</b>	<b>-11,144,552</b>	<b>30,282,918</b>	<b>-3,394,429</b>	<b>-2,932,339</b>

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