National Transmission System Energy Efficiency Review 2018

National Grid Gas plc

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Contents

1 Introduction ... 1
1.1 Scope of review ... 1
1.2 Legislative regime ... 1
1.3 Energy consumption ... 4
1.4 Asset classes (primary and secondary) ... 5
1.5 Adopting new approach for 2018 energy review ... 8
2 Review of energy consumption ... 10
2.1 Introduction ... 10
2.2 Energy consumption network trends 2014 – 2017 ... 10
2.3 Emissions associated with network energy consumption ... 10
2.4 Site profiles ... 12
3 Review of previous recommendations ... 13
3.1 Introduction ... 13
3.2 Summary of recommendations and status ... 13
3.3 Key progress since last review ... 16
4 Opportunities and recommendations 2019-2022 ... 34
4.1 Introduction ... 34
4.2 Site screening ... 34
4.3 Status of energy efficiency opportunities ... 35
4.4 Asset class-based approach to identification of opportunities ... 37
4.5 Cross network opportunities and recommendations ... 40
4.6 Site-specific energy efficiency opportunities ... 42
5 Conclusions ... 44
Appendix 1 Updated site profiles ... 46
Appendix 2 Detailed table of 2014 recommendations and status update ... 47
Appendix 3 NTS energy consumption charts ... 48

1 Introduction

1.1 Scope of review

This review is the third energy efficiency review carried out for National Grid's National Transmission System (NTS), following on from the 2010 review (covering the years 2005 to 2009) and the 2014 review (covering the years 2009 to 2013). This review covers the years 2014 to 2017; complete annual data is not currently available for 2018.

This review sets out to satisfy permit conditions for the NTS compressor stations and terminals. For sites in England and Wales, the Environment Agency (EA)/National Resources Wales (NRW) permits state:

> *Energy efficiency*
>
> *The operator shall:*
> *a) Take appropriate measures to ensure that energy is used efficiently in the activities;*
> *b) Review and record at least every 4 years whether there are suitable opportunities to improve the energy efficiency of the activities; and*
> *c) Take any further appropriate measures identified by a review.*

For sites in Scotland, Scottish Environment Protection Agency (SEPA) permits state:

> *Resource Utilisation*
>
> *At least every 4 years, the Operator shall carry out a systematic assessment of the raw material, energy and fuel consumption, emissions and waste production associated with the Permitted Activities. The purpose of the assessment shall be to identify methods of reducing raw material, energy and fuel consumption, emissions and waste production. Each assessment shall be recorded. A summary of any energy use or waste minimisation projects identified as a result of said assessment and the estimated costs and pay back period relating to each project shall be reported.*

1.2 Legislative regime

National Grid operates its assets across the NTS in compliance with an often-overlapping regime of regulatory arrangements and agreements. These regulatory regimes place various obligations upon National Grid in respect of reporting, monitoring, asset management and asset health improvements.

- National Grid is currently in Ofgem's RIIO-T1[1] price control period, which runs from 2013 to 2021. The RIIO regime links the price consumers pay for gas to investment and innovation commitments; this drives National Grid's future investment programme to deliver a reliable, safe and sustainable gas transmission network. National Grid must demonstrate value for customers in how it chooses to invest money and demonstrate asset health improvements.
- There are several environmental permitting regimes that apply to National Grid's NTS assets:
    - The Environmental Permitting (EP) regime in England and Wales.
    - The Pollution, Prevention and Control (PPC) regime in Scotland.
    - The Large Combustion Plant Directive (LCPD), implemented though the Industrial Emissions Directive (enacted via the EP/PPC regimes).
    - The European Union Emissions Trading Regulations (EU-ETS[2]) within the UK.

[1] RIIO (Revenue = Incentives + Innovation + Outputs), Ofgem's performance-based framework to set network price controls. T1 refers to the first transmission price control review to reflect the RIIO regulatory framework.
[2] EU-ETS: European Union Emissions Trading System

National Grid must demonstrate compliance with these regulatory regimes, which place limits on emissions, operating hours (for some older plant), monitoring and reporting requirements, and improvement conditions designed to ensure the protection of the environment.

As part of these obligations National Grid is required to monitor and report energy consumption and to identify and implement energy efficiency improvements across the NTS.

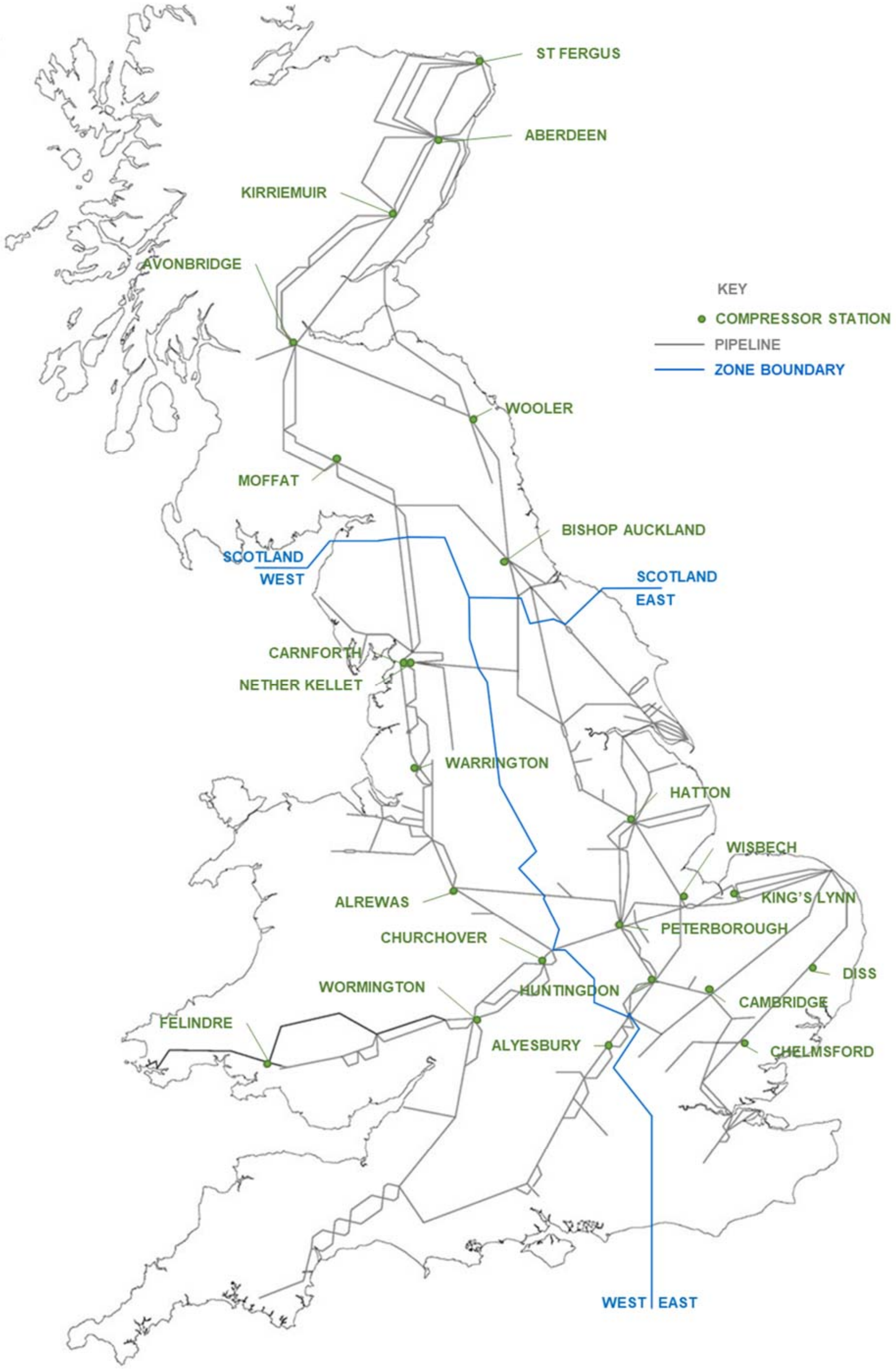
This review relates to the 23 NTS compressor stations/terminals identified in ***Table 1*** below.

Table 1 NTS EP/PPC permitted sites

Sites	
Aberdeen Compressor Station	Hatton Compressor Station
Alrewas Compressor Station	Huntingdon Compressor Station
Avonbridge Compressor Station	Kings Lynn Compressor Station
Aylesbury Compressor Station	Kirriemuir Compressor Station
Bishop Auckland Compressor Station	Moffat Compressor Station
Cambridge Compressor Station	Peterborough Compressor Station
Carnforth Compressor Station	St Fergus Gas Terminal
Nether Kellet Compressor Station	Warrington Compressor Station
Chelmsford Compressor Station	Wisbech Compressor Station
Churchover Compressor Station	Wooler Compressor Station
Diss Compressor Station	Wormington Compressor Station
Felindre Compressor Station	

Lockerley Compressor Station is excluded from this review as it is an all-electric drive compressor station not regulated by the EP/PPC regime.

Figure 1 National Grid Gas NTS map



1.3 Energy consumption

Energy consumption on the NTS sites is primarily:

- Natural gas
- Electricity
- Diesel
- Other gases
    - Acetylene
    - Propane

In many cases this energy is used in combustion processes on-site. This is direct combustion e.g. gas combustion in the compressor machinery train (CMT). In other cases, energy generation occurs off-site and is therefore in-direct, e.g. electricity supplied from the national grid used for lighting. ***Table 2*** below identifies on-site energy consumption activity.

Table 2 On site energy consumption activities

Energy	Magnitude	Energy type	Activity
Direct	Major	Gas	• CMT gas turbine operation
	Major/minor	Gas	• Fuel gas pre-heating
	Minor	Gas	• Mobile compressor operation • Water bath heater operation

	Minor	Diesel	• Ancillary site equipment usage
			    • Air compressors
			    • Mobile lighting unit
			    • Power generator
			    • Pressure washer
			    • Steam cleaner
			• Standby power generation
			• Operation of water pumps

	Minor	Other gases	• Welding (Acetylene) • Use of blow torch (Propane)
	Domestic	Gas	• Cooking • Heating
In-direct	Major	Electricity	• CMT Variable Speed Drive operation • Heating, Ventilation and Air Conditioning (HVAC)
	Minor	Electricity	• Lighting (operational site) • CCTV and security
	Domestic	Electricity	• HVAC • Lighting
Process losses	Major/minor	Gas	• Venting • Leaks • Motive gas • Shrinkage

Figure 2 below shows the different areas of a generic compressor station site and ***Figure 3***, ***Figure 4*** and ***Figure 5*** illustrate the different activities and associated energy consumption on that generic site.

Figure 2 Conceptual site model

Figure 3 Generic compressor station site illustrating activities and associated energy consumption

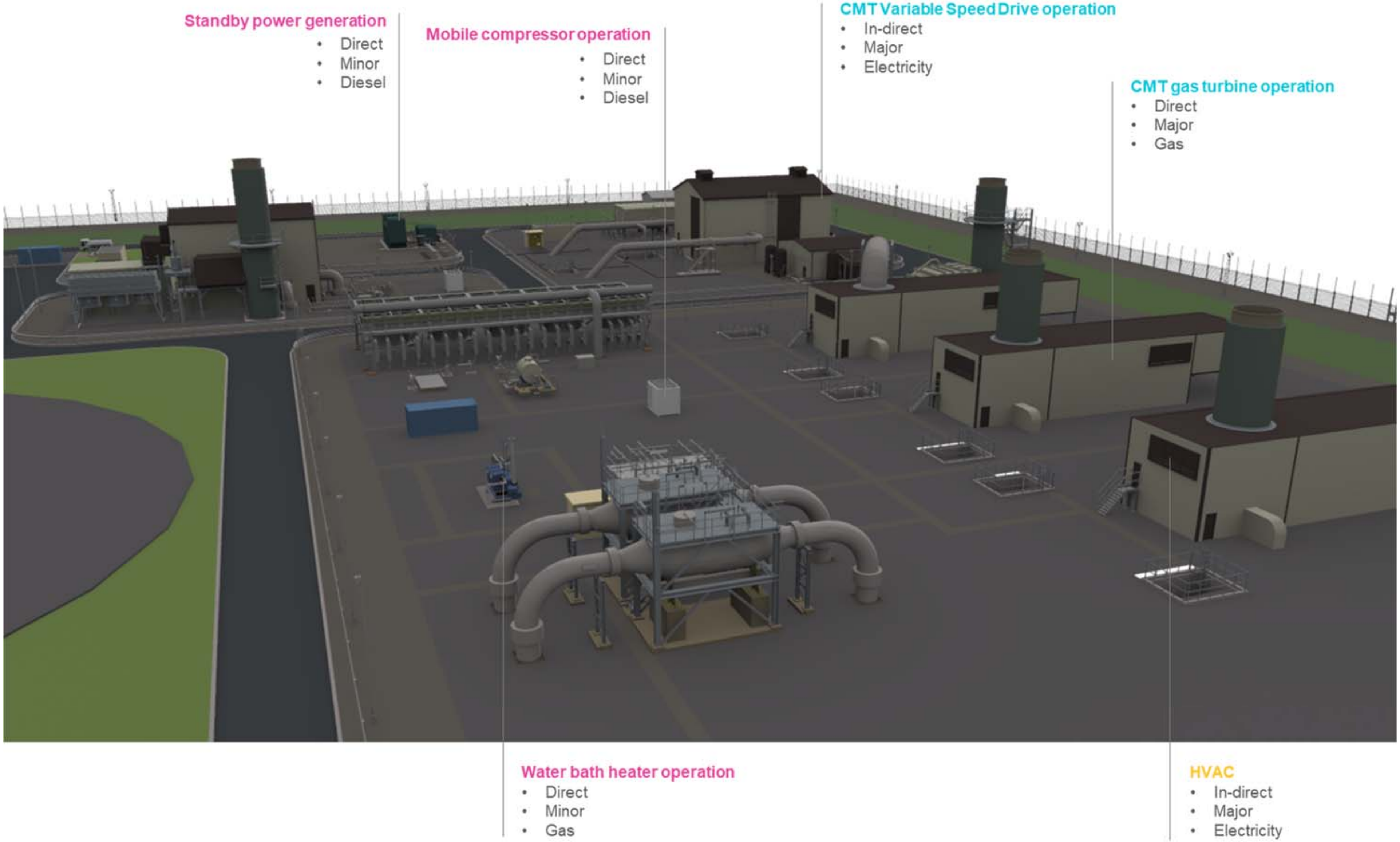


Figure 4 Generic compressor station site illustrating activities and associated energy consumption

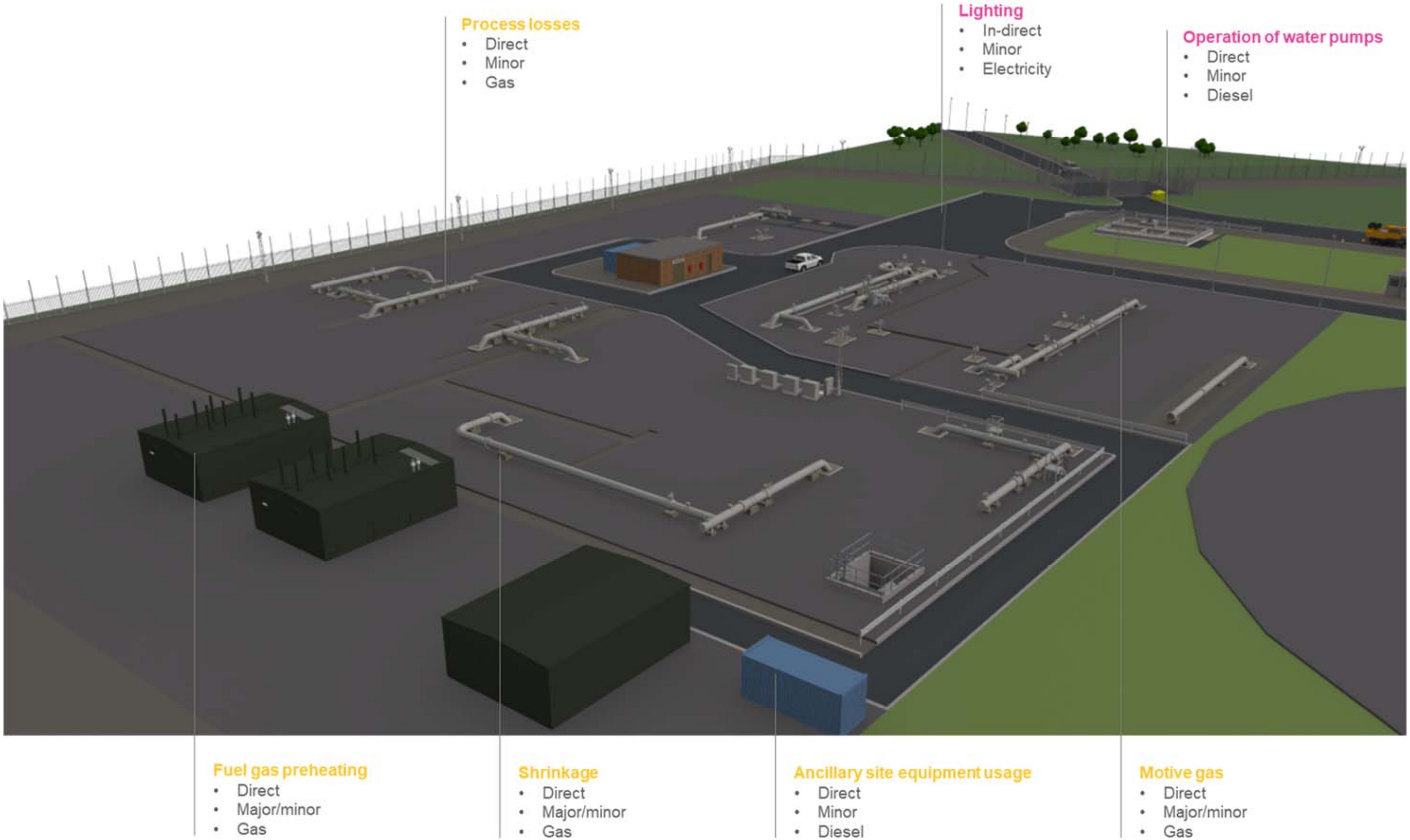


Figure 5 Generic compressor station site illustrating activities and associated energy consumption

1.4 Asset classes (primary and secondary)

National Grid has previously identified its primary asset classes across the NTS:

- Entry points
- Pipelines
- Multi-junctions
- Compressors
- Exit points

National Grid further sub-divides its primary assets into 47 secondary asset classes (SACs); these SACs form the focus of its asset management and asset investment across the NTS. The assets falling within the SACs have different potential impacts in terms of energy usage and process gas losses. This is identified in ***Table 3*** below. This review refers to the asset classes described below as it enables the findings and recommendations to be aligned to the asset investment basis for the business.

Table 3 SACs

Energy consumption	SACs	
Major	After coolers Cab ventilation Electrical Variable Speed Drive	Electrical - including standby generators Gas generator Pre-heaters
Minor	Air intake Civil assets - buildings and enclosures Compressor Exhausts	Power turbine Process valves Starter motor
Low	Anti-surge system Boundary controllers Cathodic protection Electrical - safe shutdown Fire and gas detection Fire suppression Flow or pressure regulator Fuel gas metering Fuel tanks and bunds	Gas analyser Metering Network control and instrumentation Odorisation plant Safety valves Security Slam shut system Station process control system Unit control system
Negligible	Above ground pipe and coating Acoustic cladding Below ground pipe and coating Civil assets - access Civil assets - bridges Civil assets - drainage Civil assets - ducting Civil assets - pipe supports and pits	Filters and scrubbers Impact protection Locally actuated valves Markers Non-return valve Pig trap River crossings
Gas emitting	Compressor Pig trap Process valves	Starter motor Vent system

Figure 6 and ***Figure 7*** below show views of the same generic compressor station site referenced earlier in this review and illustrates those SACs which are associated with major and minor energy consumption and/or gas emissions.

Figure 6 Generic compressor station site illustrating NTS SACs

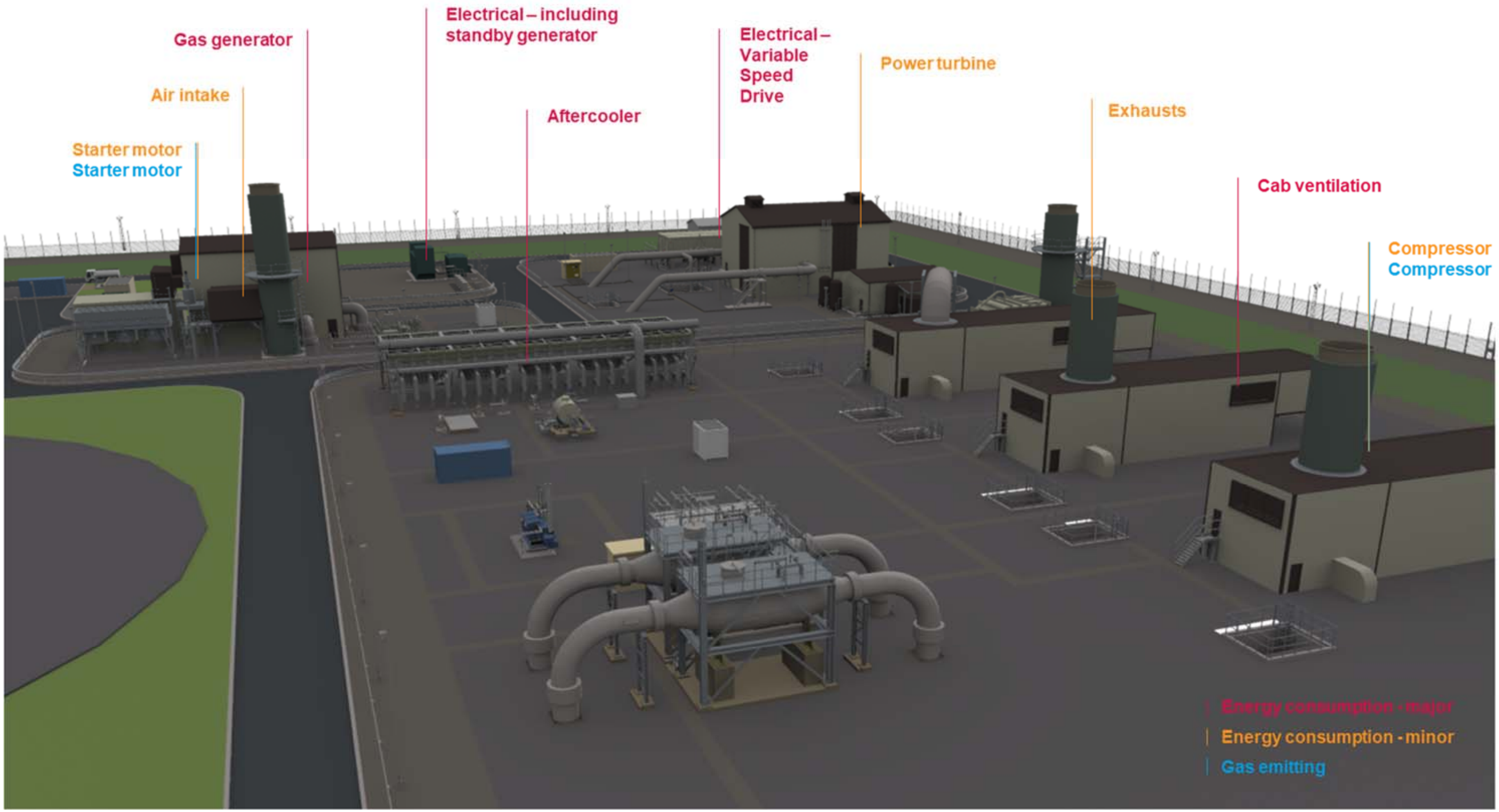


Figure 7 Generic compressor station site illustrating NTS SACs

1.5 Adopting new approach for 2018 energy review

A new approach to the preparation of the 2018 energy review has been adopted, through discussion with environmental specialists in National Grid. Whereas the previous 2010 and 2014 reviews focused on recommendations at an individual site level, the 2018 review adopts a twin track approach whereby site level reviews of energy consumption have been conducted (refer to ***Appendix 1***), but opportunities are reviewed holistically at a network level.

As discussed later in this review, the uptake of some of the recommendations from the 2014 review have been variable. Adopting a network-wide position on energy efficiency opportunities aligns this topic with how certain key regulatory, investment, asset management and planning processes are carried out within National Grid, thus increasing the likelihood of opportunity uptake in future years as the drivers will be more consistent with wider business needs.

The following subsections outline how environmental regulatory matters, asset health and investment themes, asset health financial challenges and regulatory licence conditions – all of which have an important bearing on energy efficiency matters – are now managed holistically at a network-wide level.

1.5.1 Alignment to the Network Review process

The Network Review is defined[3] as a:

> *written report produced by the Operator summarising the analysis of turbine upgrading options and forecasted annual operating hours for each compressor station within the national gas transmission system.*

As part of the conditions set out in the EA/NRW and SEPA permits, National Grid is obliged to “undertake a comprehensive review of the Network Review” on an annual basis. In carrying out the reviews, National Grid undertake a network-wide assessment of the NTS, identifying:

- environmental priorities
- previous and future compressor utilisation
- compressor performance
- emissions reduction
- investment strategy.

The Network Review supports the prioritisation of sites for investment purposes on a network-wide basis; environmental investment in sites not prioritised will be restricted to essential asset health works based on condition with the full agreement of the environmental and financial regulators.

1.5.2 Consistency with the RIIO-T1 asset health campaigns and RIIO-T2 investment themes

Under the RIIO price control regime operated by Ofgem (see ***Section 1.2***), National Grid is awarded funding for carrying out improvements to the network asset base for each RIIO period to address failing plant, obsolescence and performance improvements; collectively this is referred to as asset health. To demonstrate accountability to stakeholders and consumers, and value for money, National Grid is required to provide evidence as to where it is spending the funding the business receives approval for.

To evidence this expenditure the business has focussed on developing asset health spend strategies into a series of campaigns based on the primary and secondary classes of asset on the network. As with the Network Review the rationale for this approach is to move from a site focus to a network focus; whereas in the past asset health improvements were delivered on a site-by-site basis.

[3] Definition is taken SEPA permits; no definition is provided in EA/NRW permits

These campaigns take a consistent approach across the business to the delivery of asset health improvements and allow targeted investment at sites where:

- projects are ongoing or are planned
- asset health works are essential
- safety, supply or environmental risks can be effectively reduced, or
- where there is a high level of utilisation or strategic need across the NTS.

Asset health replacement or refurbishment can drive improvements in energy efficiency and reduction in process gas (methane) loses; when linked to network level campaigns there will be a greater uptake and by focusing implementation on sites with sufficient utilisation more meaningful improvements will be seen.

To drive consistency in asset health improvement works across the NTS National Grid has designated a grouping of Subject Matter Experts (SMEs) across the Gas Transmission business. These are in-house specialists with a high degree of knowledge in a particular primary asset type or SAC. The SMEs play an important role in identifying technologies and opportunities for improvement in a wider range of topics related to their asset classes, including energy efficiency matters and shrinkage related losses. The knowledge base for the SACs reside with the associated SME at a central network-wide level.

Future asset health improvement works beyond the current RIIO-T1 price control period are being addressed by a series of investment themes currently being drafted by National Grid for the subsequent RIIO-T2 price control period which runs for five years from 2021. This approach, which is similar to that developed through the RIIIO-T1 period, will continue to drive investment in prioritised assets and sites, thus will be instrumental in realising continued energy efficiency gains at a network level in future years.

1.5.3 The Asset Health Fitness Challenge as influencer

As part of the current RIIO-T1 campaigns National Grid has implemented an Asset Health Fitness Challenge across the network. The ambition for the challenge is to drive financial efficiencies for the remaining uncommitted or unspent funds in the final three years of the current RIIO-T1 period. This efficiency challenge is driving cost savings across the NTS by reducing operating costs through the creation of efficiency steering groups, driving accountability, and fostering closer working between the System Operator and Transmission Owner. The net result is increased scrutiny on project delivery, making this programme an important influencer in decision making with the ability to direct or defer energy related project opportunities.

1.5.4 Measuring asset management performance

The final consideration driving the adoption of a network-wide approach to the topic of energy management is National Grid’s requirement to regularly report on asset performance to Ofgem as part of its Gas Transporter Licence. This licence defines the compliance measures that National Grid is tested against and the data that the business must use to do this. These compliance measures are defined as Network Output Measures (NOMs) which include metrics on the condition of the current asset base, reliability risk, network performance and capacity, and finally National Grid’s asset management performance.

The focus of these NOMs is network-wide rather than site-specific; the National Grid business performs well against these metrics when investment measures (including those related to energy efficiency matters) align with the regulatory objectives and priorities.

2 Review of energy consumption

2.1 Introduction

This chapter reviews network-wide energy consumption and network greenhouse gas emissions, in line with previous reviews carried out in 2010 and 2014. The information is, as with previous reviews, derived from annual data collected by National Grid.

2.2 Energy consumption network trends 2014 – 2017

Whilst energy consumption on individual sites impacts on overall energy consumption this usage is driven by requirements of the network.

- Overall energy consumption across the NTS is largely determined by compression requirements driven by consumer demand for gas. Since the previous 2014 review, the UK has experienced generally milder winters, compared to longer term seasonal normal averages. This has reduced compressor utilisation compared to previous years, thereby reducing energy consumption during these periods.
- Compressor utilisation, and therefore energy consumption, is also determined by gas supply into the UK. Historically, gas production in the UK has occurred in the north with gas entering the network at St Fergus Terminal leading to a flow of gas in the system predominantly from north to south; for a number of years this north-south flow declined. However, recent flow patterns have seen higher gas flows returning to St Fergus as new North Sea gas fields have come on-line.
- The flow patterns have also been influenced by increased inflow of Liquified Natural Gas (LNG) and from interconnectors closer to the major populations in the south of the UK.

2.3 Emissions associated with network energy consumption

The following tables and charts provide a network-wide view of the data contained in the updated site profiles discussed in ***Section 2.4*** of this review. Additional supporting charts are provided in ***Appendix 3***.

Figure 8 illustrates the general decline in combustion emissions associated with reduction in network operating hours, falling to a period low in 2014, after which a sharp increase can be seen due to increased operation of the network, albeit still below 2010 levels. There is no ready metric of work done for the NTS in terms of gas flow volume or pressure lift as all sites are designed to contribute to the overall network operating objectives in a unique manner reflecting their location and purpose.

It is therefore hard to draw definitive conclusions with respect to emission 'per unit production' than can be done in manufacturing industry. What can be seen is that venting volumes have remained largely consistent over the period, and the increased emissions in the period 2014 to 2017 have seen only a gradual increase in venting volumes.

Venting has been the subject of an extensive behavioural change programme (refer to ***Section 3.3***), however a number of network factors beyond National Grid's direct control influence venting. For example, high network utilisation is characterised by prolonged periods of compressor operation and shorter periods with units off-line but in a pressurised standby condition; this can reduce the number of venting events. Conversely, lower utilisation is characterised by stop-start conditions with more venting.

Of note, electricity consumption on the network has increased significantly in the period since 2015. This is associated with increased usage of the Variable Speed Drive (VSD) electric compressors, particularly at St Fergus, which has also seen a general increase in flows. The VSD drives at Hatton, Kirriemuir, Churchover and Wormington are also routinely operated after early post-commissioning issues.

Figure 8 Emissions by year

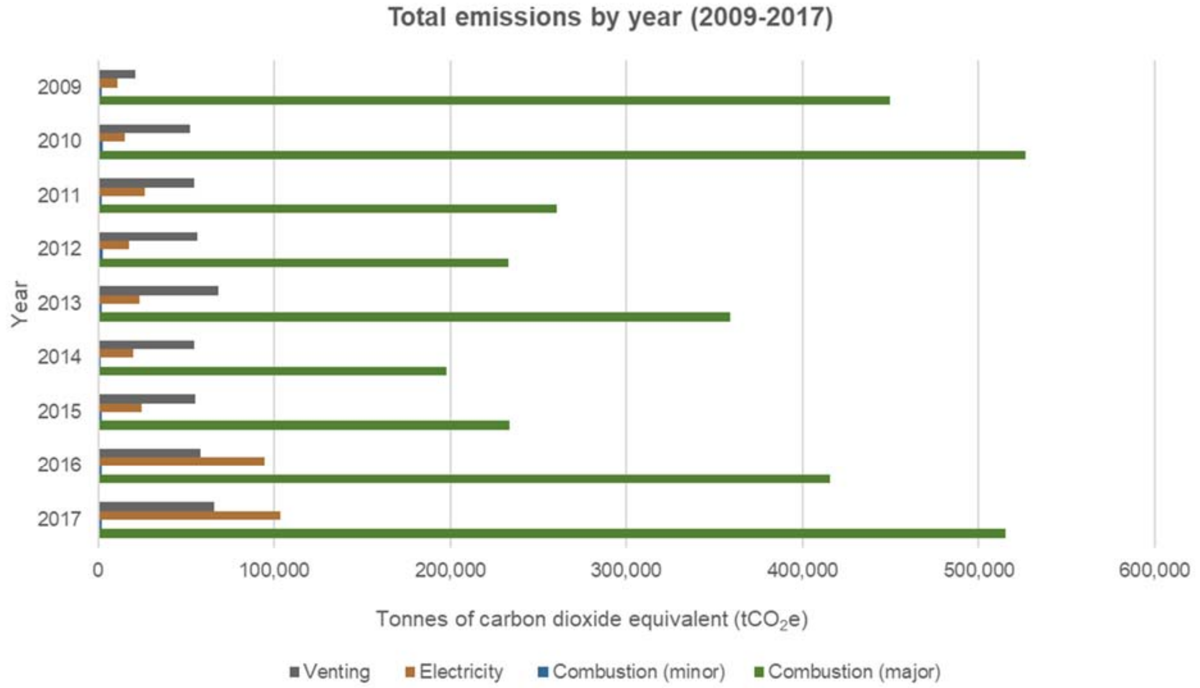
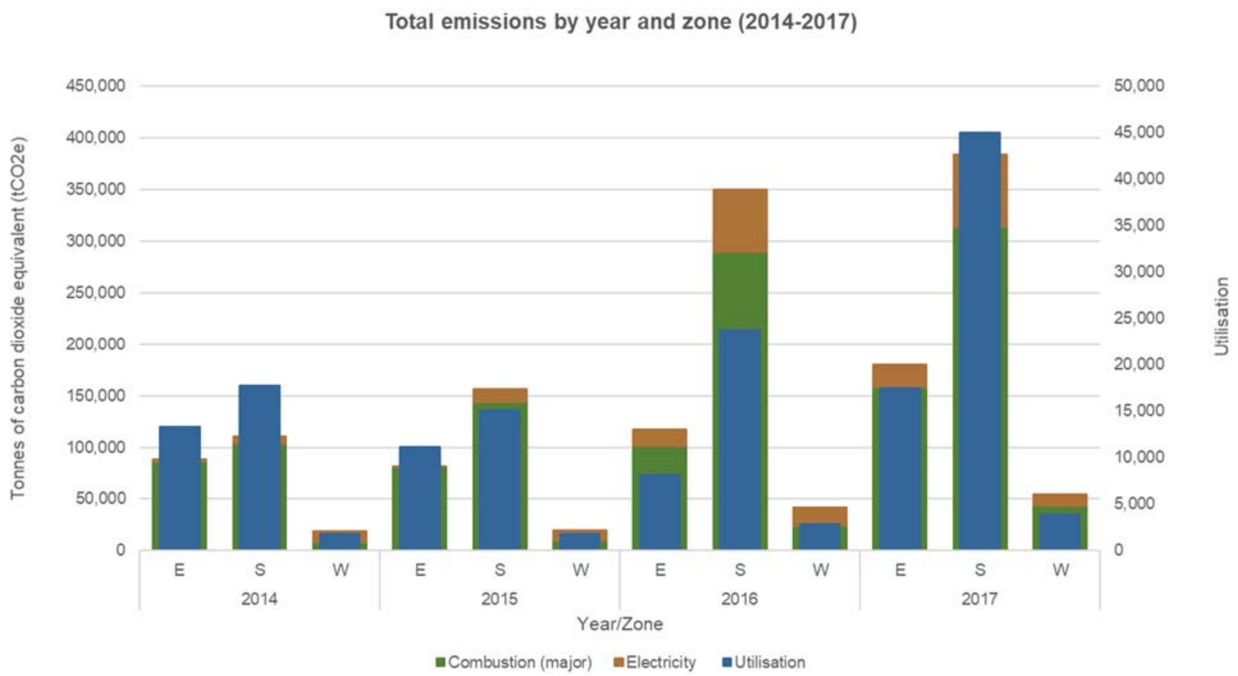


Figure 9 illustrates total emissions by operational zone for the previous four-year period (see ***Figure 1*** for operational zones). Utilisation by zone reflects the pattern of gas production and flow as discussed in ***Section 2.2*** of this review, with higher utilisation in the Scotland Zone due to the presence of St Fergus Terminal and associated inflows. Utilisation in the West Zone is reasonably consistent, and low in comparison to the East and Scotland Zones, again reflecting the relatively low flow of gas into the west compared to the other zones, with LNG imports still lower than originally forecast. The general pattern of compressor utilisation by zone shows that higher utilisation equates to higher greenhouse gas emissions, with increased VSD usage in Scotland reducing emissions relative to historical reliance on gas turbines.

Figure 9 Total emissions and utilisation by year and zone

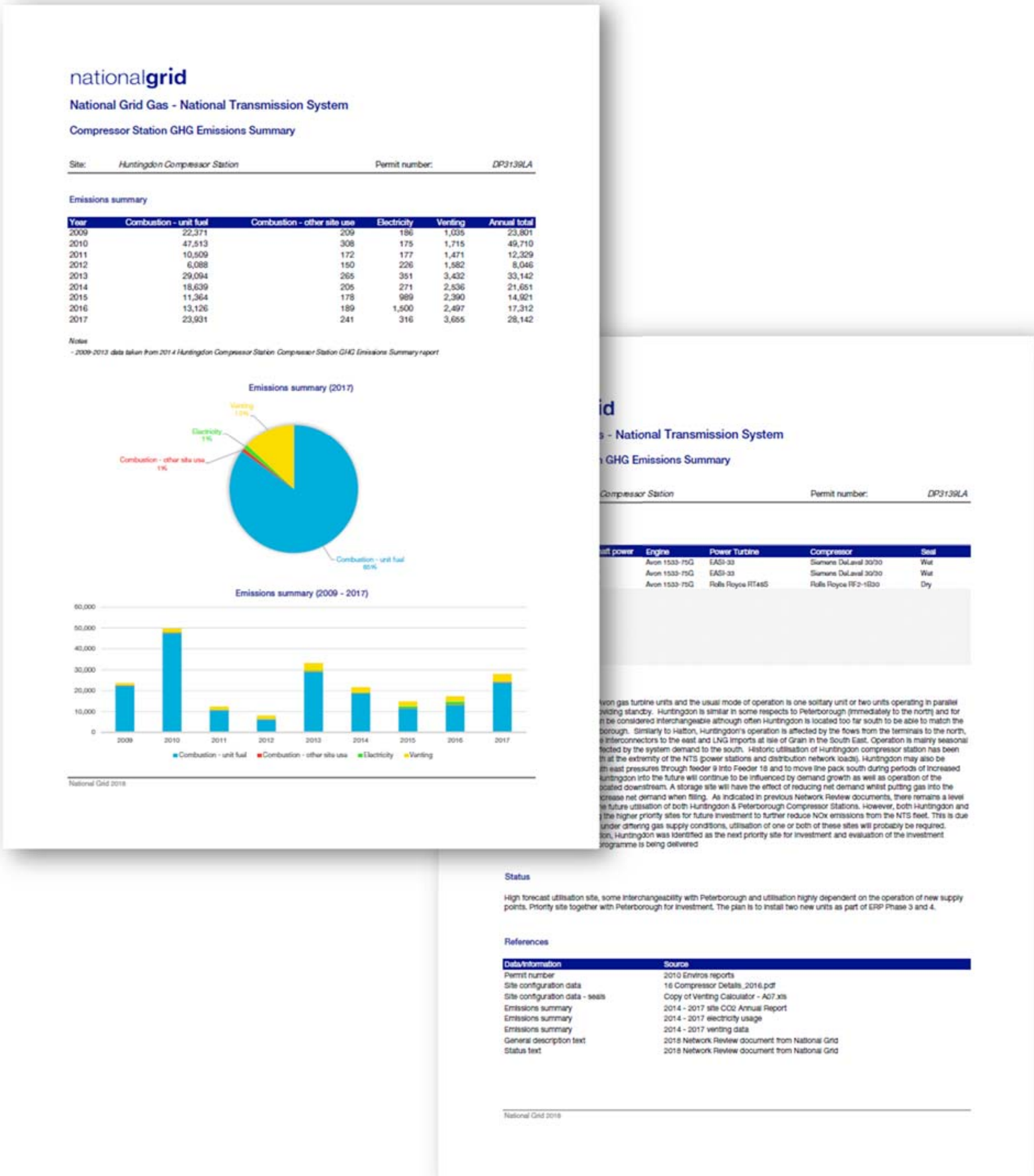


2.4 Site profiles

The first energy consumption profiles for the NTS compressor station sites were produced by National Grid in 2010 and again in 2014. This review further develops these previous profiles, providing an annual record of site energy consumption from 2009 through to 2017.

A series of updated site profiles have been produced for the sites identified in ***Table 1***. These site profiles summarise site emissions since 2009 in tabular and chart format, along with a site information profile. ***Figure 10*** below shows an example profile. These are provided in ***Appendix 1*** of this review.

Figure 10 Example site profile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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Huntingdon Compressor Station* Permit number: *DP3139LA*

Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	22,371	209	186	1,035	23,801
2010	47,513	308	175	1,715	49,710
2011	10,509	172	177	1,471	12,329
2012	6,088	150	226	1,582	8,046
2013	29,094	265	351	3,432	33,142
2014	18,639	205	271	2,536	21,651
2015	11,364	178	989	2,390	14,921
2016	13,126	189	1,500	2,497	17,312
2017	23,931	241	316	3,655	28,142

Notes

- 2009-2013 data taken from 2014 Huntingdon Compressor Station Compressor Station GHG Emissions Summary report

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Status

High forecast utilisation site, some interchangeability with Peterborough and utilisation highly dependent on the operation of new supply points. Priority site together with Peterborough for investment. The plan is to install two new units as part of ERP Phase 3 and 4.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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3 Review of previous recommendations

3.1 Introduction

Through this review the authors have sought to determine progress in energy efficiency improvements since 2014. As part of this review the authors engaged with stakeholders at each site where opportunities were identified to determine the status of each opportunity, whether that opportunity had been actioned or not, and if actioned, the outcome of that opportunity. Additionally, an objective approach was adopted to challenge and review previous recommendation and opportunities.

3.2 Summary of recommendations and status

Table 4 below summaries the recommendations from the 2014 site profiles, the number of permitted sites across the NTS where these recommendations were made and the extent to which these recommendations were taken forward on a network-wide basis.

A full site-by-site summary of 2014 opportunities and whether taken forward or not is provided in ***Appendix 2***.

Table 4 2014 recommendations summary

Recommendation	Number of sites where recommendation made	Number taken forward	Comments
Ultrasonic leak detection	21	21	Greenhouse Gas Emissions Investigation Mechanism project successfully implemented and will transition to 'business-as-usual' following support from Ofgem.
Thermal oxidation	20	0	Thermal oxidation of vented gas or seal gas losses has not been implemented. Thermal oxidation from normal/emergency operational venting remains problematic as the primary objective is to evacuate gas from the unit as quick and safely as possible, maximising dispersion to avoid the possible build-up of a potentially explosive gas and air mix. Thermal oxidation systems are not compatible with this objective and would result in the retention of pressurised gas within equipment for significantly longer. Even if it were deemed safe to gradually vent a compressor casing through an oxidiser, a complex, failsafe control logic would have to be developed (with multiple redundancy layers as a Safety Integrity Level (SIL) rated system) to determine whether it was safe to thermally oxidise the gas or whether rapid release was the correct route. This issue was formally reviewed again as part of a Best Available Techniques (BAT) study which formed part of the Peterborough and Huntingdon upgrade project and was rejected. Potential emerging opportunities associated with thermal oxidation are discussed in ***Section 3.3***.
Vent gas recompression	21	0	Recompression of routine or emergency venting is not available on operational and safety grounds due to the need to evacuate gas promptly maximising dispersion; the issues are largely the same as thermal oxidisation discussed above and represent a safety, dispersion, timing and energy trade off. However, in the review period National Grid has continued to make extensive

Recommendation	Number of sites where recommendation made	Number taken forward	Comments
			use of the two recompression rigs which offer the opportunity to reduce the amount of gas vented during planned major pipeline/site degassing activities; this is discussed further in ***Section 3.3***.
Lube oil pumps VSD	17	2	There has been limited uptake of VSD lube oil pumps. The unit lube oil system is integral to the CMT, cab, lube oil cooling system and unit control system; to implement this on an existing unit a major overhaul would be required. With the increased usage of VSD electric compressors, mothballing of old units and continued roll out of low emission gas turbines asset health works have focused on reporting plant defects and low costs replacement with like-for-like pumps due to the restricted asset health budget (as determined by the RIIO price control process). However, the new Solar Titan units (4 no.) being installed at Peterborough and Huntingdon include pre/post lube oil cooler pump motors with variable frequency drive. This is discussed further in a case study in ***Section 3.3***.
Vent fans VSD	14	1	There has been limited uptake of variable speed compressor enclosure fans. There has been an extensive programme to improve compliance with HSE PM84[4] guidance on in cab ventilation to improve unit availability and reduce risk; due to the costs of implementing full new ventilation systems compliant with the PM84 and ISO21789 (which can be £4-5m per unit) this has been restricted to two units, St Fergus 2A and Carnforth B (the latter of which does have VSD ventilation fans). Due to the restricted asset health budget (as determined by the RIIO price control process) lower cost measures have been implemented, based around retention of the motor controllers and fans. This has lowered the unit cost to below £0.25m allowing greater network-wide risk reduction and unit availability improvement rather than focusing on a very small number of units at much higher unit cost.
Fuel gas preheater - heat recovery	13	2	The new gas turbine compressors currently being installed at Peterborough and Huntingdon are to be fitted with fuel gas heat recovery via a lube oil heat exchanger. Electric heating is also provided for start-up/supplementary purposes. The decision to install the lube oil heat recovery systems was validated via a BAT assessment. Due to the integral nature of the fuel gas skid, lube oil system and compressor enclosure, fuel gas preheat would only be considered in the event of a critical asset health failure necessitating full skid replacement or a major compressor upgrade. For this reason, there have been no standalone implementations on other sites in the review period, although the Orenda units at Churchover which had non-heat recovery fuel gas skids have been disconnected.

[4] Health and Safety Executive - Control of safety risks at gas turbines used for power generation HSE guidance note PM84 Second edition HSE Books 2003 ISBN 0717621936

Recommendation	Number of sites where recommendation made	Number taken forward	Comments
Wet seal replacement	12	2	The compressor shaft seal system is integral to the CMT and directly defines a significant number of Balance of Plant (BoP) items linked to seal venting and barrier gas supply (compressed nitrogen or air). As such, a wet seal replacement would not be implemented as a standalone project unless part of a major re-lifing of the entire CMT, enclosure and BoP. Given that all existing RB211 units with wet seals are on 500 hours usage or Limited Life Derogation under the IED, there are no drivers to upgrade these units. Similarly, of the Avon wet gas seal site systems identified, over 10 units will be taking on a standby role due to ongoing planned investment in new machinery in the short/medium term. In the interim, better forecasting of venting requirements and management of releases (see ***Section 3.3***) represents the best approach to managing the issue, thereby seeking to achieve the optimal balance between holding wet gas seal system units in a pressurised standby condition (where seal gas losses continue) versus venting the compressor casing. Dry gas seals have been identified as BAT and are now mandated for all new CMT in National Grid's engineering standards documentation[5]. The four new Solar Titan units being installed at Peterborough and Huntingdon have been specified with an advanced Eagle Burgmann CobaSeal system to minimise seal gas losses (following its identification as BAT for this project via the T/SP/ENV/22 process). The seal systems have also been specified with compressed air as the secondary seal gas, which reduces the need for nitrogen generation plant on site, which can be a significant energy consumer. Furthermore, two wet gas seal units have been disconnected (the Orenda turbines at Churchover), and a wet gas seal equipped unit at Kings Lynn has been mothballed (Unit A).
Voltage optimisation	1	0	Only identified as a potential opportunity at one station (Avonbridge), not implemented.
Retaining compressor pressure	3	3	Major cross-network behavioural change programme has been implemented, including creation of the '1,000 tonnes reduction challenge', better communications, sharing of lessons and better forecasting. Lessons learnt are being shared across the network from venting reduction initiatives developed as St Fergus Terminal (Refer to ***Section 3.3***).
Mothball units	1	1	The identified recommendation to 'mothball' units at Kings Lynn was adopted, with Unit A being selected.
Office HVAC	1	1	The identified recommendation was completed; the HVAC system at Diss was replaced.

[5] T/PM/COMP/20 Management Procedure for Compressor Installations for the National Transmission System, and its subsidiary Specification Procedures.

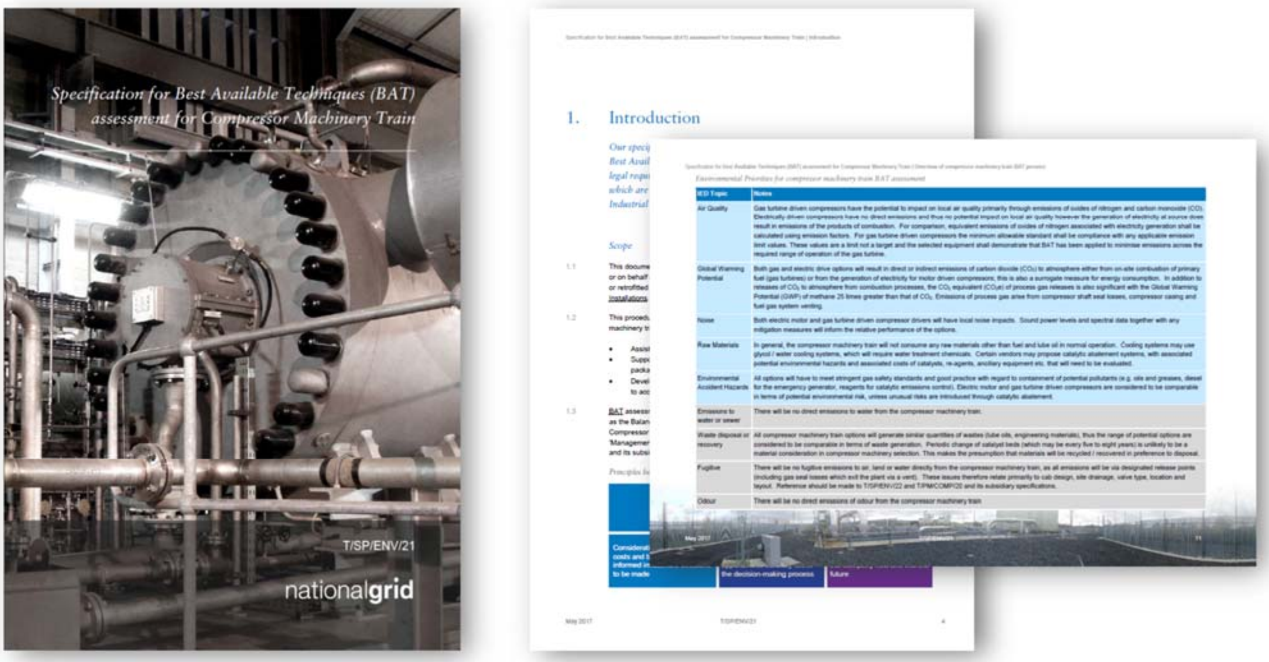
3.3 Key progress since last review

Several areas have been taken forward with regard to energy efficiency improvements across the NTS. Additionally, some further measures have been adopted that were not part of the previous recommendations but have been enacted as part of National Grid's ongoing asset health improvement works and overall management of the NTS.

3.3.1 Implementation and roll out of T/SP/ENV/21

National Grid made a policy decision in 2013 that the principles of BAT assessment (as defined under the EP/PPC regimes) would be the primary selection mechanism for all new and substantially modified or retrofitted CMTs on the NTS. This policy decision, which was formalised in National Grid specification procedure T/SP/ENV/21[6], has resulted in a fundamental shift in the way that energy efficiency (and resource consumption) is considered in selecting and identifying new and upgraded CMT. It can be readily demonstrated that this process has rapidly established itself as business-as-usual within National Grid and is realising significant tCO_2e emissions benefits through new asset investment.

Figure 11 T/SP/ENV/21 embeds energy efficiency and methane emissions in the investment decision



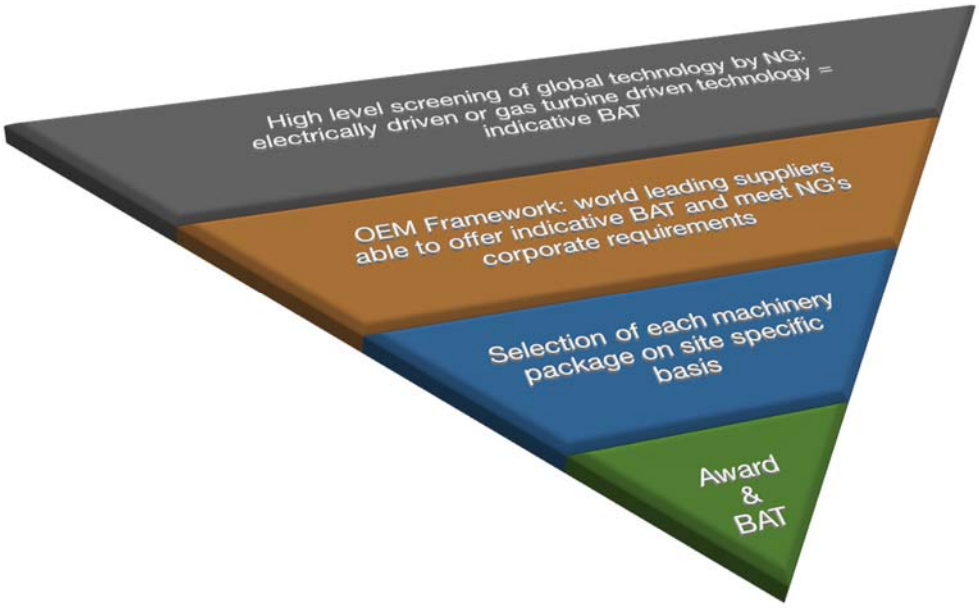
A BAT assessment is a legal requirement for gas turbine driven plant permitted under EP/PPC regimes, but is applied to both gas turbine and electric motor driven plant by National Grid. As BAT takes account of whole life costs and operating efficiency it is also consistent with National Grid's corporate objective of ensuring that every project delivers Whole Life Value (WLV).

The T/SP/ENV/21 process was developed in consultation with the EA and SEPA, and a wide range of business stakeholders, to meet both the requirements of regulatory BAT assessment and also to provide a formalised decision-making mechanism to support procurement events for new CMT (which are themselves robustly controlled under legal and regulatory mechanisms).

[6] T/SP/ENV/21: Specification for Best Available Techniques (BAT) assessment for Compressor Machinery Train, first published internally in March 2013, substantially revised and reissued in May 2017

A supplier framework has been established, which includes proven machinery packages from the world's leading CMT Original Equipment Manufacturers (OEMs). Site specific BAT assessments using cost-benefit techniques are then carried out on a project by project basis using information supplied by the OEMs through the tender process.

Figure 12 T/SP/ENV/21 BAT selection process overview



The method comprises a series of formalised assessment and evaluation steps, supported by a spreadsheet-based BAT Evaluation Toolkit containing decision support tools. The underlying principle of the model is a multi-criteria analysis, whereby a group of independent decision-making criteria that are individually important in reaching a decision are brought together in a repeatable, auditable manner.

Existing and new CMT is modelled on a 'whole life cost-benefit' basis over an extended design life (typically 20 years), including projections of future operating (fuel and maintenance) costs. This approach allows for a range of factors to be considered including cost, emissions performance, reliability, versatility and operability.

The following considerations are key aspects incorporated into the toolkit with the aim of realising long-term energy and resource management improvements in the asset base:

- Resource consumption avoided (i.e. fuel) through increased efficiency of new assets. National Grid's objective in designing this process was to use the expertise in the market place to deliver the most cost effective, flexible and environmentally beneficial compressor drivers over the whole unit lifetime. To this end, project constraints and process gas conditions are provided to the OEMs at the tender invitation stage, enabling them to propose one of more bespoke package solutions to best meet the site needs and accommodate its constraints; the objective being to deliver the highest compressor efficiency (and lowest emissions). This represents a very different approach to previous projects where National Grid indicated the type of driver (e.g. VSD electrical or gas Dry Low Emissions (DLE)) and the required size of unit (e.g. 15MW), which was then selected and delivered by an Engineering, Procurement and Construction (EPC) contractor with limited regard to future operating costs (fuel efficiency).
- Future emissions of CO_2 and methane are avoided through energy efficiency gains and reduced seal gas loses and fewer unit trips. The tool factors in electrical ancillary energy consumers, (for example lube oil heating and ventilation fans) as well as methane losses from the compressor shaft seals, and venting charge linked to compressor casing volume and compares the relative cost-benefit of the candidate options.

The process has been applied to both procurement events and to strategic BAT assessment reviews in the period 2014 – 2017, including:

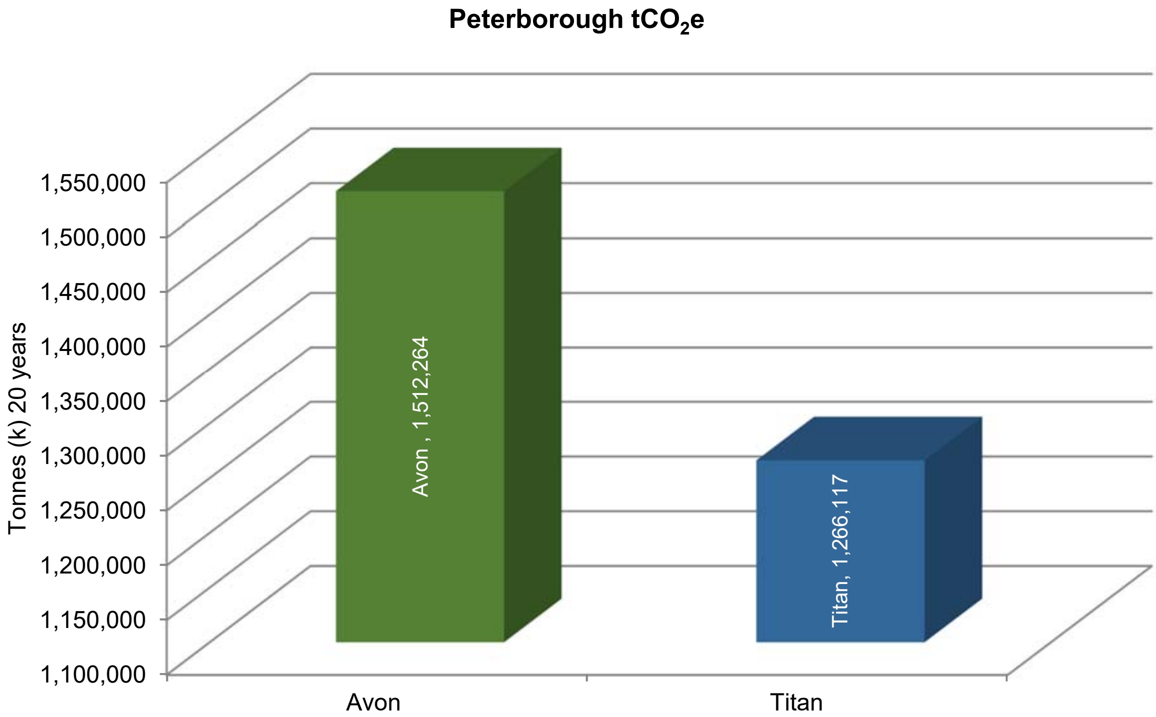
- Peterborough compressor upgrade
- Huntingdon compressor upgrade
- Aylesbury compressor upgrade
- Hatton compressor upgrade
- St Fergus Terminal compressor upgrade
- Selective Catalytic Reduction (SCR) feasibility study
- RB211 Dry Low Emission BAT review
- Avon asset life BAT review.

By way of illustration, the process was used in the selection of new CMTs for Peterborough and Huntingdon compressor stations, both to determine the most appropriate OEM solution but also to make direct comparison to the base case (continued use of the ageing Avon driven gas compressors) for the purpose of a regulatory BAT assessment. A contract award criterion of tCO_2e was set and given 38% of the available environmental score in the T/SP/ENV/21 BAT assessment, demonstrating the importance placed on this issue on the grounds that it:

- represented a direct analogy to energy efficiency and process resource efficiency (natural gas venting and non-renewable fuel use)
- is subject to strong regulatory drivers and incentives
- represents a corporate priority; and
- Peterborough and Huntingdon are high utilisation sites.

At Peterborough, for example, a reduction of over 246,000 tCO_2e was predicted to result from the investment.

Figure 13 Illustration of tCO_2e reduction over 20-year design life for new Solar Titan compared to existing Avon



Source: Assessment of Best Available Techniques (BAT) for Peterborough Gas Compressor Machinery Selection, Jacobs. 27 July 2016

3.3.2 Implementation and roll out of T/SP/ENV/22

Similarly to T/SP/ENV/21, environmental specification procedure T/SP/ENV/22[7] provides guidance for identifying and selecting gas compressor BoP, essentially mechanical, electrical, civil, control and instrumentation equipment /infrastructure required for the operation of the compressor installation and not delivered as part of the CMTs. Although the CMT itself represents the listed activity under the EP/PPC permitting regimes, almost all operational activities which are conducted on compressor installations and gas terminals relating to gas transmission activities are referred to as 'Directly Associated Activities'. These are subject to the same legal permit requirements as the CMT; this includes the requirements to apply and demonstrate the application of BAT (which includes the requirement that energy is used efficiently and that emissions (including process gas releases) are minimised.

BoP will typically result in direct or indirect emissions of carbon dioxide (CO_2) to atmosphere either from on-site combustion of primary fuel (e.g. gas or diesel) or arising from the generation of electricity elsewhere and supplied to the site from the national grid, or in some circumstances from catalytic oxidation reactions. CO_2 can be viewed as a surrogate measure to indicate overall energy consumption. In addition to direct and indirect releases of CO_2 to atmosphere, the CO_2 equivalent (CO_2e) of process gas releases (e.g. from compressor shaft seal losses, system venting and valve actuation) is also significant due to the high Global Warming Potential (GWP) of methane.

T/SP/ENV/22 adopts the BAT process to help National Grid make consistent decisions on the most practicable and cost-effective solutions for BoP on NTS sites. As part of the implementation of T/SP/ENV/22 National Grid undertook a number of studies on different technology categories of BoP, shown in ***Table 5*** below (published in 2014), and developed case studies identifying BAT for a generic BoP requirement which project teams could then refine for their specific project requirements. Project dissemination commenced in 2015 and the process has rapidly established as business-as usual with studies being delivered by National Grid's Front End Engineering Design (FEED) consultants and Detailed Design, Build and Commission (DDBC) contractors on a wide range of live projects.

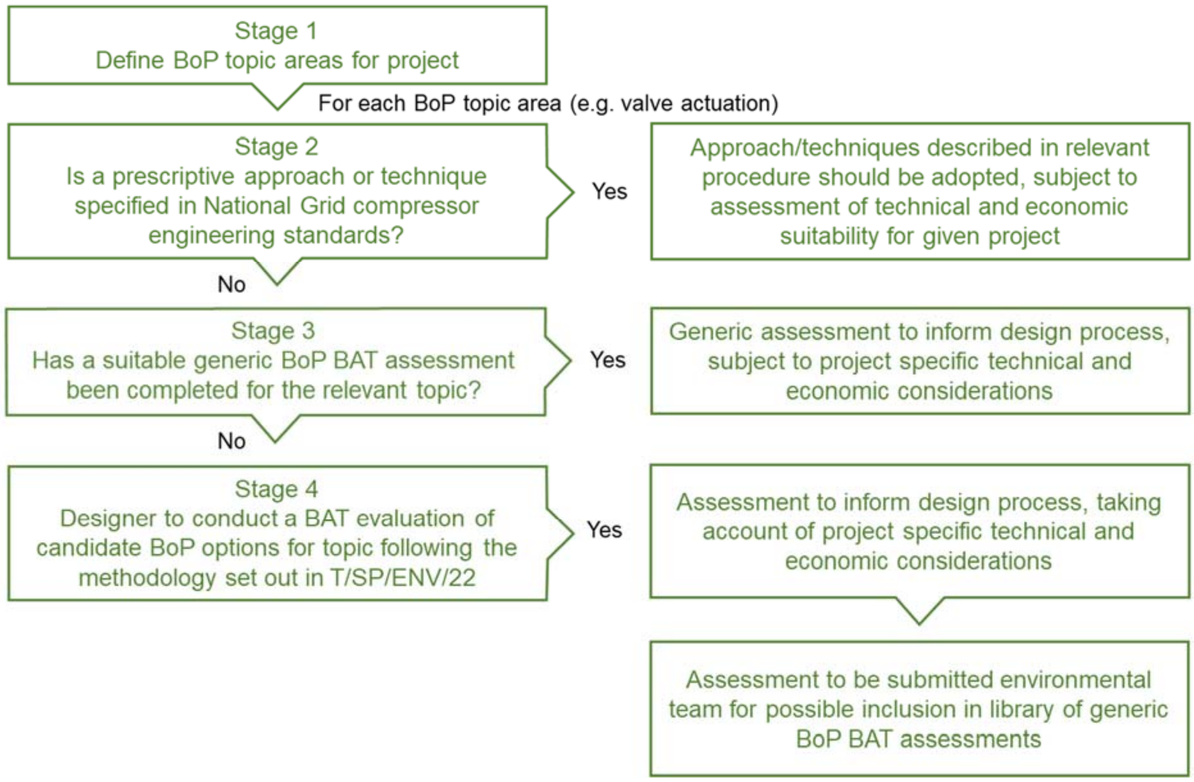
Table 5 T/SP/ENV/22 BoP BAT library studies

Technologies	
Anti-icing of gas turbine air intakes	Compressed air
Foul drainage	Fuel gas pre-heating
Gas compressor seals	Heating, cooling and ventilation of non-operational buildings
Lighting	Heating, cooling and ventilation of operational buildings
Process gas heating	Micro-renewable (for power) technologies
Standby power generation	Options for removing gas from compressor casing and pipework
Valve actuation	Ventilation of compressor unit enclosures
Supplementary studies added as developed during live project works	

The T/SP/ENV/22 specification procedure provides a framework and stepwise process for decision making, which guides users to mandated requirements first in National Grid's engineering specifications (see ***Section 3.3.3***) then the library of studies, then through carrying out a detailed BAT assessment.

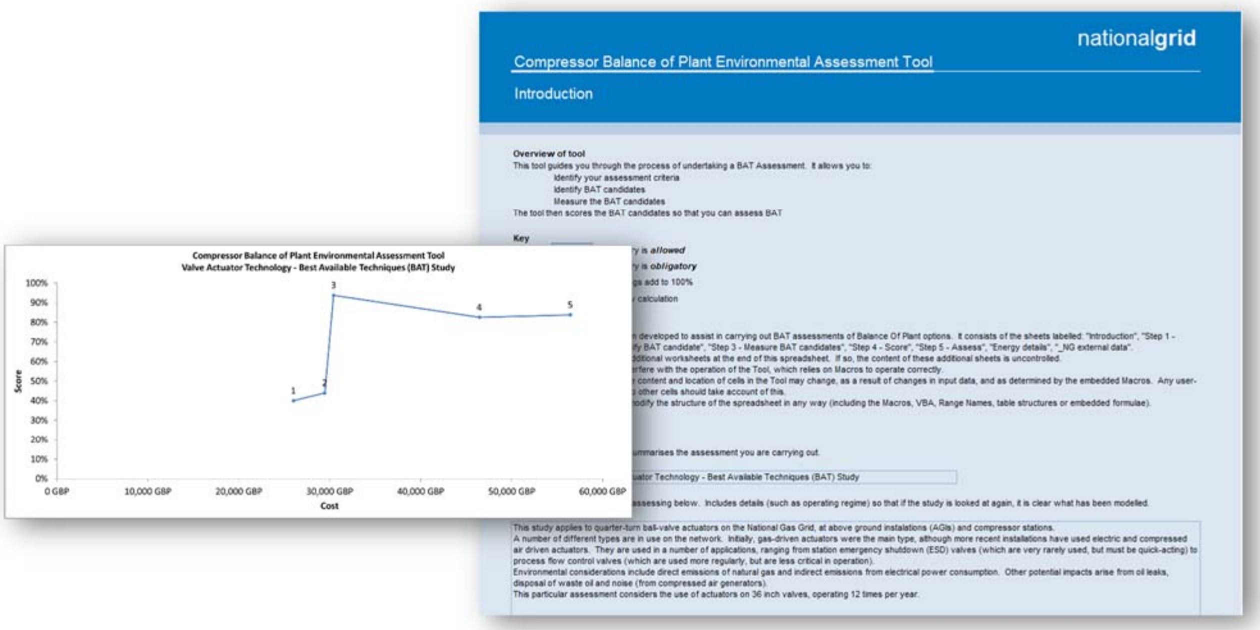
[7] T/SP/ENV/22 Specification for Best Available Techniques (BAT) assessment for Compressor Balance of Plant, first published internally in 2014, substantially revised and reissued in April 2017

Figure 14 Stepwise T/SP/ENV/22 process



The BoP BAT process also provides specifiers and designers with a decision support toolkit in addition to the specification procedure itself. At the heart of the process is a multi-criteria analysis which allows for users to define and weight a series of environmental and operational criteria depending on the class of BoP in question and the site and project priorities. For any BoP items which are significant energy users or have a direct impact on process gas emissions, users are directed and guided to quantify the whole life GWP. The energy consumed is also used to calculate future whole life operating costs, thus further directing designers to more energy efficient solutions.

Figure 15 T/SP/ENV/21 embeds energy efficiency and GWP in the investment decision



The process has been applied to a number of BoP BAT reviews in the period 2014 – 2017 on live projects, including:

- St Fergus valve actuators
- St Fergus standby generator
- Huntingdon/Peterborough gas venting options
- Huntingdon/Peterborough standby power generation
- Huntingdon/Peterborough valve actuators
- Huntingdon/Peterborough compressed air
- Huntingdon/Peterborough lighting
- Cambridge valve actuators
- Huntingdon/Peterborough building HVAC

Figure 16 BoP BAT assessment of significant energy consumers is business-as-usual

3.3.3 Update of compressor engineering 'COMP' specifications and alignment with BAT

National Grid has undertaken a detailed review of the 'COMP' suite of compressor engineering specifications, resulting in a major re-write of the documents. As well as updating standards and requirements on engineering matters a key aspect of the review was to align the documents to the requirements of BAT, by identifying environmental and energy efficiency aspects associated with engineering plant and infrastructure.

The review also sought to provide guidance for identifying when an approach could be considered to be 'indicative BAT' and thus would be mandated on all projects (such as the use of electric starter motors on gas turbines instead of the motive gas driven starter motors which results in a charge of methane being released to atmosphere) and where, in cases where there is a less clear cut position, the documents identify when a BAT assessment should be undertaken and what topics the designer should consider (for example, the range of approaches available to provide valve actuation).

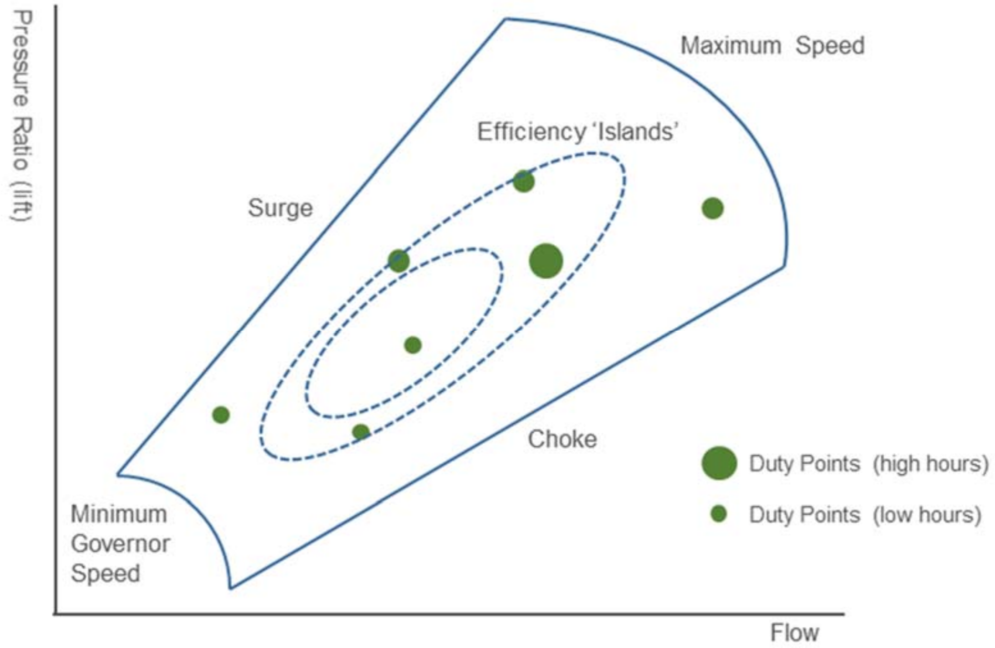
The BAT references and COMP guidance aligns very closely with the T/SP/ENV/22 specification; with the latter designed in part to act as an 'incubator' for new and enhanced BAT processes (including those delivering energy efficiency and process gas emissions reduction) which will be future indicative BAT mandated in the COMP documents.

3.3.4 Compressor optimisation (re-wheeling)

The suitability of any given gas turbine frame size and compressor envelope is dictated by the degree of matching to the likely site process duty requirements. For new CMT these are determined using predictive modelling techniques by National Grid's network analysts and reflect a wide range of supply and demand factors. These projections are distilled into a series of 'duty points' which reflect specific gas 'flow' and 'lift' (pressure) conditions to be met by any site on the NTS, in what is called a Process Data Sheet (PDS). Each duty point is attributed with a 'frequency' value which can be translated into the number of hours that running at that point is likely to be required in any given year.

Any CMT package of broadly the right size will be suited to a specific site's duty points to a greater or lesser extent; manufacturers will look to match standard drivers and pipeline compressors / compressor impellers to those site duty points. A well-matched compressor will be able to deliver the required flow or lift conditions, in efficient areas of the compressor map, avoiding poor flow (surge) or excess speed (choke) conditions. The situation is further complicated as the driver (gas turbine) must be well matched to the compressor, as if the engine load falls outside of the predetermined DLE power range, emissions can rapidly increase. A compressor package which is well matched to the site duty can result in an increase overall machinery train efficiency of several percentage points and material improvements in efficiency over the design life.

Figure 17 Efficiency islands on a compressor envelope map



Over time, the actual duty of any compressor station can alter due to changing gas supply and demand patterns on the network, meaning that a well-matched compressor becomes less well matched due to external factors. For this reason, National Grid identifies opportunities periodically where by 're-wheeling' a compressor a better alignment to site duty can be achieved (with a resulting gain in operational versatility and energy efficiency).

Re-wheeling refers to replacing the impeller in the centrifugal compressor with an alternative with more favourable flow or lift characteristics. Whilst still a major project requiring extensive design review, unit control systems modifications and re-mapping, in some circumstances the option can be more cost effective than a new unit if the driver and BoP equipment has a useful remaining design life.

In 2016 National Grid conducted a pre-feasibility study to investigate the potential benefit of re-wheeling VSD electric drive compressor Unit E at Kirriemuir Compressor. Due to investment challenges and uncertainty over future network conditions, this option was not taken forward at this time but is being kept under review.

Figure 18 Unit E at Kirriemuir, compressor re-wheel pre-feasibility (inset example compressor impeller)

3.3.5 Upgrade to variable speed drive compressor enclosure ventilation at Carnforth Compressor

As part of HSE PM84 compliance at Carnforth Compressor Station, in order to achieve positive pressure cabs, the existing four ventilation fan motors (two intake and two extract), rated at 7.5kW each, were replaced on Unit B enclosure in 2014 with two VSD motors, rated at up to 55kW each.

When compressors are pressurised, there is a need for cab ventilation which then increases as the gas compressors are put into operation. This variation in ventilation demand is well suited to the installation of VSDs which can adjust fan speed accordingly and save motor energy consumption. The VSD speed is controlled via thermostats which measure the temperature in the cabs, increasing the speed and hence ventilation rates as temperatures increase. Compressor run hours at Carnforth are relatively low (41 hours in 2017) and so the overall annual savings achieved with the VSDs have been limited in practice.

Due to the limited practical benefit of this project, VSDs have not been incorporated on other PM84 upgrade projects, due to complexity and costs associated with the variable frequency drives, necessary changes to the control logic and general unsuitability of the majority of installed motors to run at a lower frequency/speed.

3.3.6 Continued usage of vent gas recompression

Since 1992, National Grid has employed two recompression units (trailer mounted Caterpillar reciprocating engines) to reduce gas pressure and enable various line works to be carried out.

Typically, the 2-stage units reduce line gas pressure from 60bar to 7bar in pipelines which range from up to 1,050mm diameter and lengths of up to 65 km. Reduction below 7bar is currently not possible due to increased pipe temperatures. Where maintenance work is carried out, the recompression down to 20bar is sufficient and therefore achievable with the current units. In such circumstances, no gas venting is required.

Between 2015 and 2018, the 2-stage recompression has been carried out at the following locations:

- FM4 Norton Bridge Diversion
- FM11 River Eden Diversion
- FM2 Dynevor Arms Valve Removal
- FM21 ILI Digs and diversion
- Huntingdon Compressor Station and AGI
- FM3 A1607 Norwich Diversion
- FM6 Wold Newton valve works
- FM3 NARC
- FM3 NARC
- FM7 Willington Down Diversion
- FM14 NARC
- FM14 NARC
- FM2 NARC
- FM1 Paull Rationalisation
- FM15 Plumpton Head Valve removal
- FM12 NARC
- Cadent River Ancholme Project[8]

Recompression rig

(image courtesy of National Grid Pipelines Maintenance Centre (PMC))

The total amount of gas saved from venting to atmosphere was 14.8 million scm which equates to 175,892tCO_2e[9].

3.3.7 HVAC upgrades

As part of Peterborough and Huntingdon compressor upgrades a number of replacement operational and non-operational buildings are required. The heating, cooling and ventilation (HVAC) systems to be installed in the new buildings, are being supported by BAT assessments[10]. These assessments have been used to develop detailed design documents and specifications.

The BAT assessments considered the buildings which include the following rooms:

- Non-Operational Buildings
  - Permit Office
  - Technicians' Office
  - Engineer's Office
  - Records Room
  - Meeting Room
  - Kitchen
  - Changing Room
- Toilet Facilities
- Operational Buildings:
  - Control Room
  - Instrument Room
  - LV Switch Room
  - UPS (Uninterruptible Power Supply) Room
  - Battery Room

[8] Now part of asset base transferred from National Grid Gas Distribution to Cadent Gas.
[9] The figures provided use a GWP figure for methane of 17 (this appears to be the figure used in NG calculations). If a figure of 25 is used (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/507942/Emission_Factor_Methodology_Paper_-_2015.pdf), then carbon savings would increase.
[10] Document Ref 7050-0180-075-03-1103-001 (Rev A), Emission Reduction Project Phase 3 Peterborough Compressor Station Project Ref PAC2697. Carried out by Costain Group plc.

All have different temperature and ventilation requirements to support the different functions such as protecting equipment and providing comfortable working environments. Various BAT options have been considered for the heating, cooling and ventilation requirements covering the use of gas fired boilers, electric heating, heat pumps, split and packaged air conditioning units and natural/forced ventilation.

The use of gas fired boilers was not carried forward as the Peterborough and Huntingdon sites have no access to odourised gas. Additionally, ground source heat pumps were excluded due to their high installation costs.

Key conclusions:

- *Operational Buildings.* The BAT assessment considered the use of Reversible Air Source Heat Pumps with natural ventilation to be both the lowest cost and best environmental option along with offering the greatest potential reliability. Tight temperature control requirements for optimal equipment performance in the battery room would require some forced ventilation and additional consideration given to heat extraction in the UPS room.
- *Non-Operational Buildings.* The BAT assessment considered the use of a Low Temperature Hot Water (LTHW) system powered by an electric air to water heat pump for the heating requirement in the welfare areas. Ventilation will be natural apart from the toilets which will require standard supply/extract fans. Packaged and split air conditioning units to provide cooling are also proposed for the control room (depending on the provision of detailed heat output and equipment prices). This option was considered to be able to provide the required versatility, ensuring sufficient control is maintained whilst minimising cost and energy consumption.

These options for the operational and non-operational buildings were deemed to offer the best overall solutions and considered to be preferable to utilisation of single source heating and cooling for the whole building. The findings are currently undergoing detailed design appraisal.

Case Study: Managing energy in the corporate estate

Although it is recognised that energy management within National Grid's wider corporate property estate is outside of the scope of this permit energy review, it is relevant to understand that a companywide strategy is in place in this area, which is delivering measurable improvements.

National Grid operates out of 24 offices (rented and owned) in the UK which predominantly use grid electricity and natural gas. There are small quantities of LPG and gas oil used in the more remote locations. The focus is on the top 10 largest energy consuming facilities for which half hourly data is received and monitored by National Grid's Facility Management (FM) partners and on a weekly basis by the Corporate Property team.

In general, energy saving opportunities are identified on an ongoing basis by the FM contractors and internal energy audits (such as those carried out under the ESOS[11] scheme). All opportunities are centrally logged with the Corporate Property team and site-specific opportunities communicated to the individual property managers. Active management of energy use in offices by Corporate Property has delivered 8.8% year to date reductions in energy use across their top sites.

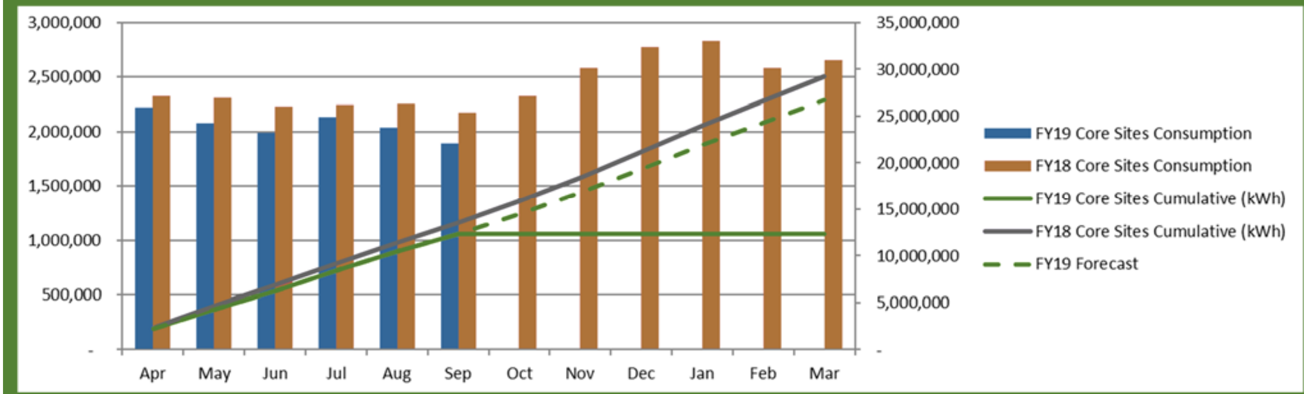
Examples of completed projects include:

- Hot water and cold water primary and secondary circulation pumps upgraded to VSD control and to modern hydraulic design, plus recommissioning and demand driven control of secondary circuits resulted in site energy savings of 10% at Homer Road. Similar upgrades are set to be rolled out at the offices in Wokingham and Warwick;
- UPS optimisation at Wokingham reduced the number of "active" redundant systems to increase loading and efficiency on the remaining units. This project realised an energy saving of 6% of site demand;
- Remote energy management pilot programme carried out at the top sites (using a proprietary energy management solution) to identify low and no cost energy saving measures.

Future planned projects include:

- LED lighting upgrades, Building Energy Management Systems (BeMS) optimisation and fabric insulation across all sites;
- Air Handling Unit (AHU) motor and control upgrades within HVAC systems;
- Continuation of the FM audit programme.

Corporate property year to date progress 2018



Source: Workplace environmental update, National Grid Property

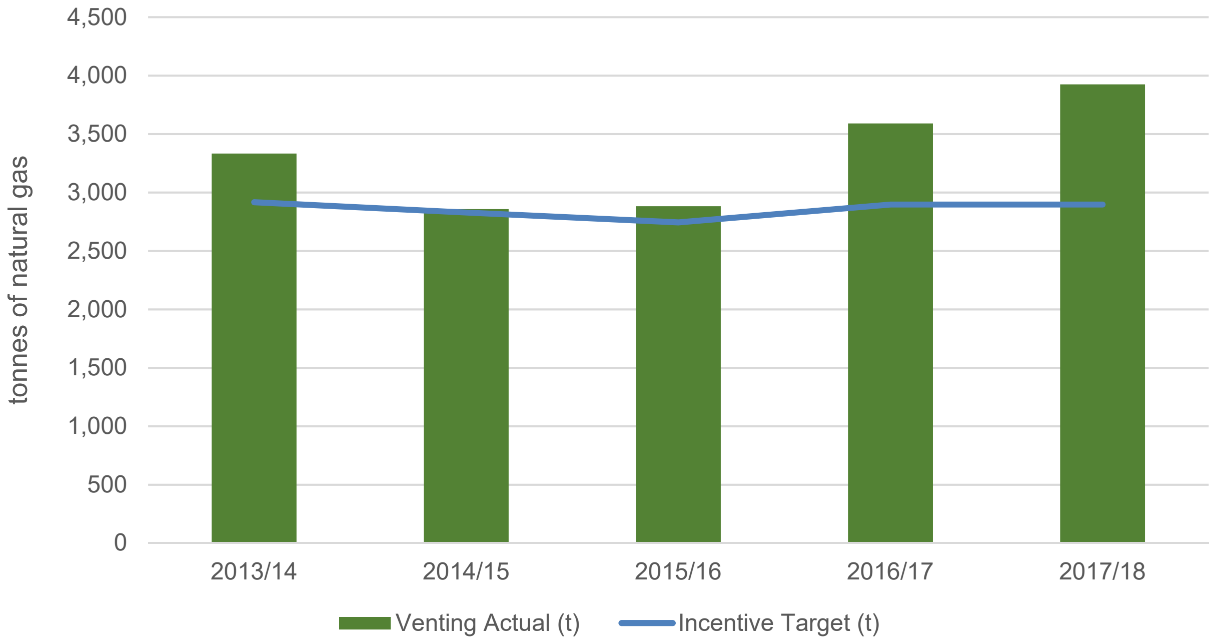
[11] The Energy Savings Opportunity Scheme (ESOS) is a mandatory energy assessment scheme for organisations in the UK that meet the qualification criteria; it is administered by the EA / SEPA

3.3.8 Maintaining compressor pressure, enhanced management practices

National Grid has initiated a campaign to reduce gas emissions from the venting of compressors – known internally as the ‘1000 tonne Reduction Challenge’. This focuses on working practices to reduce the number of times compressors are pressurised and vented, while still meeting all the necessary safety and operational standards.

Under OFGEM’s incentive scheme, National Grid is set an allowance for the quantity of gas released as a result of compressor venting. Currently this is set at 2,897 tonnes of natural gas vented per year; if the actual amount exceeds this level, then National Grid must pay a penalty for each tonne that exceeds the allowance (currently £1,447 per tonne).

Figure 19 Approximate levels of compressor venting over the last five years across the network



The level of venting has risen since 2014/15. A main driver for this has been a change in the pattern of gas supply into the NTS. A decrease in the amount of gas from the LNG terminals in England and Wales has led to an increase in gas supplied from the North Sea, via St Fergus Terminal. This places greater load on the compressor stations and more frequent compressor venting. In addition, shippers have changed their hourly supply patterns, which has placed a greater burden on the NTS to provide sufficient capacity at short notice, again leading to a need for more compressors to be running or held in readiness in pressurised stand-by.

Compressors are vented for operational and safety reasons, including:

- Making compressor available for maintenance.
- Compressor testing after maintenance. Some maintenance routines require the compressor to be run under pressure during recommissioning. Depending on the compressor, this may require several re-pressurising, purging and venting cycles.
- Venting when on stand-by. If compressors are not going to be used for several days, then it may be beneficial to vent them and hold them un-pressurised (this can depend upon the particular compressor design), to minimise total emissions from both gas leaks and energy consumption. The “break-even” period for optimum venting will depend on the characteristics of each compressor (in particular its compressor shaft seal design, being either ‘wet’ oil or ‘dry’ gas design) and its associated pipework configuration.

- Safety venting. Some of the older compressors operate with relatively aged control strategies, which trigger venting under certain circumstances. Although modern compressors might not follow the same logic, it would be very expensive to alter the control strategies of the older machines.
- Test runs. Most of the compressors on the NTS follow a 28-day test run policy i.e. if a machine hasn't been run under normal conditions in the last 28 days, it is given a test-run to ensure it is still operating correctly and available if required. This may require the compressor to be pressurised and vented, specifically for the test-run to be carried out.
- Station emergency shut-down (ESD) events. If the whole station is depressurised for any reason, then the compressors would vent as well.

During 2017/18, National Grid initiated a behavioural and policy change campaign to reduce the amount of gas released as a result of compressor pressurisation and venting. This has focused on raising awareness of the issue, in order to reduce the number of "controllable" venting actions. The main actions have included:

- A joint workshop with operators from the compressor stations and the network control (Gas National Control Centre (GNCC) to raise awareness of the environmental and financial impacts of venting, and to identify opportunities to reduce venting.
- Strong sponsorship from senior management.
- Improved reporting of venting and associated key performance indicators (KPIs), including:
    - Improved SCADA[12] reports
    - Individual site reporting.
- Staff are encouraged to challenge the need for pressurisation and venting: "Is it really necessary?"
- Focus on "bundling" of venting requirements – e.g. if a compressor needs venting for several reasons over the next few days, could they all be bundled into one maintenance action, rather than triggering a number of separate vent cycles?
- Compressor requirements are addressed during weekly planning meetings, in order to coordinate efforts to reduce venting.
- Clearer accountabilities and responsibilities between compressor station staff and GNCC.
- Improved understanding of the "Critical Compressor" list. For different network operating conditions, a set of compressors are identified as critical i.e. they must be ready for operation, or on immediate stand-by, in order to meet the expected network demands.

3.3.9 Process gas losses, leakage and the Greenhouse Gas Investigation Mechanism (GHGIM)

National Grid has an obligation to manage its direct greenhouse gas (GHG) emissions. In addition to operational and planned venting discussed above, direct releases of natural gas to the atmosphere include gas losses and leakage.

Gas losses can result from a number of sources and activities, including:

- Leaks from pipework, flanges and valves as part of normal operations (fugitive emissions)
- Leaks from compressor shaft seals in operation and during pressurised stand-by
- Passing valves (due to a failure to correctly seat on a temporary or permanent basis) leading to continuous unplanned emissions from point sources, such as vent stacks and vent lines.

National Grid's standard procedure for identifying gas leaks from pipeline equipment on compressor stations is to follow a 4-yearly programme of site surveys – such that each site is surveyed once every 4 years, using a schedule to focus on the most at-risk locations. These surveys are carried out manually, with trained staff using ultra-sonic leak detectors, spending typically one day at each site. The surveys are then followed by repairs to faulty equipment to reduce emissions. The most common faults include, for example, leaking valve stems (thought to account for around 80% of all fugitive leaks). Based on an assessment of leak

[12] SCADA - Supervisory control and data acquisition; process control software

surveys carried out between 2008 and 2010, these surveys resulted in a reduction of 109 tonnes of gas emissions per year.

During 2017, a new initiative, the Greenhouse Gas Investigation Mechanism (GHGIM), was carried out to assess the effectiveness of continuous monitoring of gas leaks, at two compressor stations. This consisted of a real-time gas analyser (housed in a standard 6 metre container) connected, via a network of small-bore pipes, to an array of sampling points located around the perimeter fence.

Together with continuous weather measurements and an innovative system of "reverse dispersion modelling", it was shown to be possible to detect and quantify gas emissions and provide information on the likely location of their source within the compressor station area, followed by remedial action to repair the leaks. In comparison with the current 4-yearly programme of "snap-shot" leak surveys, this new approach would allow continuous monitoring during a range of site operations, and leaks to be identified and repaired more quickly, resulting in reduced total emissions. The "proof of concept" study was carried out by National Grid in conjunction with the National Physical Laboratory.

The GHGIM study considered the use of a number of mobile real-time gas monitoring units, which would be installed at each site for a period of around 4 weeks providing continuous monitoring and leak detention during that period. Once the majority of leaks had been identified and repaired, the equipment would be removed, for transportation to and installation at the next site.

The study conclusions include an estimate of potential leak reductions, if regular real-time gas-detection was carried out across all 23 compressor stations, of 265 tonnes of natural gas per year. This would be a significant improvement on the estimated reductions of 109 tonnes per year resulting from the current system of 4-yearly surveys.

3.3.10Fuel gas skid heat recovery on new compressors

The compressor fuel gas skid is required to supply clean, dry, metered gas at the required pressure and temperature for use in the gas turbine engine fuel system. The fuel gas supply is taken from the process gas pipework at NTS pressures; when this high-pressure gas expands during pressure reduction, it is subject to rapid cooling (due to the Joule-Thompson effect). This can cause liquid condensates to form in the fuel gas lines, and therefore the gas must be preheated prior to pressure reduction.

National Grid undertook a cost-benefit analysis BAT assessment to look at fuel gas skid technologies for the new compressor units at Peterborough and Huntingdon, which included greenhouse gas emissions (tCO_2e associated with energy consumption or on-site direct combustion) as a key environmental factor. There are several fuel gas preheating/gas conditioning technologies in use on National Grid gas transmission compressor stations; the technologies in use reflect the differing design practices on assets of different ages and different compressor OEMs.

Water bath heaters have traditionally provided the preheating function, however, as they have aged they have been found to be increasingly unreliable whilst their energy efficiency is considered very low. Electric heating and heat recovery from oil cooling systems[13] are alternative pre-heating solutions that have been implemented more recently however the energy and environmental performance of these different technologies was not understood and there was little available information to help quantify this. New technologies investigated in the BAT study and considered 'available' due to their being proven in use in similar applications included: gas fired boilers (used widely for process gas preheating on gas AGIs), thermo-catalytic solutions (trialled in the UK on some AGIs in the gas distribution sector), and electric immersion/trace heating.

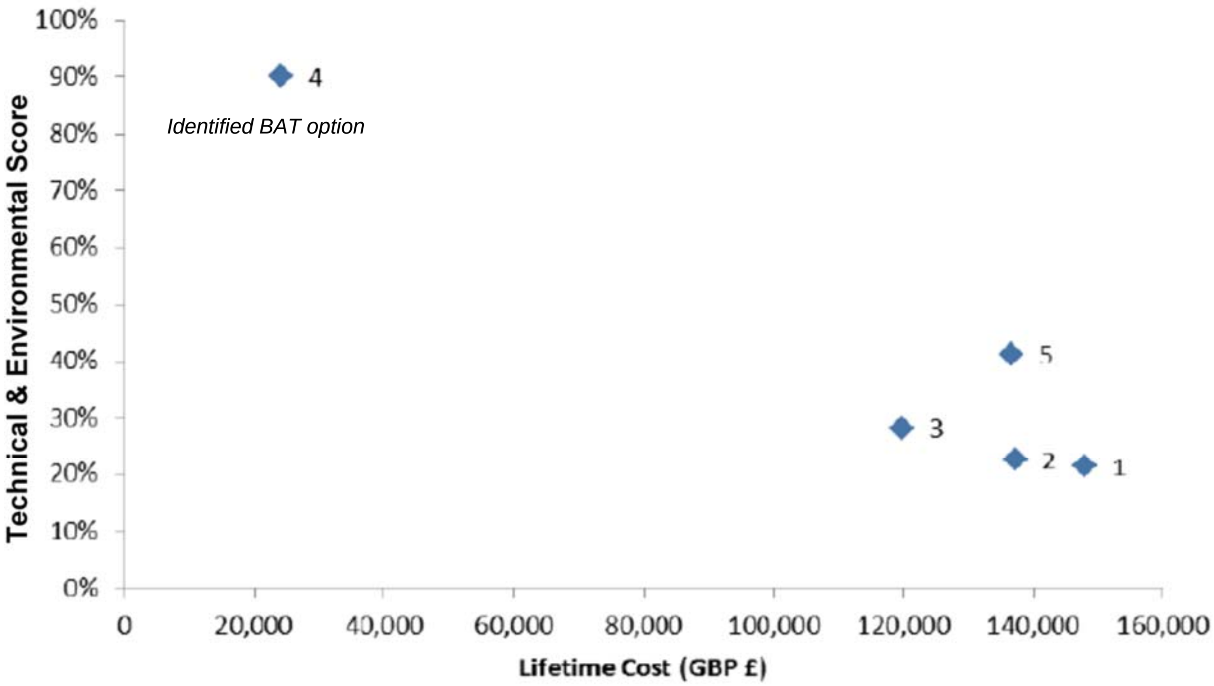
[13] There are examples of this technology in use on some existing NTS compressors, reflecting the technology availability at the time. Some of the RB211 have basic heat recovery functionality, all of the LM2500 and SGT-400 units also incorporate heat recovery.

New fuel gas skids are proposed for each of the new units at Peterborough and Huntingdon, these will operate on a cold start using electric gas pre-heating elements, when the engine oil has reached the correct operating temperature fuel gas preheating continues by lube oil heat recovery, to make use of waste engine heat. This significantly reduces energy consumption compared to traditional gas fired water bath heater or boiler systems or relying solely on electric heating.

The results showed that using waste heat recovery from the compressor oil cooling system is the best performing solution for new build compressors and offers a very favourable cost benefit balance; the study concluded that this technology was likely to be the primary solution for new installations.

National Grid has therefore procured fuel gas conditioning skids utilising lube oil heat recovery. The chosen BAT design has the potential to offer a simple financial payback of less than two years at Peterborough compared to an all-electric heating solution, due to the reduced electricity consumption, and a saving in excess of 1,250 tonnes of tCO_2e over a nominal 20-year design life. At Huntingdon the high efficiency design offers a simple financial payback of less than four years compared to an all-electric heating solution, and a saving in excess of 750 tonnes of tCO_2e over a nominal 20-year design life.

Figure 20 BAT assessment of alternative new build fuel gas systems at Peterborough



Key
1 Water Bath Heater
2 Gas fired boiler house
3 Thermo Catalytic System
4 Waste Heat Recovery
5 Electric immersion heaters/trace heating

Source: Peterborough Compressor Upgrade – Application for Variation to Environmental Permit, Reference UP3038LG/V003, July 2016

3.3.11 Valve actuation upgrades

Compressor stations, Terminals and AGIs typically contain many process valves, of different types, purposes and sizes. Most of these valves are fitted with actuators to allow them to be controlled remotely. When many of the compressor stations were first built, most of these actuators were driven using the pressure of the natural gas itself, either directly in a gas cylinder, or indirectly using an intermediate hydraulic oil system (known as "gas over oil"). On actuation, a small amount of gas was released to atmosphere. Since then, other actuator technologies have become available, including pneumatic actuators and electric actuators.

Table 6 Summary of actuator type advantages and disadvantages

Motive Power	Advantages	Disadvantages
Gas actuators	• Always available • No additional service connections required • Allows use of smaller cylinders, due to high pressure	• Intentional release of gas, vented after each use. • Fugitive leaks of gas from seals, joints.
Pneumatic actuators	• Avoids release of natural gas • Well established technology	• Requires the additional installation and maintenance of air compressors and distribution pipework. • Requires constant operation of air compressors, consuming energy. • Can require large cylinders due to lower pressure.
Electro-hydraulic actuators	• Low energy consumption • Zero on-site emissions	• Requires installation of power and control cabling • High capital cost

In 2014, National Grid carried out a BAT review looking at valve-actuation technologies as there had been long standing uncertainty over the best environmental-technical option questions having previously been raised by the environmental regulators. A preliminary study was carried out to illustrate the methodology used to assess alternative actuation technologies. The conclusions depended to a degree on the type of location, and application. For sites with a convenient electricity connection (i.e. all compressor station sites), for valves used fairly regularly, electro-hydraulic actuators are likely to provide the optimum balance of cost and environmental performance so were identified as "BAT" for most applications. For some applications (e.g. sites without electricity), gas actuators may be the only practical option; or for site Emergency Shut Down (ESD) valves, when they may need to be used during a power-cut.

This BAT methodology has been used to assess the choice of gas actuators for several recent capital projects including:

- NARC Campaign East Area Batch 2017 Refurbishment and Replacement Works – at Cambridge Compressor Station
- Emissions Reduction Project (ERP) Phase 3 – at Peterborough and Huntingdon compressor stations
- Theme 2 Actuator BAT Assessment – at St Fergus Terminal (April 2015)

In both cases, the BAT assessments concluded that electro-hydraulic actuators will provide a better choice than other technologies, including gas and compressed air driven actuators.

In the case of Cambridge, the BAT study was carried out on the choice of actuators, for the replacement of five 36-inch valves. On the basis of three actuator-operations per year, it was estimated that the choice of electric actuators over new gas actuators would save approximately 36 kg of direct gas emissions per year – over and above any improvement in performance from replacing the old valves which was the primary project driver.

In the BAT assessment for Peterborough, the assessment was based on 16 actuators, each operating 12 times per year. If gas actuators were used, each with a 50-litre double-acting cylinder, the total emissions of gas would be approximately 750 kg per year (some 18.75 tCO_2e). The choice of electric actuators avoids this future level of gas emissions altogether.

3.3.12 Electrical and mechanical services

National Grid identified a number of potential improvements to energy efficiency on electrical and mechanical services at the Compressor Stations. However, restricted capital budgets, (as determined by the RIIO price control process) have prevented them from being implemented so far, although the position is being kept under review. These include:

- Air compressors. Certain sites with fixed-speed air compressors (e.g. Wormington) have been identified for potential upgrade to variable speed compressors.
- Transformers. A number of sites have transformers which are due to be replaced. Modern transformers operate with significantly lower electrical losses than old ones.
- Standby generators. The older sites were fitted with small gas-driven gas turbine back-up generators. In order to continue to meet the required reliability levels, and due to obsolescence, there are plans to replace these (for example at Peterborough and Huntingdon). Although they do not have a significant impact on energy consumption (as they are generally only use for testing and in the rare event of a mains electricity outage), modern generators, chosen to meet BAT requirements, should provide the optimum balance of environmental and financial performance.

Also, most of the Compressor Stations have now had a major upgrade to their security systems. This has included a refurbishment of the boundary fences, with cameras and associated lighting. That lighting was installed using LED lamps. Although the driver for this was not energy efficiency, it demonstrates the take-up of BAT low-energy technology in this area.

Case Study: Major upgrades under the EP/PPC regime - Emission Reduction Project (ERP) Phase 3 (ERP3)

The period 2014-2018 has seen the first major compressor station upgrade projects where the feasibility, conceptual and detailed design stages have been wholly carried out on sites with established permits under the EP/PPC regimes. Although previous major upgrade programmes (such as ERP phases 1 and 2 and the South Wales Expansion Project (SWEP)) brought sites into the EP/PPC regime, much of the design work took place under the earlier regulatory regime; the majority of National Grid compressor stations being permitted in late 2006.

This change in emphasis of the importance of BAT driven energy and resource efficiency improvements (linked to the T/SP/ENV/21 and T/SP/ENV/22 processes described previously) can be seen throughout the design for the ERP3 upgrades. Key elements are summarised below and described in detail elsewhere in this review.

- Improvements in thermal efficiency and overall compressor train efficiency brought about by:
    - modern combustion plant.
    - compressor mapping to predicted site duty requirements.
    - compressor matching to power turbine speeds.

  These measures will reduce the potential for requiring units to run in reduced efficiency 'recycle' conditions for key process duty points.
- Increased BoP energy efficiency including variable speed air compressors, and localised waste heat recovery accommodated via lube oil heat recovery for fuel gas pre-treatment and through use of engine compressor bleed air for air intake filter anti-icing.
- Adoption of electro-hydraulic or electric valve actuators on new large process valves, which avoids the release of natural gas (methane) associated with operating more traditional process gas actuated valves, which use the pressure in the gas as the motive force for valve operation.
- Increased versatility and unit flexibility, offering a wide compressor operating envelope over which emissions compliant engine performance is achieved, increasing the likelihood of the site being able to accommodate future gas process supply and demand scenarios without adversely impacting on environmental performance.
- Improvement in control of process gas (methane) losses associated with potentially passing site valves.

Architects impression of the completed ERP3 upgrade at Peterborough

4 Opportunities and recommendations 2019-2022

4.1 Introduction

As part of this energy review, National Grid is required to identify opportunities and proposed recommendations for implementing energy efficiency measures for the period from 2019 to 2022.

4.2 Site screening

A site screening exercise, peer reviewed by environmental specialists in National Grid, was carried out in 2018 to identify potential target sites where energy efficiency improvements could be applied, trialled or further investigated. This approach recognises that National Grid's regulatory environment requires prioritisation in all activities potentially linked to expenditure. It should be noted that the screening exercise was not intended to exclude sites from possible energy efficiency enhancements, rather to provide focus for energy efficiency measures. National Grid will continue to review the other sites for energy efficiency opportunities as appropriate.

Figure 21 Stepwise site screening exercise

1 Decommissioning status
Sites which have been potentially identified for decommissioning (subject to regulatory approval and business confirmation) are not appropriate for investment in energy efficiency measures. The residual life of the site is unlikely to allow investment payback to be realised and, by definition, the site has been deemed to be a non-critical asset therefore will only be retained on a safe basis with operationally critical or legislatively driven asset health investment securing approval. All other items being deferred until the decommissioning is confirmed or operational maintenance activities cease on closure.

2 Major project works
Sites where major projects are currently being undertaken or are planned (subject to Ofgem approval) are reviewed under the T/SP/ENV/21 and T/SP/ENV/22 BAT processes in respect of energy optimisation and emissions reduction. As such the potential for replacement or upgraded CMT and/or BoP will already be addressed, with the project providing a framework for implementation, as appropriate.

3 Pressurised standby hours
In order to optimise network availability, certain units are periodically retained in pressurised standby (i.e. with the compressor casing at line pressure) to maximise operational readiness. In the pressurised standby condition certain cab ancillary plant and safety equipment is "switched on", and therefore adds to the overall energy consumption of the site. Therefore, sites with high pressurised standby hours could be candidates for review of the energy usage by compressor cab balance of plant, other sites less so.

4 Site run hours
Sites with low run hours are not likely to be appropriate for investment in energy efficiency measures. The rationale behind this step is that the greater the current run hours on site the larger the payback in energy cost savings from improved on site efficiency measures. If a site has low run hours then plant and equipment where energy efficiency measures can be installed will be used less and therefore any investment in energy efficiency improvements will have a much longer, potentially unacceptable, payback period. Conversely, if a site current has high run hours usage payback on that investment could be reduced. Therefore, sites with low run hours are screened out.

5 Significant additional on-site energy usage
Sites which have potentially high run hours, but due to the technologies employed at site (i.e. non-DLE compressors with low electrical loads and no compressed air/nitrogen seal gas systems) have limited additional on-site energy usage from balance of plant. These have been screened out on the basis that viable opportunities for energy efficiency gains are unlikely to be realised from balance of plant items, and upgrade of the compressor machinery train on energy efficiency grounds alone would not be BAT.

Sites taken forward	
• Aberdeen	• Nether Kellet
• Avonbridge	• Diss
• Bishop Auckland	• Kirriemuir
• Churchover	• Wormington

4.3 Status of energy efficiency opportunities

Table 7 below summarises the 2014 opportunities, identifying those still relevant and provides a justification for the screening out of those no longer considered appropriate. New energy efficiency opportunities and developments identified during the course of research are also presented.

Table 7 Status of energy efficiency opportunities

Opportunity category	Energy efficiency measure	Status	Justification
2014	Fuel gas preheater - heat recovery	BAT for new CMT (subject to site specific assessment).	The major upgrade project at Hatton[14] will include a BAT and technical assessment on fuel gas heat recovery; without pre-determining that assessment it is likely that heat recovery will similarly be specified due to the potential cost and carbon savings which could be realised.
2014	Lube oil pumps VSD	BAT for new CMT (subject to site specific assessment).	Due to the restricted asset health budget (as determined by the RIIO price control process) the focus for existing units will continue to be on re-lifing and limited asset health replacement with 'like for like' systems. Provision of VSD lube oil cooler pump motors will be reviewed as part of the BAT assessment for new CMT, with live projects currently ongoing at St Fergus[13] and Hatton[13].
2014	Mothball units	To be adopted where operationally prudent.	The ongoing requirement for units will continue to be kept under review, as there are potentially operational and environmental benefits if units are switched off for extended periods. Engines can be treated with an inhibitor to prevent corrosion which enables them to be kept in a stable condition for an extended period, which means that 28 day run tests (with associated fuel use and process gas purging and venting) are not required.
2014	Office HVAC	BAT assessment on a project by project basis (replacement and new plant).	Installation of new, or replacement of failed, HVAC systems as indicated by asset health will continue to offer opportunities for BAT technologies to be considered. System re-lifing for lower priority asset health issues will continue to be on a like-for-like basis.
2014	Retaining compressor pressure	Business as usual – continued roll-out.	The established behavioural change programme will continue to be rolled out.
2014	Thermal oxidation	Not taken forward for routine and emergency venting. Specific innovation opportunities under review.	Thermal oxidation of routine and emergency compressor venting is not being investigated, with retaining compressor pressure initiatives being prioritised. Two aspects of thermal oxidation are being investigated at present: seal gas thermal oxidisers for Solar Units or a final stage thermal oxidation process instead of a third stage compressor on recompression rigs used for route maintenance recompression.

[14] Subject to Ofgem investment funding agreement

Opportunity category	Energy efficiency measure	Status	Justification
2014	Ultrasonic leak detection	Business as usual, continued roll-out. Specific innovation opportunities under review.	Application of the successful GHGIM process will continue with opportunities for further enhancements under investigation for future consideration.
2014	Vent fans VSD	Determined by site specific BAT assessment for new CMT. Not taken forward for existing sites.	Due to the restricted asset health budget (as determined by the RIIO price control process) the focus for existing units will continue to be on incremental asset health replacement works to drive compliance with HSE PM84, allowing a much lower unit cost than full system replacement, allowing greater network-wide risk reduction and unit availability improvement. VSD vent fans will continue to be investigated on a project by project basis as part of BoP BAT assessments (under procedure T/SP/ENV/22).
2014	Vent gas recompression	Planned maintenance venting only, not taken forward for route and emergency venting. Specific innovation opportunities under review.	Recompression of routine and emergency compressor venting is not being investigated, however, vent gas recompression rigs will continue to be used on a project by project basis for planned maintenance vents only. A possible third stage compression is being investigated which could allow for gas recovery below the residual 7 bar point, below which gas is currently vented.
2014	Voltage optimisation	No further investigation.	Not relevant to load characteristics typically seen on NTS sites and inconsistent with VSD usage.
2014	Wet Seal replacement	BAT for new CMT (subject to site specific assessment)	Not under consideration for existing machinery (would only be considered as part of complete CMT and enclosure overhaul).
New	Compressed air	Variable speed drive air compressors	Currently proposed to be installed at one site (Wormington) in 2019. Potential opportunity for investigation at other sites with significant compressed air requirements (e.g. where dry gas seals are in use or compressed air actuated valves).
New	Compressed air	Air compressor heat recovery	Currently under investigation at one site (Wormington), with potential opportunities including supply of space heating and hot water to offices.

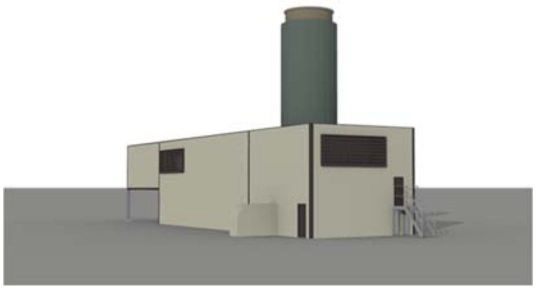
Whilst ***Table 7*** identifies new energy efficiency opportunities the scope of this review does not include a detailed market technology review. Although decisions to invest are made at network level, the unique nature of each site means that site specific requirements must also be considered as there is no "one size fits all" technology solution for all sites.

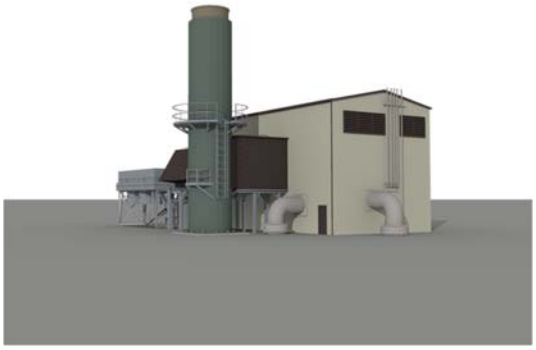
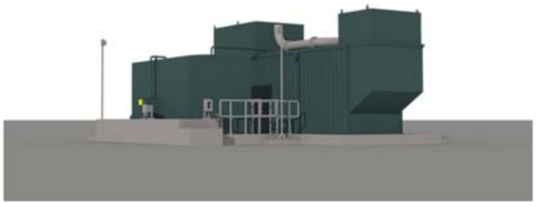
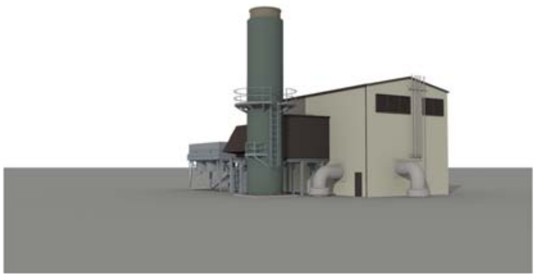
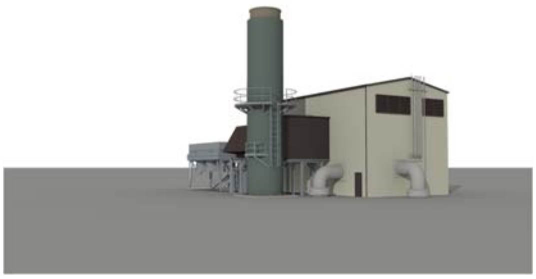
As previously discussed in ***Section 3.3.2*** of this review these opportunities would be considered BoP since they fall outside of the scope of CMT and as such would be carried out on a project by project basis under T/SP/ENV/22. Any new technologies identified currently covered by a BoP BAT study (as identified in ***Table 5***) would necessitate an update of that study; new technology areas would require a BoP BAT study to be carried out in accordance with T/SP/ENV/22.

4.4 Asset class-based approach to identification of opportunities

Table 8 below identifies opportunities for energy efficiency measures for those SACs with major or minor energy consumption. These have been derived through discussion with Subject Matter Experts in Network Engineering. The SACs included reflect those identified in ***Section 1.4*** above.

Table 8 SAC based energy efficiency opportunities for major, minor and gas emitting

SAC	Opportunity summary
After coolers 	• Regular maintenance to maximise design efficiency. • Only two operational aftercooler systems on the NTS at St Fergus Terminal due to high gas pressure lift.
Air intake 	• Remedial works on air intakes to be determined by plant status (fault) reports. • Filtration systems to be kept under review, in respect of potential opportunities to provide equivalent or enhanced filtration without impact on engine efficiency (backpressure).
Cab ventilation 	• VSD enclosure fans to be considered for new build compressor enclosures, as determined through BAT principles. • Smaller on or off-skid enclosures (standalone or within larger cab enclosure building) for new build CMT can reduce the volume of air subject to most stringent ventilation requirements, offering potential for downsizing of ventilation equipment. Cab configuration would be determined as part of a wider CMT BAT assessment. • For asset health works, ensure inner/outer cab sealing is adequate to avoid ineffective and unplanned airflow routes.
Civil assets – buildings and enclosures 	• Maintenance of existing enclosure to avoid incorrect circulation and potential inefficiencies. • Selection of new or substantially modified HVAC on the basis of the principles of BAT. • Low energy and natural lighting systems to be selected on the basis of the principles of BAT.

SAC	Opportunity summary
Compressor 	• Regular maintenance and overhaul in line with manufacturer's recommendations. • New or substantially modified equipment to be selected based on T/SP/ENV/21 BAT process, having due regard to tCO_2e in the decision process (as part of overall CMT efficiency assessment). • Review of compressor matching to site duty requirements, if dictated by operational needs (compressor re-wheel). • Dry gas seals considered BAT for new or substantially modified CMT to reduce seal gas losses in operation and pressurised standby conditions. Seal gas loses would not, in their own right, warrant a replacement of a wet seal due to very high project costs.
Electrical Variable Speed Drive 	• Regular maintenance and overhaul in line with manufacturer's recommendations. • New or substantially modified equipment to be selected based on T/SP/ENV/21 BAT process, having due regard to tCO_2e in the decision process.
Electrical – including standby generators 	• Material electricity consumers to be selected in accordance with principles of BAT. • Consideration of variable speed drive air compressor equipment, with potential opportunities for air compressor heat recovery. • Modern diesel package generators to replace older gas fired small scale gas turbine generators on as required basis.
Exhausts 	• Use of Computational Fluid Dynamics (CFD) techniques for design optimisation of new or replacement unit exhaust stacks to minimise back pressure, with associated impact on engine efficiency (as dictated by new machinery requirements or asset health needs). • Use of catalytic abatement systems would require BAT assessment to consider relative benefits compared to potential reduction in efficiency associated with increases in engine back pressure.
Gas generator 	• Regular maintenance and overhaul in line with manufacturer's recommendations. • New or substantially modified equipment to be selected based on T/SP/ENV/21 BAT process, having due regard to tCO_2e in the decision process. • Energy efficiency would not, in its own right, warrant a machinery train replacement due to very high project costs.

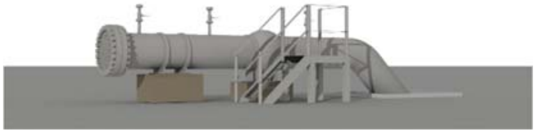
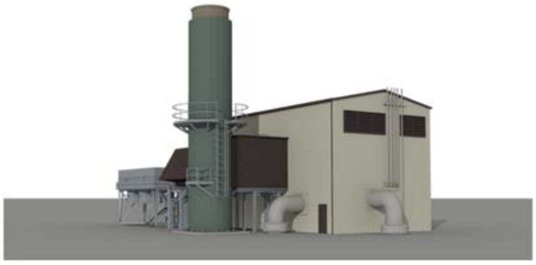
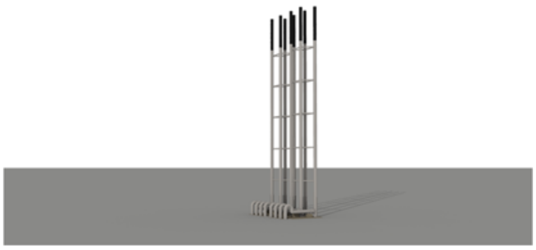
SAC	Opportunity summary
Pig trap 	• Gas release on venting and purging when in operation, however no reduction opportunities identified as pigging carried out in line with statutory pipeline safety inspection requirements.
Power turbine 	• Regular maintenance and overhaul in line with manufacturer's recommendations. • New or substantially modified equipment to be selected based on T/SP/ENV/21 BAT process, having due regard to tCO_2e in the decision process (as part of overall CMT efficiency assessment).
Pre-heaters 	• Pre-heating technology for new or substantially modified pressure reduction installations to be determined using the principles of BAT (having regard to energy consumption as a material environmental decision criteria). • Represents an area where there have been a number of potential new technology approaches identified and trialled, in particular, by gas Distribution Network Operators (DNOs). • Strategic disconnection of pressure reduction installations where this can be justified based on customer connection requirements.
Process valves 	• Valve actuation for new or major process valves upgrade to be determined in accordance with the requirements of BAT (with energy consumption from e.g. compressed air systems and methane releases from gas actuated systems included in decision criteria). • Recent valve actuation BAT studies have indicated that electro-hydraulic actuation represented a favourable candidate BAT option.
Starter motor 	• Electric starter motor considered BAT for new or substantially modified CMT to reduce gas actuated starter motor losses on operation. Starter gas loses would not, in their own right, warrant a replacement of a gas driven starter due to high project costs.
Vent system 	• Gas release on venting and purging when in operation, however no asset-based reduction opportunities identified as venting is carried out for safety and operationally critical requirements. Potential for continued improvements relate to venting alternatives and management practices.

Table 9 Other SAC based energy efficiency considerations

Consumption	SAC	Opportunity summary
Minimal	• Anti-surge system • Boundary controllers • Cathodic protection • Electrical - safe shutdown • Fire and gas detection • Fire suppression • Flow or pressure regulator • Fuel gas metering • Fuel tanks and bunds • Gas analyser • Metering • Network control and instrumentation • Odorisation plant • Safety valves • Security • Slam shut system • Station process control system • Unit control system	Discrete opportunities for small scale local energy efficiency gains to be realised through National Grid's normal procurement processes on selection of new replacement plant, as dictated by operational or asset health demands.

4.5 Cross network opportunities and recommendations

A number of cross network opportunities have been identified during the course of this review. These can be divided into those that represent continuation of existing opportunities and emerging opportunities.

4.5.1 Continuation of existing measures

- Venting management
  The use of enhanced management processes will continue to drive further positive behavioural change in respect of retaining compressor pressure and avoiding unnecessary venting losses. The campaign is continuing to raise the awareness of venting with compressor station staff and GNCC. Further opportunities are being pursued, including:
  - Further challenging of current procedures, especially for planned venting actions.
  - An investigation at St Fergus Terminal identified an annual maintenance procedure which includes 13 full depressurisation cycles when bringing the compressor back in operation, and concluded that this could be re-organised to only require one or two cycles. This would save approximately 95 tonnes of gas emissions per year at St Fergus Terminal.
  - Further learning from St Fergus Terminal will be shared across the network.
  - Improvements to the modelling of compressor venting, to optimise the "break-even" calculation of when to vent a compressor.
  - Improved forecasting of network demands and the associated "critical compressor list".
  - Coordination with the GHGIM initiative to reduce total site gas emissions.
  - Further opportunities to improve coordination between GNCC and compressor station staff.
  - Investigations into limited vent-gas flaring to reduce global warming impact of emitted gas.

  It is forecast that these actions will contribute to a reduction of around 500 tonnes of vent gas emissions in the current 2018/19 year, although there may be other contributing factors as well. Furthermore, 2018/19 has included two of the five lowest-venting months in the RIIO-T1 period, despite the general tendency for increased system demands described previously in this paper.

- Embedding of T/SP/ENV/21 and T/SP/ENV/22 as business-as-usual
  The continued use of the T/SP/ENV/21 and T/SP/ENV/22 procedures are formalised within National Grid governance and their continued usage is mandated for compressor projects subject to Formal Environmental Assessment (FEA). This will ensure that whole life energy efficiency, and greenhouse gas emissions will continue to be key decision-making factors, where relevant, in the selection of new and replacement CMT and BoP. The library of BAT assessment case studies has been and will continue to be supplemented as BAT assessment are carried out on projects, driving learnings from one project to the next.
- RIIO-T2 asset health investment programme
  National Grid is currently planning its strategy for managing asset health intervention works during second RIIO price control period (RIIO-T2), which will run for five years. As with the RIIO-T1 asset strategy campaigns (described in ***Section 1.5.2***) this will be delivered on a network-wide basis; the result being a risk-based prioritisation of planned asset health investments. Although many measures will necessarily be remedial and comprise like for like replacement due to continuing funding restrictions. It is envisaged that opportunities will arise for review of technology options on a number of projects, with the potential for energy efficiency improvements and reductions in greenhouse gas emissions.
- Vent gas recompression (maintenance)
  Mobile gas recompression rigs will continue to be used, where appropriate and practical, to manage large scale planned maintenance degassing operations, to reduce the quantity of gas vented (see also emerging opportunities below).
- Gas leakage losses
  The ongoing programme of gas leak detection and remedial works will continue; Ofgem support was granted to the first stage of the GHGIM[15] to assess continuous emissions monitoring techniques (see also emerging opportunities below).

4.5.2 Emerging opportunities

- Enhancement of recompression rig through addition of third stage (LP) compressor.
  Where full pipe evacuation is required (e.g. pipe relocation), the pipe pressure must be reduced to atmospheric pressure. In such circumstances, venting is carried out to reduce the pressure from 7bar. Data provided by National Grid on venting quantities between 2015 and 2018 states that over 2 million scm of gas (at 7 bar) was vented which equates to 24,280tCO_2e released to atmosphere. There is anticipated to be a further six evacuations in 2019. At an average recompression of 110,000scm of gas between 2015 and 2018, the overall carbon emissions are expected to be 7,667tCO_2e in 2019. Current forecasts from 2021 to 2030 would produce 200,000tCO_2e. Should a third stage (LP) compressor be brought into operation, the gas could be diverted from venting and these carbon emissions could be saved. An indicative cost of £2M has been stated for the specification, build and testing of a LP unit.
- Thermal oxidation (residual vent gas).
  National Grid has requested an initial concept paper from one of its major engineering design and delivery suppliers to look at the outline feasibility of a mobile gas thermal oxidiser. This could be an alternative approach to using a third stage compressor on a recompression rig for management of residual gas within sections of pipework and on sites when conducting planned maintenance decompression.
- Further development in real time process gas emissions monitoring.
  The GHGIM innovation study was concluded in 2018, providing a “proof of concept” for real-time gas emission monitoring of compressor station sites. A new innovation study, known as “Monitoring of Real-time Fugitive Emissions” (or MORFE), has been proposed, to carry out research into more cost-effective means of gas-monitoring. The system used in the GHGIM study was based around a large, gas-detection unit (housed in a standard 20-foot container), connected to sampling points via small-bore pipes. This equipment is relatively expensive and could not be justified as a permanent installation at each site. However, it is hoped that a new generation of gas detectors, each one much smaller, would provide an alternative, lower cost solution. An array of such detectors could be installed, on a

[15] https://www.ofgem.gov.uk/system/files/docs/2018/03/20180312_ghgim_decision_letter_2018_final.pdf

permanent basis at each compressor station – to provide the same information as for the GHGIM system, to detect and locate gas leaks.

- UAV thermal imaging.
  In addition to the real time gas emissions monitoring opportunities discussed above, there may be alternative technologies, such as infra-red cameras, which could provide further leak detection capabilities. Initial investigations and discussions have also commenced regarding the possible use of unmanned aerial vehicle (UAV, or 'drone') based cameras.
- Seal gas thermal oxidation.
  National Grid are currently investigating a 'new to market' technology offering from Solar Turbines who are proposing a seal gas thermal oxidation system for the residual process gas losses arising from dry gas seal systems; there are a number of technical restrictions related to the control system model which may preclude any further investigation. However, as National Grid currently operates four Solar gas compressor sets, and another four more are being installed (at Peterborough and Huntingdon) they are presently in discussion with Solar, but as yet no cost or operational performance data has been made available to undertake a BAT assessment. This, together with technical applicability, will be kept under review although the preliminary view is that whilst this is an interesting technological development seal gas losses from modern dry gas seals are so low that no further abatement will be warranted.

4.6 Site-specific energy efficiency opportunities

A number of site-specific opportunities have been identified during the course of this review. These can be divided into those that relate to ongoing project opportunities and those that relate to specific priority sites arising from the screening exercise.

4.6.1 Project opportunities

- Hatton Compressor Upgrade
  The ongoing works to implement the planned major compressor upgrade at Hatton (subject to Ofgem funding approval) will deliver a range of opportunities for implementation of BAT based technology with the potential for energy efficiency improvements and reductions in greenhouse gas emissions. For example, new gas turbine driven CMT is currently being procured to replace the existing RB211 gas turbine driven units and provide back up to the lead VSD electric drive compressor, this will provide opportunity for enhanced overall CMT efficiency and matching of the gas turbine compressors to site duty, individually and when operating in support of the VSD electric drive compressor. Any new plant falling under the remit of the Large Combustion Plant (LCP) requirements of the IED will also be required to comply with the BAT Associated Energy Efficiency levels (AEELs) which require a net mechanical energy efficiency of 36.5% or higher. This would be significantly higher than the current units (which due to their design and as a result of over 30 years of operational degradation are assumed to have a mechanism efficiency of around 30%). There will also be opportunities to undertake detailed BAT assessments covering topics including fuel gas pre-heating and valve actuation.
- St Fergus Compressor Upgrade
  Similar to the above ongoing works to implement the planned major compressor upgrade At St Fergus Terminal (subject to Ofgem funding approval) will deliver a range of opportunities for implementation of BAT based technology in terms of CMT and BoP.
- NARC Phase 3 and 4
  Planned works comprising the third and fourth stages of the National AGI Renovation Campaign (NARC) (subject to Ofgem funding approval) will provide opportunities, on a project by project basis, for evaluation of valve actuator replacement options based on BAT principles.
- St Fergus Asset Health Campaign
  A project has been proposed to consider replacement valve actuators at St Fergus Terminal as part of the wider asset health upgrade works. The project, which remains subject to Ofgem funding approval, could see the replacement of a significant number of old gas-driven actuators by new electro-hydraulic actuators.

4.6.2 Site specific opportunities

Table 10 below identifies the sites shortlisted in the site screening exercise discussed in ***Section 4.2***. and introduces, where relevant, potential site-based opportunities that have been identified during the course of this review.

Table 10 Site specific energy efficiency opportunities

Site	Energy efficiency opportunities
Aberdeen	• No specific opportunities identified yet, National Grid to keep site under review for possible opportunity assessment.
Avonbridge	• Site operations identified the potential operational and energy efficiency benefits which may arise from consideration of VSD drives on the oil cooling systems, in particular the benefits that this could bring in terms of managing fuel gas temperature in winter running. Detailed technical feasibility study, BAT assessment and financial appraisal would be required to determine if potentially viable.
Bishop Auckland	• No specific opportunities identified yet, National Grid to keep site under review for possible opportunity assessment.
Churchover	• Potential for air compressor variable speed drive upgrades similar to those under consideration at Wormington as much plant is of a common design (see below). Detailed technical feasibility study, BAT assessment and financial appraisal would be required to determine if potentially viable.
Nether Kellet	• No specific opportunities identified yet, National Grid to keep site under review for possible opportunity assessment.
Diss	• No specific opportunities identified yet, National Grid to keep site under review for possible opportunity assessment.
Kirriemuir	• The potential for re-wheeling VSD electric drive Unit E will be kept under review.
Wormington	• New air compressors with VSD are proposed to be installed at Wormington in early 2019. Based on a proposal provided by Atlas Copco, the two existing GA160 units (160kW electrical input) will be replaced with two GA132VSD units (132kW electrical input). These new units will incorporate VSDs which are anticipated to further reduce the input demand by 35%. The site's compressed air demand is continuous, serving the nitrogen generators (required for the dry gas seals) and actuators which are pneumatic driven pistons. The installation of the new units will achieve an anticipated annual cost saving of £65,000 and a carbon saving of 250tCO_2e. • Up to 80% of the electrical energy demand of an air compressor is lost as heat. This heat can be reclaimed in many ways, thus increasing the overall efficiency of the unit. At Wormington consideration is being given to the potential reclamation of this heat. Current opportunities include supply of space heating and hot water to the offices which would render the current gas boilers obsolete (additional savings include the elimination of maintenance of boilers and fire detectors). Other potential opportunities include preheating of fuel gas and maintenance of lube oil temperatures when the generators and gas compressors are off. Further analysis is due to be undertaken. If full heat reclamation is achieved, the indicative annual savings (against heat supply by gas boilers) could be £21,800 with carbon savings of 138tCO_2e.

5 Conclusions

This energy efficiency review has identified that National Grid has made real and demonstrable progress in energy efficiency and greenhouse gas management in the period since the last review in 2014, within the network of permitted compressor installations, the wider NTS and as a corporate entity. The focus of these works has been on network-wide opportunities with the greatest potential to deliver material change, although a number of site-specific improvements have also been implemented.

The degree to which energy efficiency and greenhouse gas emissions are prioritised in major project investments is on the leading edge, driven by policy decisions within the business which saw the implementation of decision making based on BAT assessment (the T/SP/ENV/21 and T/SP/ENV/22 processes to determine CMT and BoP BAT respectively). Change management programmes and initiatives to investigate and control venting and leakage are continuing to drive improvements in performance.

The 2014 review identified a series of opportunities for consideration at a local level, as presented in ***Appendix 2***. Whilst progress has been made, a number of restrictions have impacted on National Grid's ability to deliver local level objectives of this nature, given ever tightening budget restrictions, and the complexities associated with operating with a widely dispersed network with extensive asset health issues, in a regulated financial environment. These restrictions are only going to increase as the business prepares for and moves into the next phase of the RIIO price control period; all expenditure decisions need to be made holistically balancing a wider range of safety, operational, financial, and reliability factors at a network level.

For this reason, the methodology applied in carrying out this review has been adapted to reflect the wider shift from a largely site-based document to one which reflects a network-wide approach. This review seeks to provide the necessary site-specific requirements of the permit condition but set up the basis for the next four years to adopt a network-wide approach, this being consistent with the wider approach that is being applied across business to rationalise investment prioritisation.

A number of cross-network opportunities have been identified, some of which continue initiatives that have already commenced, while others represent emerging opportunities. In line with the asset health campaign and investment theme approach, a series of opportunities based on National Grid's asset class divisions have been identified; as have a series of higher priority sites which could be suitable for future opportunity roll-out. With energy and BAT considerations now established as business-as-usual (BAU), this subject will continue to directly influence major investments on the network, underpinned by corporate policy decisions and management buy-in.

Due to the inherent variability in the gas supply and demand patterns, which are outside of National Grid's control, it is very hard to predict future network operating conditions for a period as long as four years, so conclusions reached and investments described remain subject to change for unforeseen reasons. However, energy (and process gas release) management has every potential (based on the information obtained and personnel interviewed in compiling this review) to further establish itself as a major business driver in the next four years and beyond.

Appendices

Appendix 1 Updated site profiles

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Aberdeen Compressor Station* Permit number: *PPC/A1008692*

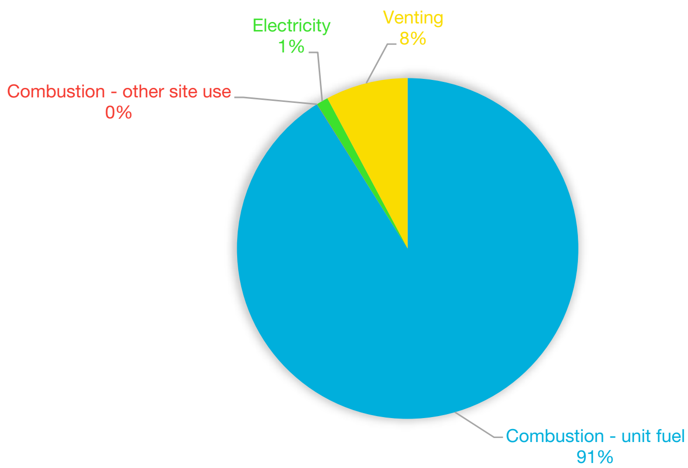
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	47,478	29	1,085	4,234	52,826
2010	17,132	39	894	4,802	22,867
2011	2,704	15	936	3,372	7,027
2012	5,951	3	998	4,571	11,523
2013	61,382	99	1,366	7,204	70,052
2014	20,342	51	1,243	4,170	25,806
2015	25,778	13	1,343	5,309	32,443
2016	79,482	18	1,431	7,760	88,692
2017	90,363	22	1,103	7,736	99,223

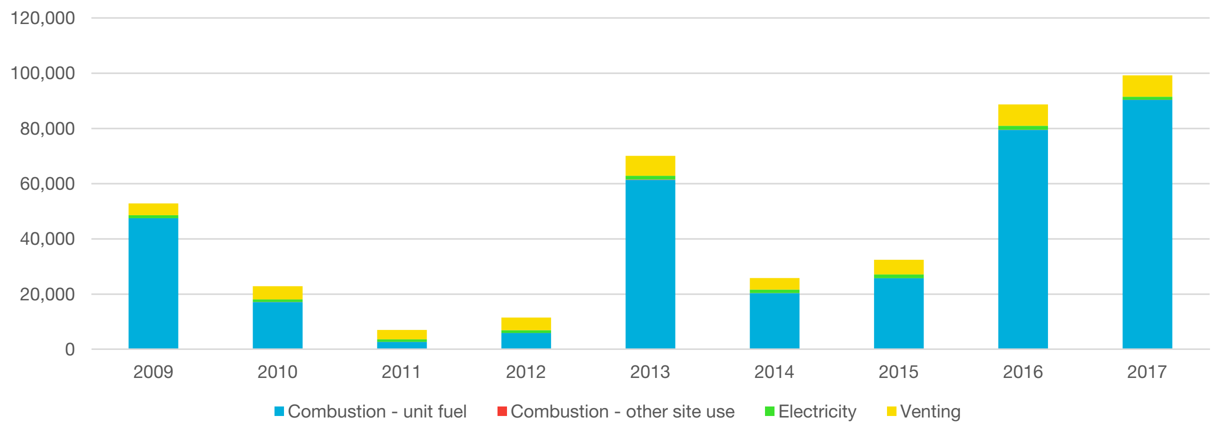
Notes

- 2009-2013 data taken from 2014 Aberdeen Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Aberdeen Compressor Station* Permit number: *PPC/A1008692*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	30.5	GE LM2500+DLE	Dresser Rand DR61-P Vectra	Dresser Rand PD70	Dry
B	GT	30.5	GE LM2500+DLE	Dresser Rand DR61-P Vectra	Dresser Rand PD70	Dry
C	GT	30.5	GE LM2500+DLE	Nuovo Pignone HS PGT 25	Pignone PCL 802	Dry

General description

Aberdeen currently consists of 3 x LM2500 DLE gas turbine units. The usual mode of operation is either a single unit or two units operating in parallel with the remaining unit(s) providing standby. Each of the three (A, B & C) low emission gas turbine driven machinery trains have the same power rating but differ in their compressor performance characteristics. This difference aims to offer sufficient performance flexibility to effectively manage a wide range of potential process conditions. Two matched machines, A&B, cover the highest process demand requirements with a single machine, C optimised to meet the lower flow requirements. There is capability to load share between any two of the three machines when necessary, although inevitably with some compromise in terms of optimisation against certain demand conditions. The use of Aberdeen is primarily determined by flows through the St Fergus terminal and associated process conditions across the Scottish portion of the NTS. However, system configurations for high terminal flows further south on the Network require also influence the operation of the station, requiring either a reduction in head across the station or for the East coast feeder to be configured on the suction of Aberdeen, reducing throughput. National Grid's foremost strategy is to optimise the use of the DLE gas Turbine units to ensure the most efficient configuration is utilised to meet the prevailing operational requirements. Recent flows indicate that extended use of a single machine, Unit 'C' at Aberdeen may meet the system requirements into the future. However, on occasions where process conditions have been unsuited to efficient A or B machine operation, use of other network compression installations has been a requirement to deliver our gas transmission throughput obligations.

There is still uncertainty of future supplies through St Fergus and hence operational requirements. National Grid continue to monitor the potential for new gas supplies to be delivered at St Fergus in addition to monitoring the rate of depletion of established UKCS gas fields. St Fergus flows have recently increased significantly, although they remain below current unit design. If this trend is sustained, then re-wheeling may become an option to increase efficiency.

Status

High forecast utilisation with one unit operation becoming the norm unless flows from St Fergus increase or there are requirements for high Scottish line pack or to meet the Scottish Assured Pressures.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Alrewas Compressor Station* Permit number: *PP3039LM*

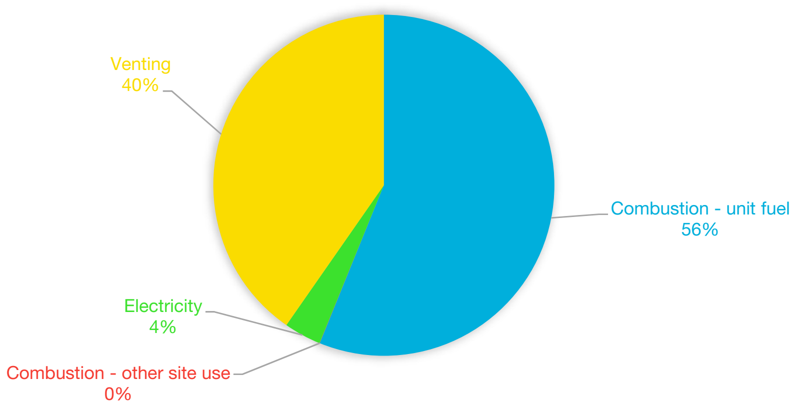
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	2,578	18	445	420	3,460
2010	13,523	13	497	1,929	15,962
2011	10,028	7	510	2,063	12,608
2012	1,633	2	419	1,964	4,018
2013	1,430	9	301	1,354	3,093
2014	607	13	278	1,589	2,488
2015	660	14	324	2,112	3,111
2016	154	6	208	1,511	1,879
2017	3,606	2	227	2,590	6,424

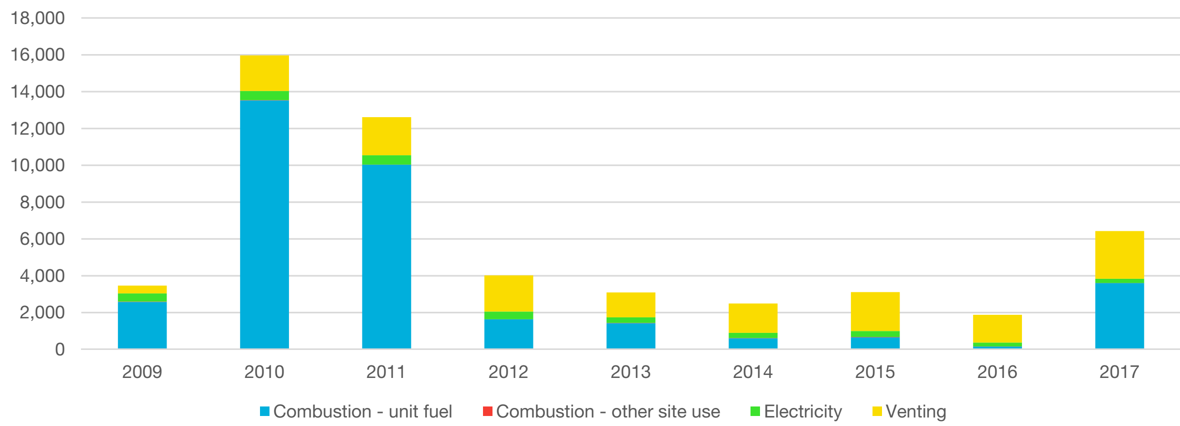
Notes

- 2009-2013 data taken from 2014 Alrewas Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site:	*Alrewas Compressor Station*	Permit number:	*PP3039LM*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	12	Avon 1533-75G	Rolls Royce RT48	Rolls Royce RFB30	Dry
B	GT	12	Avon 1533-75G	Rolls Royce RT48	Rolls Royce RFB30	Dry
C	GT	15.5	Solar Titan 130S	Solar Integral Turbine	Dresser Rand PDI60	Dry

General description

Alrewas consists of 1 x Solar Titan DLE and 2 x Avon gas turbines and where availability and operating conditions allow, the lead unit is the Solar Titan with the Avon units providing standby. Under low and high flow conditions the operational duty may be such that an Avon operating by itself or in parallel with another will be required. Given the versatility of the multijunction, significant flexibility is offered in the configuration of compression available to the network. Alrewas has traditionally been used seasonally during the winter to help meet high gas demands in the south west by pushing gas southwards from St Fergus however it has a number of multijunction configurations available and is used to compress gas eastwards for high interconnector exports and can be reversed to push gas northwards particularly in recent times to accommodate high Milford Haven flows. The duty requirements under this scenario have also been directly impacted by the availability and performance of the upstream plant (to the south) i.e. Wormington and Churchover. The utilisation of Alrewas compressors will be influenced by the interaction between St. Fergus and Milford Haven supplies. It will still be required to be operational in its traditional direction under low Milford flow scenarios while being required to reverse under high flow from Milford Haven. Future operational requirements will not be fully understood until the Felindre compressor station is fully operational. Additionally, the potential North West storage sites are likely to impact upon operation of Alrewas, particularly under scenarios when the storage sites are filling and compression may be required to operate north to satisfy this added regional demand. Given the number of potential triggers for increasing Alrewas utilisation it is anticipated that further investment will be required at this site in the future.

Status

Low forecast utilisation site, DLE gas turbine unit as lead machine. MCPD strategy for the two Avons being developed.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Avonbridge Compressor Station* Permit number: *PPC/E/20045*

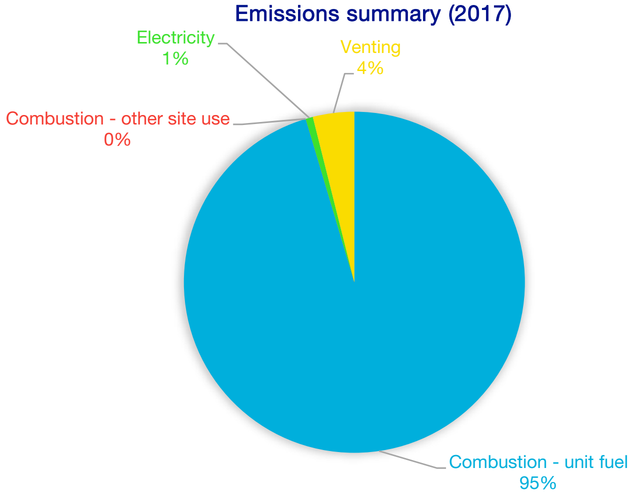
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	57,389	2	1,318	765	59,474
2010	75,001	0	1,443	8,603	85,048
2011	1,593	9	980	3,212	5,794
2012	282	75	1,015	2,414	3,787
2013	21,639	1	986	4,114	26,741
2014	9,597	2	863	5,148	15,610
2015	28,421	13	958	1,752	31,144
2016	89,913	3	906	3,843	94,664
2017	89,931	3	649	3,695	94,278

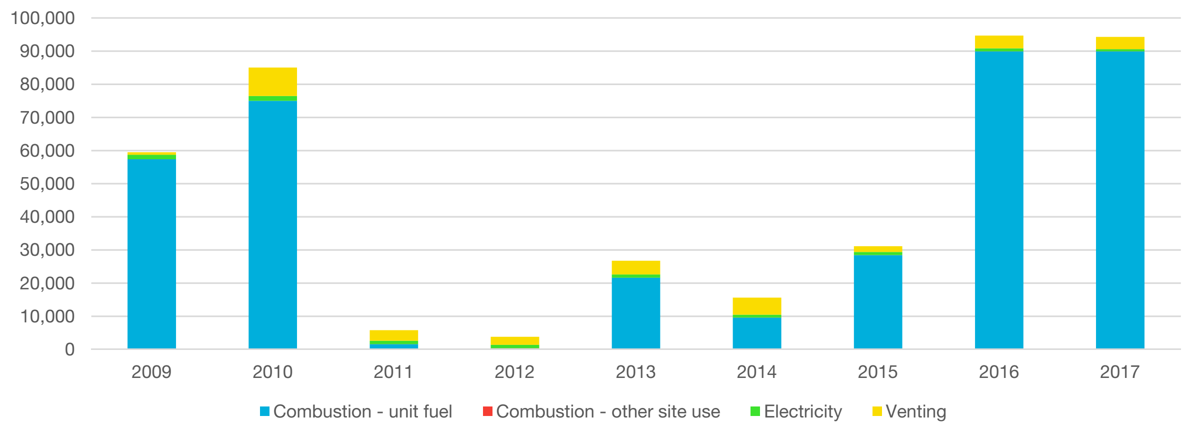
Notes

- 2009-2013 data taken from 2014 Avonbridge Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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Compressor Station GHG Emissions Summary

Site: *Avonbridge Compressor Station* Permit number: *PPC/E/20045*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
1A	GT	30.5	GE LM2500+DLE	Nuovo Pignone HS PGT 25	Pignone PCL 802	Dry
1B	GT	13.4	Siemens SGT400	Siemens Integral Turbine	Pignone PCL 602	Dry
2A	GT	30.5	GE LM2500+DLE	Nuovo Pignone HS PGT25	Pignone PCL 802	Dry
2B	GT	13.4	Siemens SGT400	Siemens Integral Turbine	Pignone PCL 603	Dry

General description

Avonbridge compressor station consists of 2 x LM2500 and 2 x Cyclone DLE gas turbine units. With flows from St. Fergus gradually reducing, Avonbridge is typically required when St Fergus is supplying gas into the NTS at average levels or during high Scottish line pack periods to move gas south. The higher input seen at St Fergus in 2016 and 2017 have increased the utilisation of the site.

Status

High forecast utilisation site, to meet the Scottish Assured Pressures.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Aylesbury Compressor Station* Permit number: *AP3139LE*

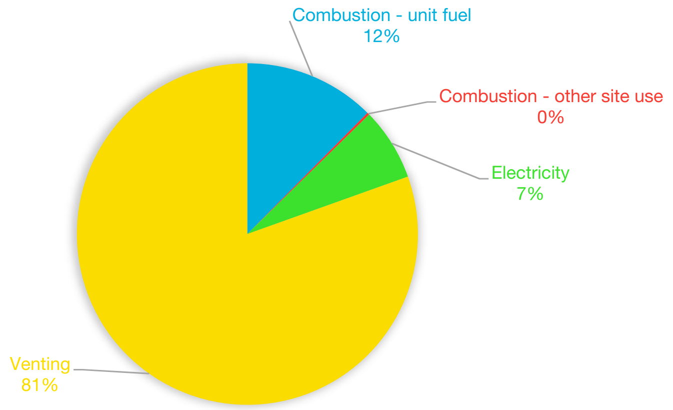
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	1,885	13	230	267	2,394
2010	9,031	45	220	1,025	10,321
2011	73	4	260	939	1,276
2012	86	144	86	681	997
2013	342	7	399	1,418	2,166
2014	129	2	242	790	1,164
2015	159	7	210	1,370	1,746
2016	254	7	153	1,690	2,104
2017	355	6	196	2,293	2,850

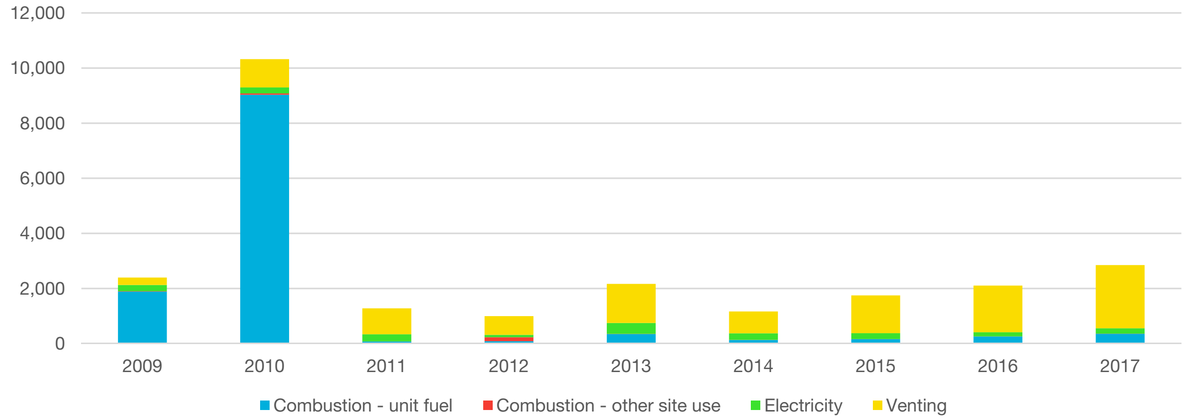
Notes

- 2009-2013 data taken from 2014 Aylesbury Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site:	*Aylesbury Compressor Station*	Permit number:	*AP3139LE*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	18.5	Avon 1535-DLE	Rolls Royce RT56	Dresser Rand 36	Wet
B	GT	18.5	Avon 1535-DLE	Rolls Royce RT56	Dresser Rand 36	Wet

General description

Aylesbury consists of 2 x Avon (retrofit DLE) units. Located on the southern feeder the utilisation of Aylesbury is greatly affected by Southern and South West demand and hence its operation is largely seasonal. Aylesbury can be utilised to provide a backup capability to Lockerley compressor station as well as supporting South NTS demand (primarily Langage Power Station and Choakford Offtake at the SW extremity of the NTS). Improved Lockerley availability, coupled with milder weather, can significantly reduce the required operation of Aylesbury. Aylesbury operation into the future is forecast to remain in the region of current levels and possibly rise with demand growth and it is required to support the 1 in 20 requirement. As the engines are currently compliant on NOx across the entire operating range, National Grid are currently planning the installation of CO oxidation catalyst to bring CO emissions into compliance with the ELVs.

Status

Low forecast utilisation site, old gas turbine units retrofitted with DLE technology – investment in progress. Both units are being fitted with exhaust catalyst systems to enable them to meet IED ELVs. One has been operationally accepted, the other is expected to be in mid-2018.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Bishop Auckland Compressor Station* Permit number: *SP3938LQ*

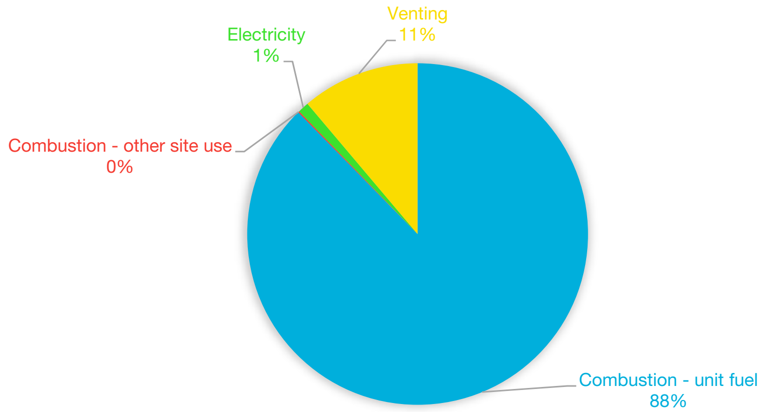
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	3,064	70	622	2,118	5,874
2010	1,011	59	519	1,339	2,927
2011	711	48	519	1,401	2,679
2012	6,185	59	616	3,343	10,203
2013	3,264	88	576	3,712	7,640
2014	1,446	50	473	2,530	4,499
2015	8,339	55	543	2,709	11,646
2016	45,979	72	581	4,408	51,039
2017	53,473	72	638	6,828	61,012

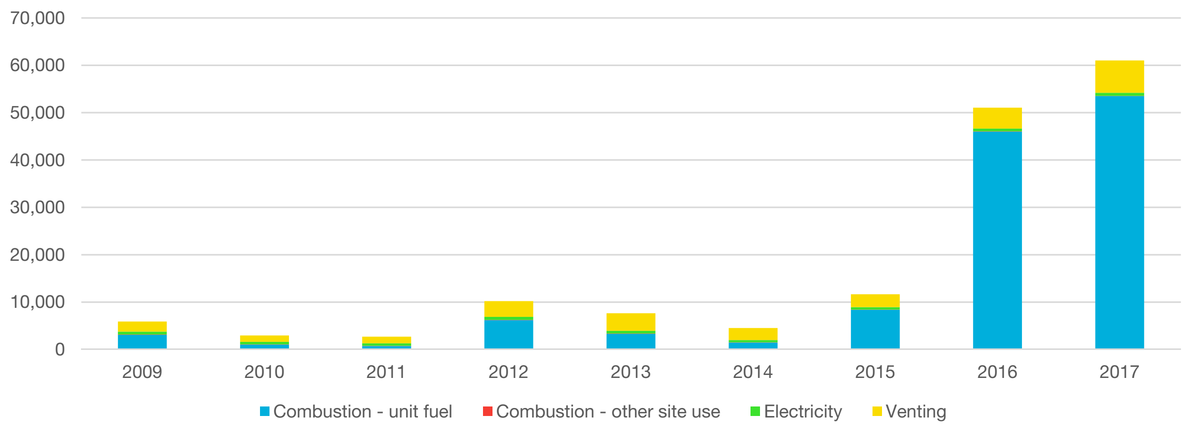
Notes

- 2009-2013 data taken from 2014 Bishop Auckland Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Bishop Auckland Compressor Station* Permit number: *SP3938LQ*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	31.4	GE LM2500+DLE	Dresser Rand 40G	Dresser Rand PDI70	Dry
B	GT	31.4	GE LM2500+DLE	Dresser Rand 40G	Dresser Rand PDI70	Dry

General description

Bishop Auckland consists of 2x LM2500 DLE gas turbines and has historically been used for north to south bulk transmission of gas particularly for high St Fergus and Teesside inputs. Bishop Auckland compressor station has seen increased running hours due to the increased inputs at St Fergus since 2016. The installation is also used to support a local industrial load on a periodic basis. Bishop Auckland is a key multijunction in the network and will be the primary station considered for investment to enable compression to the north. Should such investment be completed then plant capability will be reviewed.

Status

High forecast utilisation site, DLE gas turbine units – monitor.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Cambridge Compressor Station* Permit number: *DP3739LX*

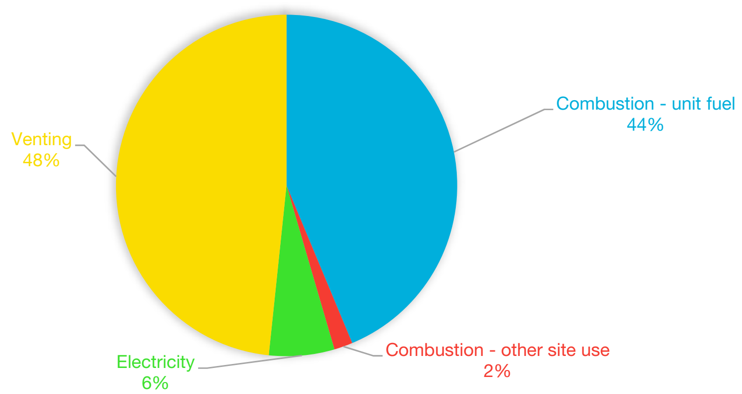
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	323	19	347	1,277	1,965
2010	652	14	186	575	1,427
2011	130	11	182	1,215	1,538
2012	366	15	242	1,633	2,255
2013	323	39	261	1,309	1,932
2014	287	82	180	1,288	1,838
2015	858	113	228	1,972	3,171
2016	2,946	48	199	2,060	5,253
2017	1,558	63	221	1,723	3,565

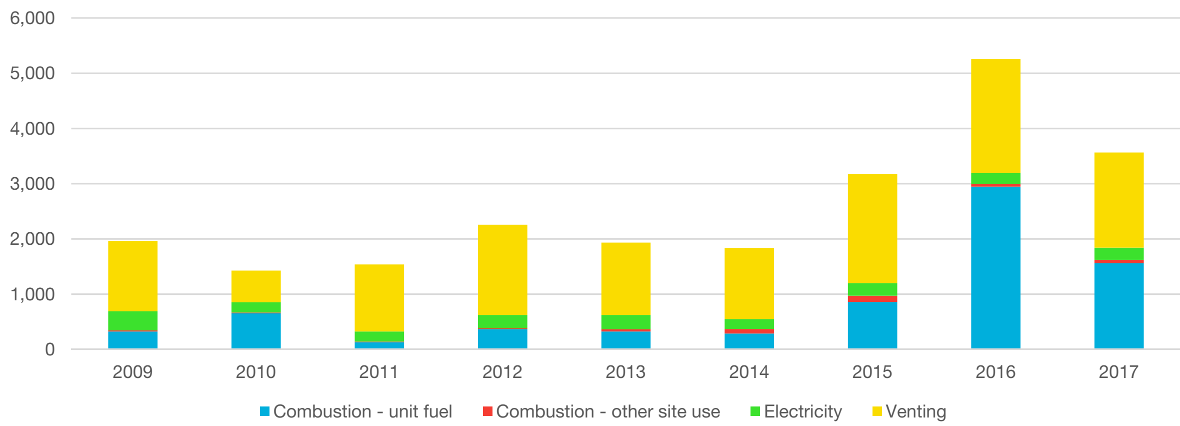
Notes

- 2009-2013 data taken from 2014 Cambridge Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site:	*Cambridge Compressor Station*	Permit number:	*DP3739LX*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	12	Avon 1533-75G	Rolls Royce RT48	Rolls Royce RF2-1B30	Wet
B	GT	12	Avon 1533-75G	Rolls Royce RT48	Rolls Royce RF2-1B30	Wey
C	GT	13.4	Siemens SGT400	Siemens Integral Turbine	DeLaval PV37	Dry

General description

Cambridge consists of 1 x Cyclone SGT400 DLE and 2 x Avon gas turbine units and the usual mode of operation is one solitary unit or two units operating in series with the remaining unit(s) providing standby. The preferred configuration is the solitary operation of the newer Cyclone DLE unit. Cambridge has traditionally been required to operate seasonally during periods of high demand in the South East. The operation of Cambridge has increased as a result of constraints on the network meaning it has been used to support demand in the South East. Additionally, Cambridge may be required to compress gas to the west under very high Grain LNG inputs.

Status

Medium forecast utilisation site, DLE gas turbine unit as lead machine. MCPD strategy for the two Avons being developed.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

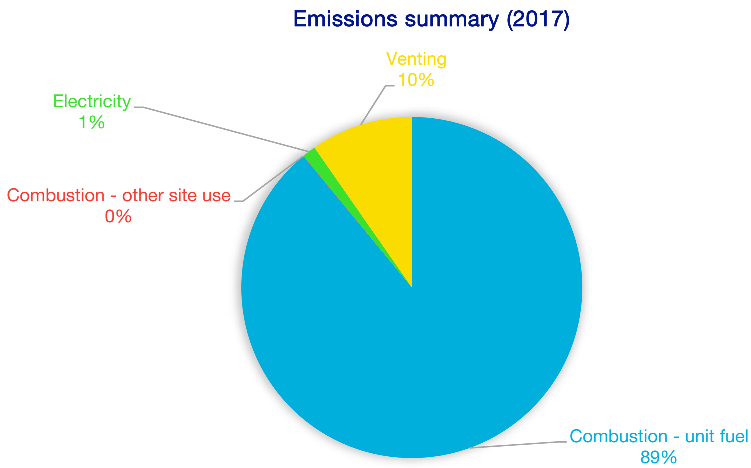
Site: *Carnforth Nether Kellet Compressor Station* Permit number: *BU5631IR*

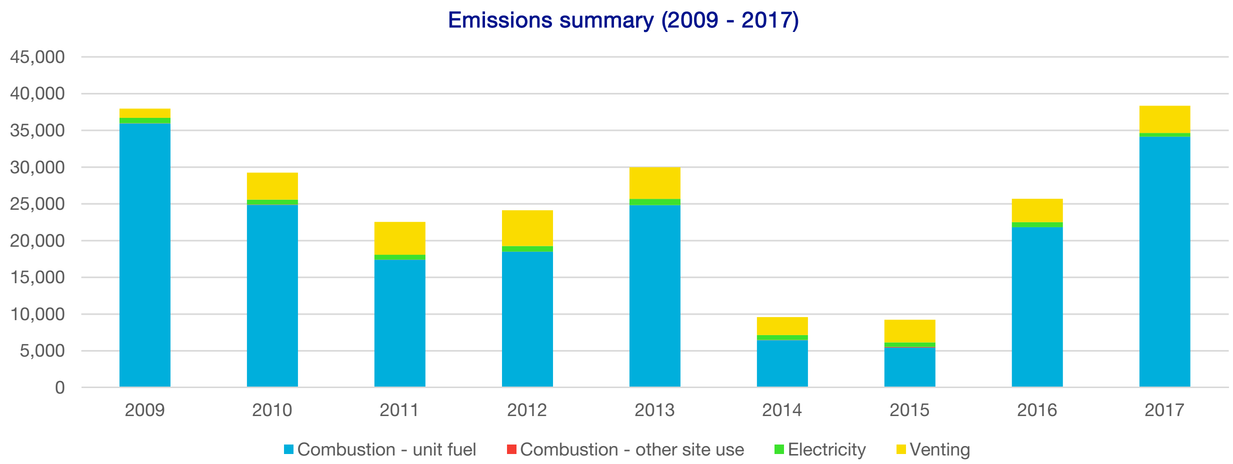
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	35,933	29	735	1,263	37,960
2010	24,856	54	667	3,663	29,241
2011	17,382	12	669	4,472	22,535
2012	18,477	16	772	4,861	24,126
2013	24,799	17	862	4,307	29,985
2014	6,445	20	669	2,453	9,588
2015	5,434	84	623	3,088	9,229
2016	21,822	8	684	3,170	25,684
2017	34,137	9	493	3,711	38,349

Notes

- 2009-2013 data taken from 2014 Carnforth Nether Kellet Compressor Station Compressor Station GHG Emissions Summary report





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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Carnforth Nether Kellet Compressor Station* Permit number: *BU5631IR*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A (Carnforth)	0	0	No GG in berth.	Rolls Royce RT56	Rolls Royce RF2-1B30	Dry
B (Carnforth)	GT	24.7	RB211-24C	Rolls Royce RT56	Rolls Royce RF2-1B30	Dry
C (Carnforth)	GT	30.5	GE LM2500+DLE	Dresser Rand DR61-P Vectra	Dresser Rand PD70	Dry
A (Nether-Kellet)	GT	13.4	Siemens SGT400	Siemens Integral Turbine	Siemens DeLaval PV37	Dry
B (Nether-Kellet)	GT	13.4	Siemens SGT400	Siemens Integral Turbine	Siemens DeLaval PV37	Dry

General description

Carnforth compressor station is equipped with 1x LM2500 DLE and 1 x RB211 gas turbine driven compressors. The site is configured to allow the operation of a solitary LM2500, or a solitary RB211. The LM2500 as a solitary unit is the preferred unit for operation where possible. Carnforth is a gateway compressor station between the north and the south and has traditionally been required for bulk gas transmission down the west coast, predominantly from the northern terminals of St Fergus and Barrow. Recent years have shown a decline in its utilisation due to declining flows, especially those from St Fergus and the Barrow Terminal. For the majority of configurations Carnforth is considered as one with the most efficient stations chosen for lead operation depending on flow and head requirements. The majority of the forecast gas flows are within the capability of the LM2500 DLE gas turbine unit (depending on discharge pressure requirements) and hence are used as the lead units under most of the system requirements. New storage supply points downstream of Carnforth have recently reduced the need to run the stations when they are exporting but as these supply points have a high degree of operational variability they cannot be relied upon for consistent operation and supply to the network and when in Import mode they increase the local demand significantly. National Grid has an ongoing requirement for the station to maintain operational resilience. Possible future developments at Barrow terminal could see significantly different volumes, and/or quality, of process gas at Carnforth, which adds an element of uncertainty in the future utilisation of the station. Nether Kellet was built in 2001 consisting of 2x Cyclone DLE gas turbines and was originally built to meet demand and pressure requirements in feeder 11 towards Blackrod. These 2 units are able to operate in parallel with one another and these units are used singly or in parallel to meet certain flow conditions now being experienced. Although having separate control, it is situated adjacent to and is connected to the Carnforth station via a number of pipeline links. The smaller units of Nether Kellet are used instead of Carnforth where possible for low flow and head conditions although were not part of the original design concept. In addition, they are used in parallel for higher flow and head conditions. For the majority of configurations these stations are considered as one with the most efficient stations chosen for lead operation depending on flow and head requirements. The majority of the forecast gas flows are within the capability of the Cyclone SGT400 DLE gas turbine units (depending on discharge pressure requirements) and hence are used as the lead units under most of the system requirements. The higher inputs in 2016 at St Fergus have led to increased use of both Nether Kellet units operating in parallel. Potentially into the future there may also be a requirement for moving gas originating at Milford Haven northwards to support Scottish Line Pack. New storage supply points downstream of Nether Kellet have recently reduced the need to run the stations when they are exporting but as these supply points have a high degree of operational variability they cannot be relied upon for consistent operation and supply to the network and when in Import mode they increase the local demand significantly. National Grid has an ongoing requirement for the station to maintain operational resilience. Possible future developments at Barrow terminal could see significantly different volumes, and/or quality, of process gas at Nether Kellet, which adds an element of uncertainty in the future utilisation of the station.

Status

High forecast utilisation site, existing DLE gas turbine technology used as lead units – monitor efficiency and reliability of DLE units and maximise their usage. The two RB211's are not compliant with IED ELVs one of which will be decommissioned the other has been entered into the 500 hours derogation. We also intend to undertake additional site modifications to integrate the sites more closely and provide increased flexible operation. High forecast utilisation site, existing DLE gas turbine technology used as lead units – monitor efficiency and reliability of DLE units and maximise their usage. The two RB211's are not compliant with IED ELVs one of which will be decommissioned the other has been entered into the 500 hours derogation. We also intend to undertake additional site modifications to integrate the sites more closely and provide increased flexible operation.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO_2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Chelmsford Compressor Station* Permit number: *LP3839LV*

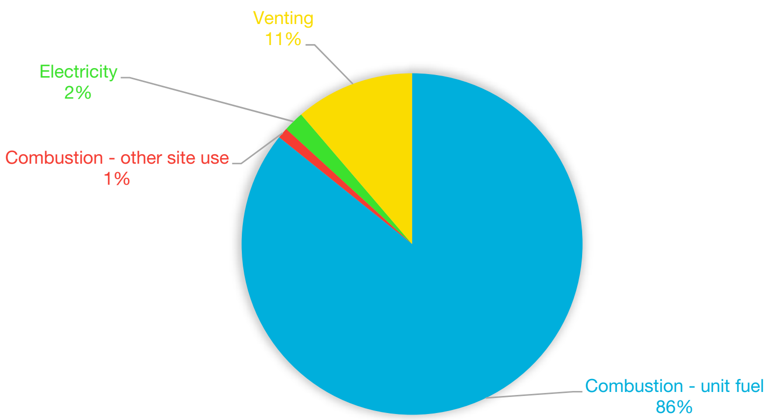
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	31	104	80	154	369
2010	116	132	82	252	583
2011	49	87	120	205	462
2012	64	103	119	406	693
2013	3,281	153	112	617	4,163
2014	29	115	85	179	408
2015	572	83	127	684	1,465
2016	1,265	71	255	440	2,031
2017	5,434	64	123	715	6,335

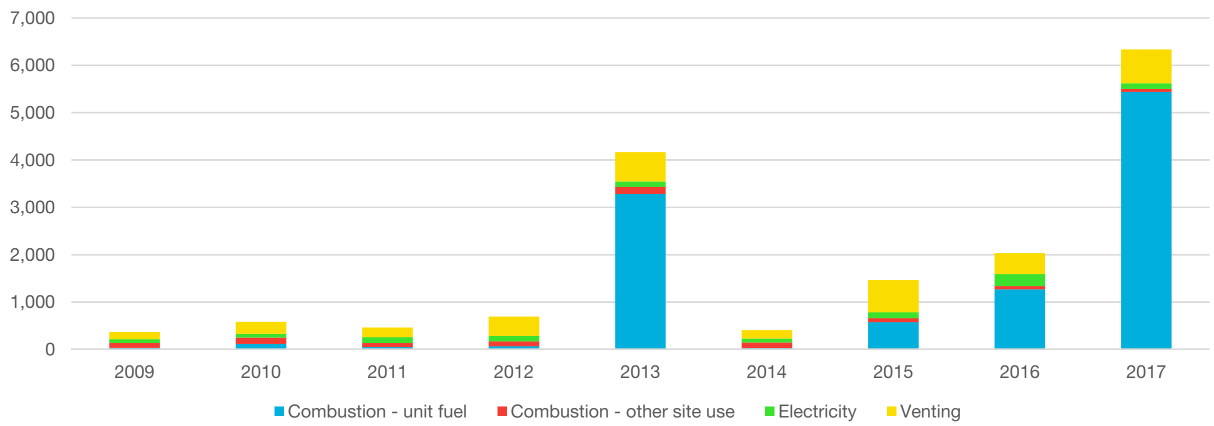
Notes

- 2009-2013 data taken from 2014 Chelmsford Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Chelmsford Compressor Station* Permit number: *LP3839LV*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	12	Avon 1533-76G	Rolls Royce RT48	Rolls Royce RF2-1B30	Wet
B	GT	12	Avon 1533-76G	Rolls Royce RT48	Rolls Royce RF2-1B30	Wet

General description

Chelmsford consists of 2 x Avon gas turbine units and has traditionally been required to operate seasonally during periods of high demand in the South East. The commissioning of additional future power stations and industrial demand development in the South East may see Chelmsford utilisation increase, if not matched by increased LNG deliveries. Hence it is anticipated that Chelmsford will still be required to be operational in its traditional configuration under combined high system demand and low Isle of Grain flow scenarios. Should significant expansion at the Isle of Grain terminal occur then there may be a requirement for Chelmsford multijunction to be modified to allow reverse operation in the future. Due to their locations being in close proximity, Diss and Chelmsford are considered to be closely interacting and so anticipated future utilisation changes carry the potential to influence either station.

Status

Low forecast utilisation site – monitor. Some interchangeability with Diss and utilisation highly dependent on the operation of local supply points. MCPD strategy for the two Avons being developed.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Churchover Compressor Station* Permit number: *P3135LV*

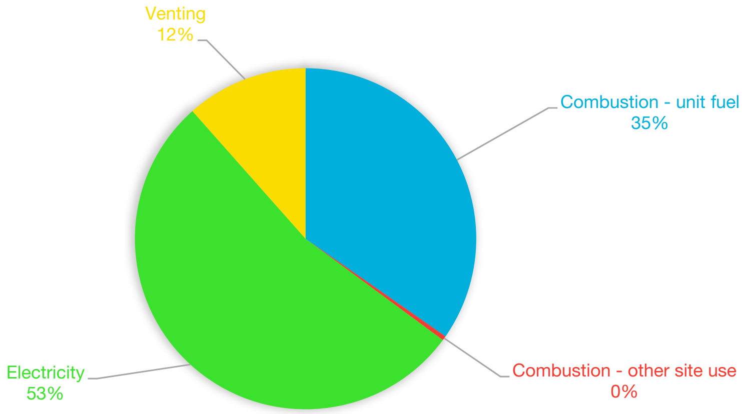
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	10,946	102	263	429	11,740
2010	4,075	104	1,195	1,471	6,846
2011	18,721	104	2,308	2,009	23,141
2012	717	78	1,395	734	2,924
2013	978	111	5,883	2,085	9,056
2014	75	77	2,626	2,210	4,988
2015	1,967	80	2,804	1,996	6,847
2016	1,195	79	4,731	2,245	8,249
2017	2,958	35	4,547	983	8,523

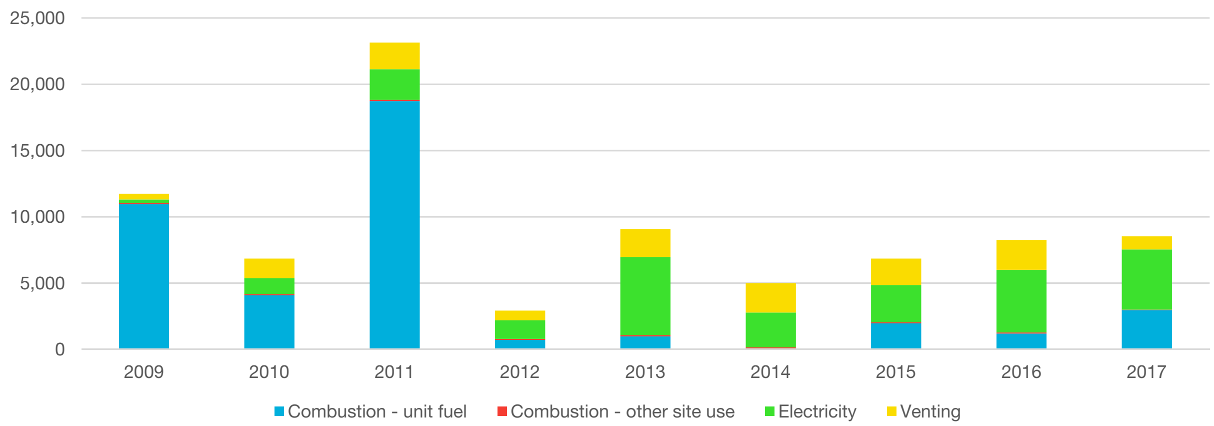
Notes

- 2009-2013 data taken from 2014 Churchover Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site:	*Churchover Compressor Station*	Permit number:	*P3135LV*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
D	GT	15.5	Solar Titan 130S DLE	Solar Integral Turbine	Dresser Rand PDI60	Dry
E	EL	16	Siemens	N/A	Siemens STC/SV	Dry

General description

Churchover currently consists of 1 x Solar Titan DLE and a 15MW electric drive VSD. The electric VSD unit became operationally available in early 2013. Historically the preferred configuration has been the solitary operation of the Solar Titan unit although as performance of the new electric VSD becomes more established, the VSD has taken up lead bulk duty and this trend has been observed over the course of the past winter. Future utilisation of Churchover compressor will be largely influenced by levels of Milford Haven flow, the availability of upstream compression at Felindre and Wormington and the interaction with local network demand. Further observation of this interaction is required to adequately forecast future utilisation.

Status

The electric VSD unit became operationally available in early 2013 and is now the lead unit. Medium forecast utilisation.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Diss Compressor Station* Permit number: *LP3539LH*

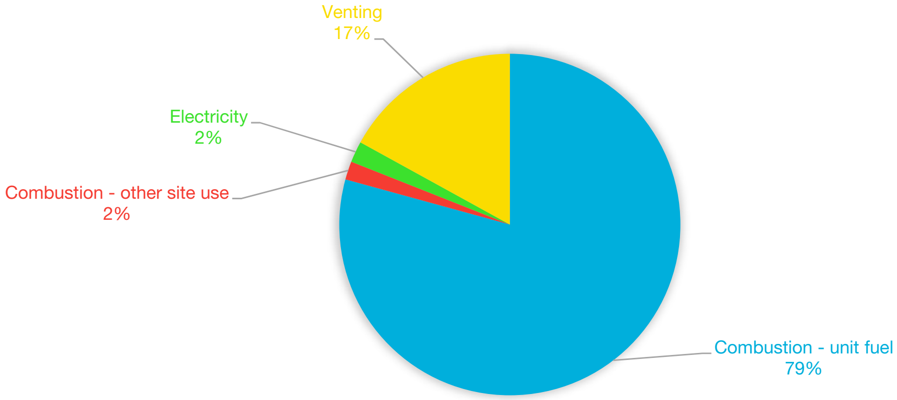
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	513	127	160	372	1,171
2010	2,234	138	141	995	3,508
2011	40	123	120	506	790
2012	66	123	128	347	663
2013	5,535	161	186	1,102	6,985
2014	215	140	108	572	1,034
2015	873	127	178	1,540	2,719
2016	2,019	138	167	1,144	3,467
2017	7,718	169	195	1,656	9,736

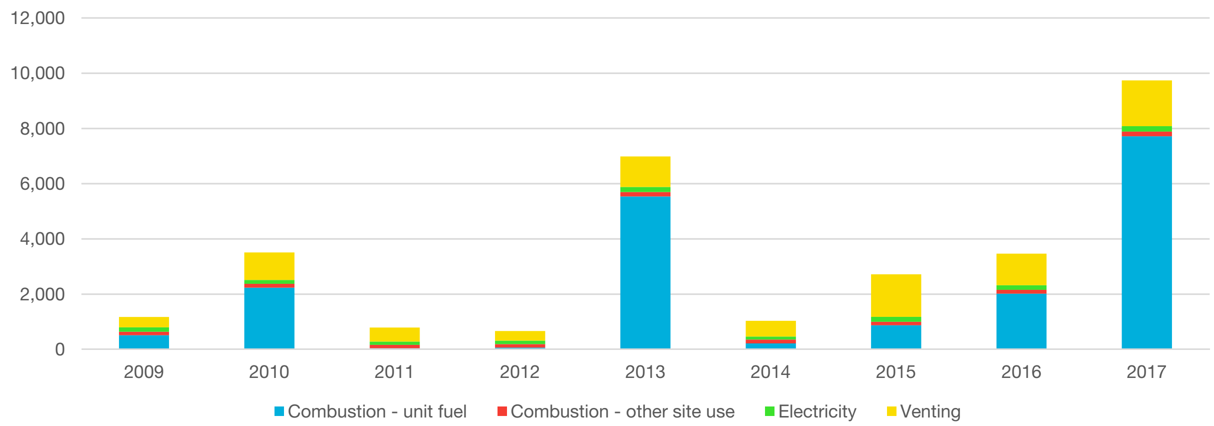
Notes

- 2009-2013 data taken from 2014 Diss Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Diss Compressor Station* Permit number: *LP3539LH*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	12	Avon 1533-76G	Rolls Royce RT48	Rolls Royce RF2-1B30	Wet
B	GT	12	Avon 1533-76G	Rolls Royce RT48	Rolls Royce RF2-1B30	Wet
C	GT	12	Avon 1533-76G	Rolls Royce RT48	Rolls Royce RF2-1B30	Wet

General description

Diss consists of 3 x Avon gas turbine units and the usual mode of operation is one solitary unit or two units operating in series with the remaining unit(s) providing standby. Diss has traditionally been required to operate seasonally during periods of high demand in the south east. Its operation is being directly impacted by imports of LNG at the Isle of Grain which offsets south east NTS demand. Diss has experienced a small increase in utilisation during 2017 due to an operational issue at another site which meant that Kings Lynn's operation were limited so Diss was needed to back up gas flow requirements during this period. Diss will still be required to be operational in its traditional configuration under combined high system demand and low Grain LNG flow scenarios. However, should supplies located in the South East increase sufficiently, then there may come a time when reverse operation is required and utilisation may increase from the current low forecast. As such, Diss is considered to be a potential site at which investment may be required. Due to their locations being in close proximity, Diss and Chelmsford are considered to be closely interacting and so anticipated future utilisation changes carry the potential to influence either station.

Status

Medium forecast utilisation site – monitor. Some interchangeability with Cambridge and utilisation highly dependent on the operation of local supply points. A potential future priority site for investment as MCPD strategy for the two Avons being developed.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

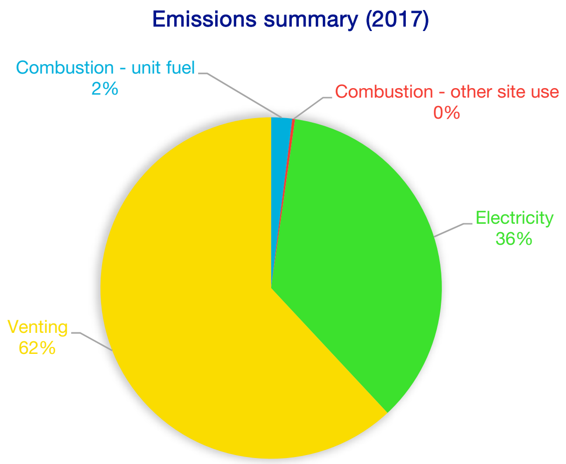
Site: *Felindre Compressor Station* Permit number: *RP3232LD*

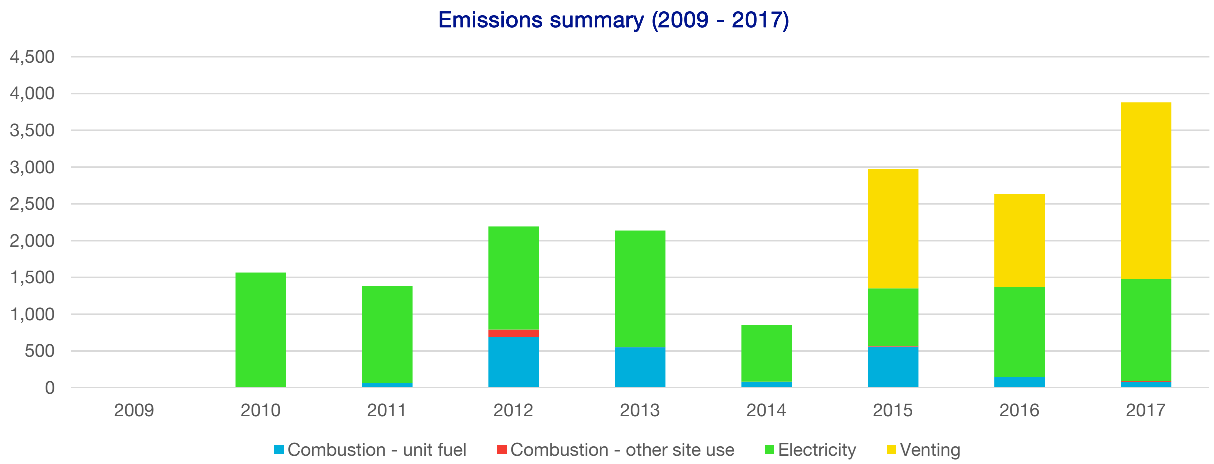
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	0	0	0	0	0
2010	0	0	1,566	0	1,566
2011	62	0	1,322	0	1,384
2012	689	102	1,401	0	2,192
2013	549	5	1,583	0	2,137
2014	76	6	771	0	853
2015	560	7	783	1,624	2,974
2016	145	1	1,223	1,262	2,632
2017	77	10	1,389	2,402	3,878

Notes

- 2009-2013 data taken from 2014 Felindre Compressor Station Compressor Station GHG Emissions Summary report





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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Felindre Compressor Station* Permit number: *RP3232LD*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	EL	35	Siemens	N/A	Rolls Royce RF1BB-36	Dry
B	GT	15	Solar Titan 130S DLE	Solar integral turbine	Solar C85	Dry
C	GT	15	Solar Titan 130S DLE	Solar integral turbine	SolarC85	Dry

General description

Felindre is a new station and is required to transport bulk Milford Haven gas flows into the system. The station was completed at the end of 2008 but cannot be fully commissioned until sufficient flows from Milford Haven materialise. It has been built as a hybrid site with a 30MW electric VSD as the lead unit with 2 x 15MW Solar Titan DLE gas turbines as standby; the gas units are designed to operate in isolation or in parallel with each other and the electric VSD designed to operate as a solitary unit. These units have been designed to accommodate a range of duty requirements with the appropriate units and configurations being selected to meet the prevalent conditions. The operation of Felindre is solely required to meet high levels of Milford Haven imports.

Status

Commissioning of the 2 new DLE gas turbines has been completed with Operational Acceptance agreed in December 2015. Work to commission the electric drive is now in progress.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

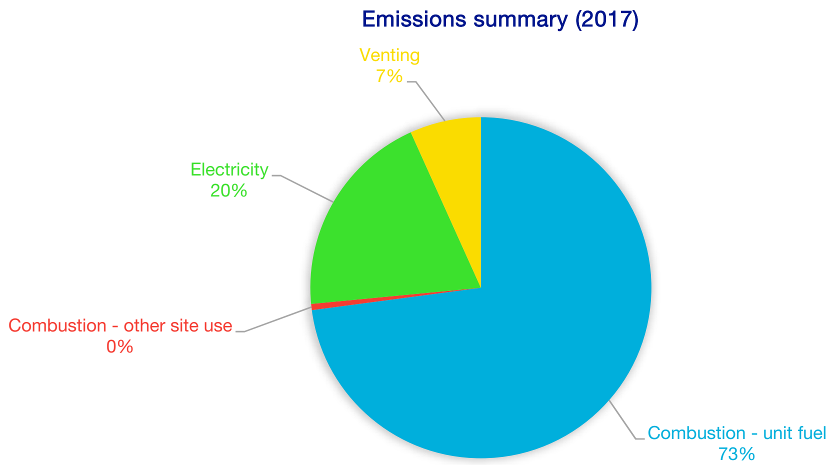
Site: *Hatton Compressor Station* Permit number: *UP3333LL*

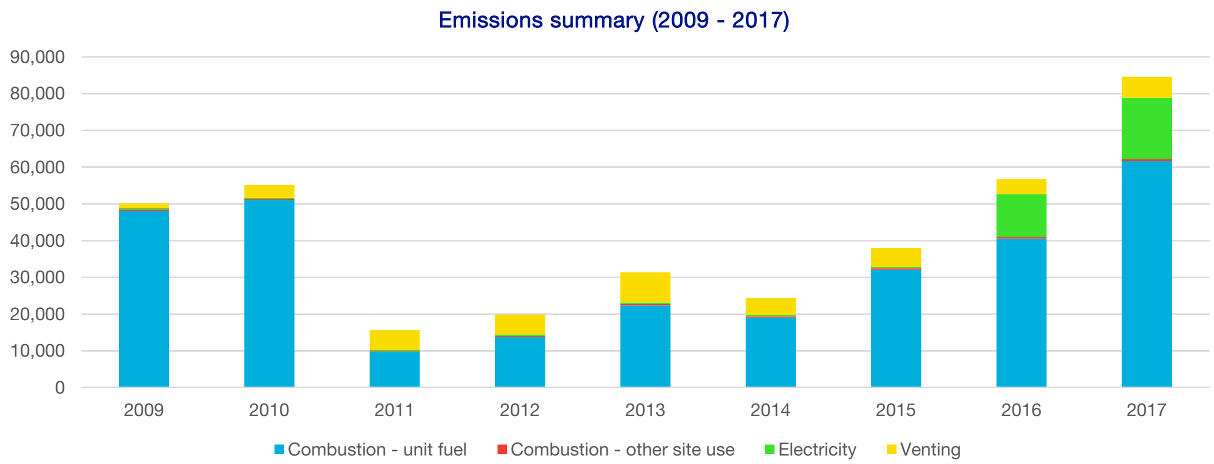
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	48,055	408	406	1,220	50,090
2010	50,957	400	315	3,501	55,174
2011	9,664	219	352	5,370	15,605
2012	13,818	243	361	5,460	19,882
2013	22,366	348	442	8,195	31,351
2014	19,056	313	365	4,609	24,344
2015	32,095	360	443	5,045	37,943
2016	40,535	393	11,640	4,110	56,678
2017	61,660	491	16,723	5,705	84,578

Notes

- 2009-2013 data taken from 2014 Hatton Compressor Station Compressor Station GHG Emissions Summary report





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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Hatton Compressor Station* Permit number: *UP3333LL*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	24.7	RB211-24C	ERB1	Siemens DeLaval 2PB62	Dry
B	GT	24.7	RB211-24C	ERB1	Siemens DeLaval 2PB62	Dry
C	GT	24.7	RB211-24C	ERB1	Siemens DeLaval 2PB62	Dry
D	EL	35	Siemens	N/A	RFBB36	Dry

General description

Hatton consists of 3 x RB211 gas turbine units and the new 35MWe electric drive VSD and, like Carnforth, is a gateway compressor station between the north and the south and has traditionally been required for bulk gas transmission, transporting northern supplies to the southern demand centres. With St Fergus, Teesside, Easington and Theddlethorpe terminals including various storage sites located to the north, its operation has been greatly affected by input levels from these supply points. Hatton's operation became less seasonal with the construction of the UK interconnector at Bacton, requiring it to operate during the summer to transport gas towards the Interconnector for export. Hatton was a site identified as a high priority site for investment to reduce emissions. Due to the number of supply permutations and configurations (especially into the future) it has been difficult to predict required operating characteristics. Forecast variations in gas supplies from the Easington area and other developments across the system will affect the utilisation of Hatton. Net north to south flows may reduce should consistently high gas flows materialise from the Grain LNG importation terminal in the south east. However, these may be offset by increased interconnector exports and/or the filling of potential new storage facilities at Bacton. Hatton is a compressor station that will continue to be required to meet many of the supply pattern permutations possible into the future. The new 35MW electric VSD compressor unit, to take up the bulk duty of the site, has now been operationally accepted and has entered commercial service.

Status

High forecast utilisation. New electric VSD is available, and in service. Three RB211s not compliant with IED ELVs, two entered into Limited Lifetime derogation and one entered into the 500 hour derogation. The plan is in the early stages of development, with FEED and BAT studies to determine future plant configuration.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Huntingdon Compressor Station* Permit number: *DP3139LA*

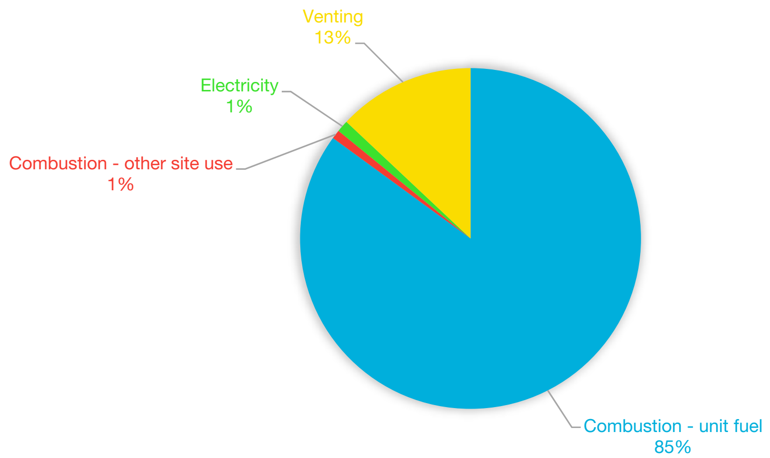
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	22,371	209	186	1,035	23,801
2010	47,513	308	175	1,715	49,710
2011	10,509	172	177	1,471	12,329
2012	6,088	150	226	1,582	8,046
2013	29,094	265	351	3,432	33,142
2014	18,639	205	271	2,536	21,651
2015	11,364	178	989	2,390	14,921
2016	13,126	189	1,500	2,497	17,312
2017	23,931	241	316	3,655	28,142

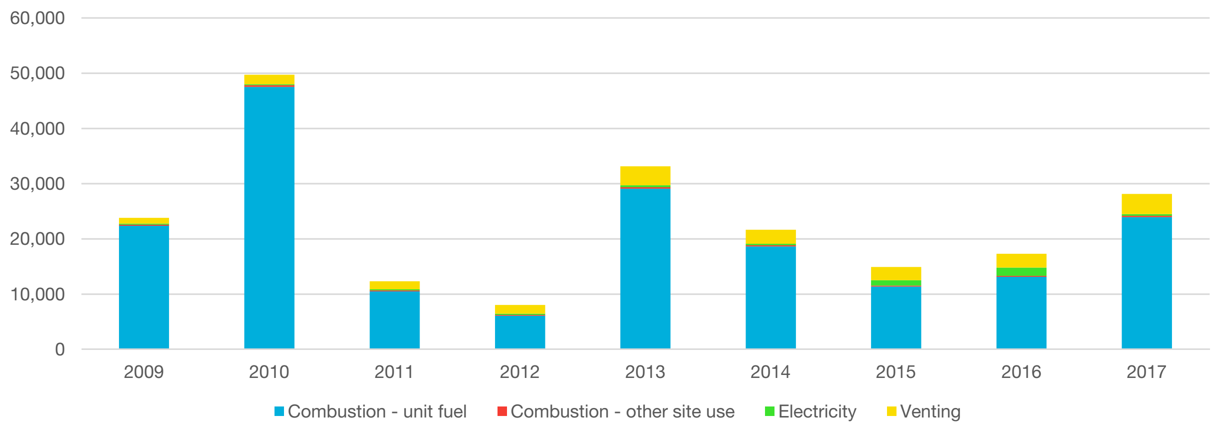
Notes

- 2009-2013 data taken from 2014 Huntingdon Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Huntingdon Compressor Station* Permit number: *DP3139LA*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	12	Avon 1533-75G	EASI-33	Siemens DeLaval 30/30	Wet
B	GT	12	Avon 1533-75G	EASI-33	Siemens DeLaval 30/30	Wet
C	GT	12	Avon 1533-75G	Rolls Royce RT48S	Rolls Royce RF2-1B30	Dry

General description

Huntingdon consists of 3 x Avon gas turbine units and the usual mode of operation is one solitary unit or two units operating in parallel with the remaining unit(s) providing standby. Huntingdon is similar in some respects to Peterborough (immediately to the north) and for some network conditions can be considered interchangeable although often Huntingdon is located too far south to be able to match the capability provided by Peterborough. Similarly to Hatton, Huntingdon's operation is affected by the flows from the terminals to the north, Bacton terminal including the interconnectors to the east and LNG imports at Isle of Grain in the South East. Operation is mainly seasonal as the utilisation is largely affected by the system demand to the south. Historic utilisation of Huntingdon compressor station has been influenced by demand growth at the extremity of the NTS (power stations and distribution network loads). Huntingdon may also be required to support NTS south east pressures through feeder 9 into Feeder 18 and to move line pack south during periods of increased demand. The operation of Huntingdon into the future will continue to be influenced by demand growth as well as operation of the Humbly Grove storage site located downstream. A storage site will have the effect of reducing net demand whilst putting gas into the system but will conversely increase net demand when filling. As indicated in previous Network Review documents, there remains a level of uncertainty surrounding the future utilisation of both Huntingdon & Peterborough Compressor Stations. However, both Huntingdon and Peterborough remain among the higher priority sites for future investment to further reduce NOx emissions from the NTS fleet. This is due to predictions showing that, under differing gas supply conditions, utilisation of one or both of these sites will probably be required. Based on anticipated utilisation, Huntingdon was identified as the next priority site for investment and evaluation of the investment solution and an investment programme is being delivered

Status

High forecast utilisation site, some interchangeability with Peterborough and utilisation highly dependent on the operation of new supply points. Priority site together with Peterborough for investment. The plan is to install two new units as part of ERP Phase 3.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Kings Lynn Compressor Station* Permit number: *DP3839LK*

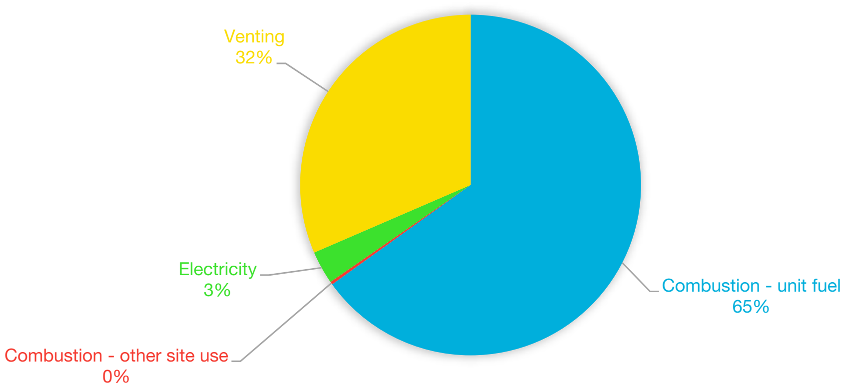
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	7,149	78	659	1,116	9,002
2010	8,843	60	703	1,895	11,501
2011	2,962	13	612	2,871	6,458
2012	420	29	526	3,906	4,881
2013	11,326	9	560	3,985	15,880
2014	266	10	425	2,566	3,266
2015	111	33	455	3,913	4,512
2016	500	22	386	4,216	5,124
2017	8,180	34	396	3,958	12,568

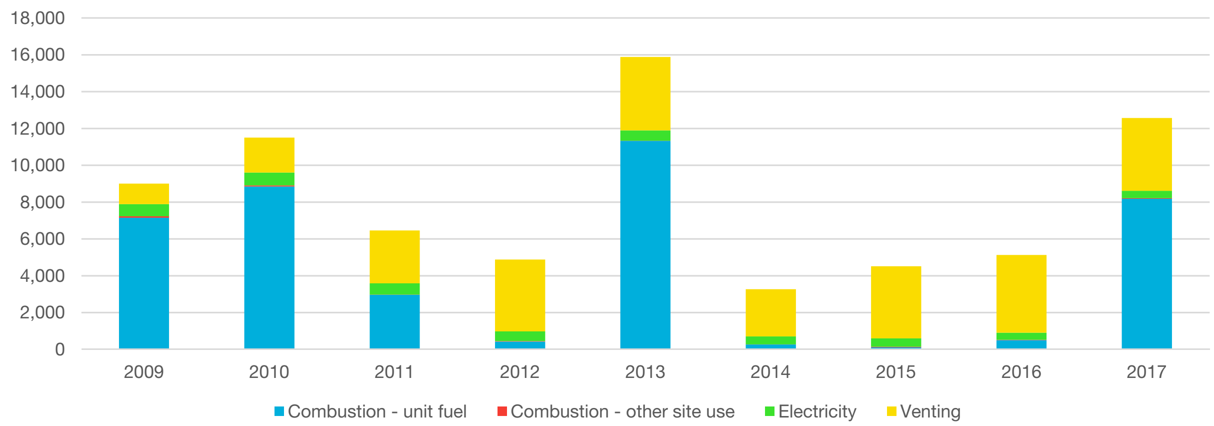
Notes

- 2009-2013 data taken from 2014 Kings Lynn Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Kings Lynn Compressor Station* Permit number: *DP3839LK*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	12	Avon 1533-75G	EAS1	Siemens DeLaval 30/30	Wet
B	GT	12	Avon 1533-75G	EAS1	Siemens DeLaval 30/30	Wet
C	GT	13.4	Siemens SGT400	Siemens Integral Turbine	Siemens DeLaval PV37	Dry
D	GT	13.4	Siemens SGT400	Siemens Integral Turbine	Siemens DeLaval PV37	Dry

General description

Kings Lynn consists of 2 x Cyclone SGT400 DLE and 1 x Avon gas turbine unit and the usual mode of operation is one solitary Cyclone unit or two Cyclone units operating in parallel with the Avon unit providing standby. Kings Lynn is bi-directional and can be considered to have two “modes” of operation; “import mode” is when the station is required to compress west towards Peterborough for high Bacton flow scenarios particularly during the winter; “export mode” is when the station is required to compress east towards Bacton when high interconnector exports are required during periods of low Bacton inputs during the summer. Under scenarios between these extremes, Kings Lynn has not been required, which has made the utilisation of the station difficult to predict. The unpredictability of Kings Lynn operation will be further compounded into the future with numerous forecast developments around the south of the system; potential development off the coast of Bacton terminal may affect the utilisation during times of storage filling as would performance of the interconnectors to Europe, the Milford Haven and the Grain LNG terminals. Owing to the forecast requirement for future duty increase, greater flexibility and the capability to quickly reverse the direction of compression operation, investigations are being made into the potential need for modifications to the compressor station, both in terms of plant and multijunction capability. Both of these potential scenarios will be informed by our ongoing Stakeholder Engagement process on future NTS user requirements.

Status

Medium forecast utilisation site, DLE gas turbine technology used for lead duty. MCPD strategy for the remaining Avon being developed.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

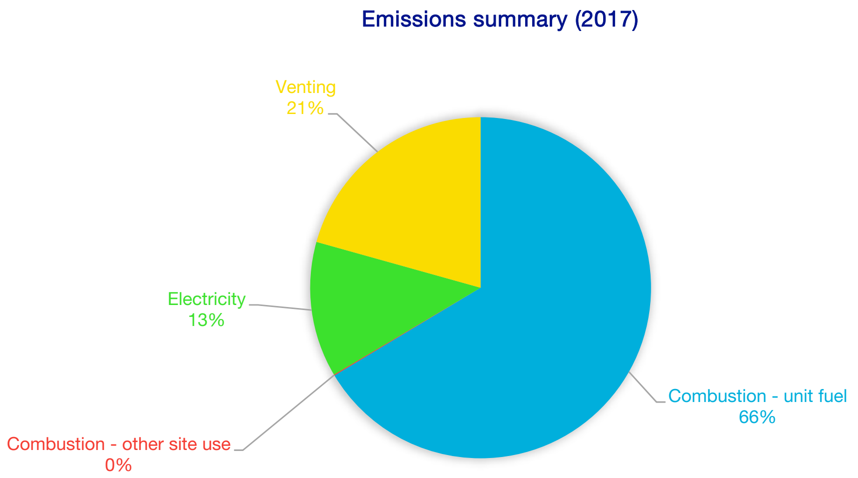
Site: *Kirriemuir Compressor Station* Permit number: *PPC/A/1008867*

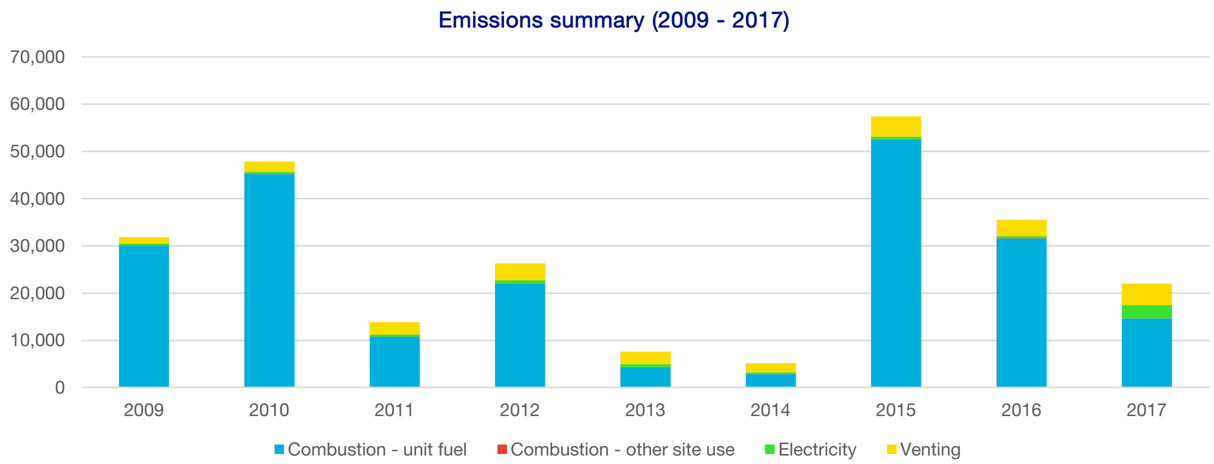
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	30,007	43	419	1,373	31,842
2010	45,193	51	399	2,188	47,831
2011	10,745	34	432	2,630	13,842
2012	21,985	50	668	3,568	26,270
2013	4,344	15	570	2,673	7,602
2014	2,816	13	388	1,933	5,151
2015	52,477	101	489	4,325	57,392
2016	31,541	66	466	3,435	35,507
2017	14,606	20	2,826	4,546	21,998

Notes

- 2009-2013 data taken from 2014 Kirriemuir Compressor Station Compressor Station GHG Emissions Summary report





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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Kirriemuir Compressor Station* Permit number: *PPC/A/1008867*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	12	Avon 1533-75G	EAS1	Siemens DeLaval 30/30	Wet
B	GT	12	Avon 1533-75G	EAS1	Siemens DeLaval 30/30	Wet
C	GT	12	Avon 1533-75G	EAS1	Siemens DeLaval 30/30	Wet
D	0	0	No engine in berth.	ERB1	Siemens DeLaval 30/30	Wet
E	EL	35	Siemens	N/A	Rolls-Royce RF1BB-36	Wet

General description

Kirriemuir currently consists of 3 x Avon gas turbine units and the new 35MWe electric drive VSD. Due to the failure of D unit other sites have been used where possible in preference to Kirriemuir. Depending on local demand requirements and pressure requirements along the East coast feeders Kirriemuir may have to be used. The variable speed drive (VSD) compressor, designed to take up bulk duty at the compressor station, is now operationally accepted. Late design modifications, to allow the new electric drives meet Electricity Grid requirements, had contributed to delays pre-commissioning.

Status

Medium forecast utilisation site, Electric Drive commissioned. Unit D (RB211) has suffered a failure which has put it beyond economical repair. Due to increasing flows from St Fergus re-wheeling unit E is no longer required and final work is being completed to make the unit available for winter 2018. Peer review suggests that hours may be required for VSD in the coming years, to support maintenance of other stations, has required an upward projection of running hours. MCPD strategy for the three Avons being developed.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Moffat Compressor Station* Permit number: *PPC/A/1008863*

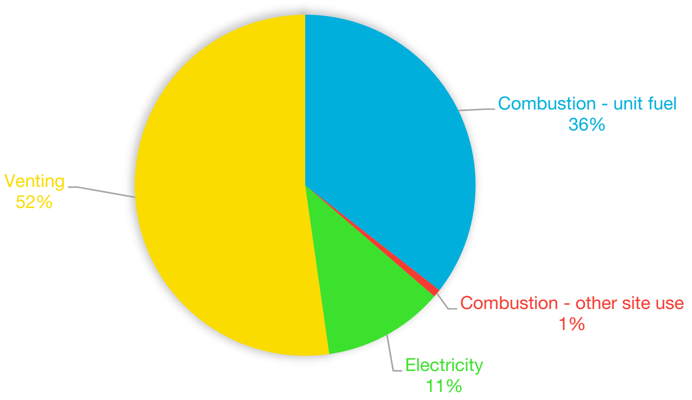
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	4,470	46	376	855	5,747
2010	358	57	225	998	1,638
2011	809	59	264	1,107	2,239
2012	252	62	234	760	1,308
2013	2,627	59	294	1,645	4,625
2014	208	39	273	1,284	1,803
2015	1,381	5	369	1,873	3,627
2016	1,647	15	278	1,310	3,251
2017	765	16	246	1,124	2,151

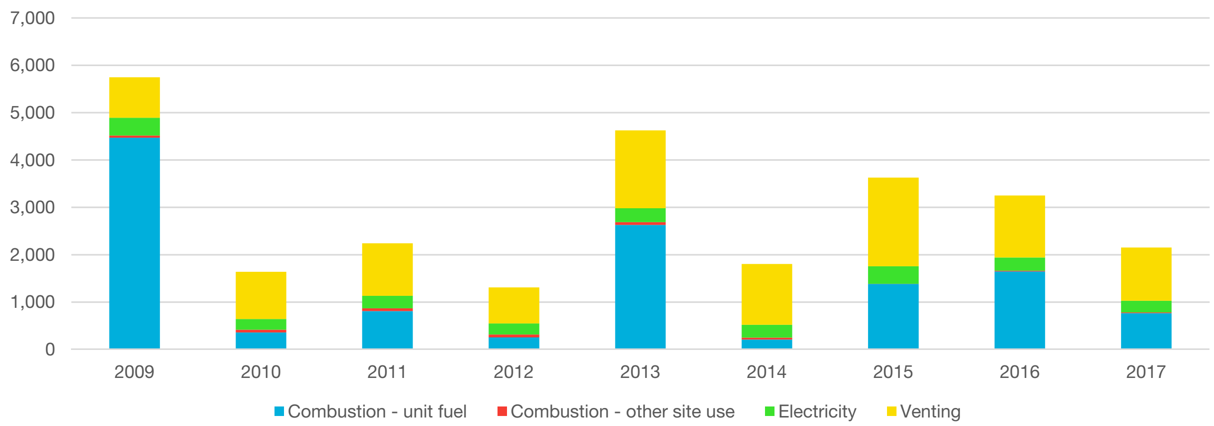
Notes

- 2009-2013 data taken from 2014 Moffat Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Moffat Compressor Station* Permit number: *PPC/A/1008863*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	22.7	RB211-22	ERB1	Nuovo Pignone PCL 802-1/30	Wet
B	GT	22.7	RB211-22	ERB1	Nuovo Pignone PCL 802-1/30	Wet

General description

Moffat consists of 2x RB211 gas turbine units and has traditionally been used to transport bulk gas flows from the St Fergus terminal down the west coast.

Status

Low forecast utilisation site – monitor. Two RB211's which are not compliant with IED ELVs and have been entered into the 500 hours emergency use derogation.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Peterborough Compressor Station* Permit number: *UP3038LG*

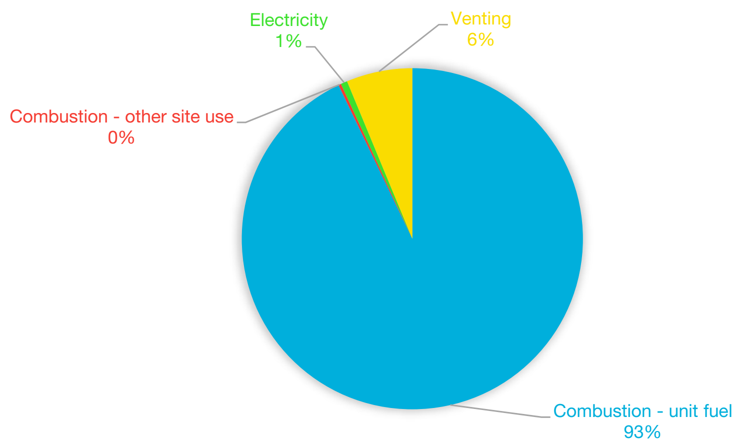
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	44,184	140	394	463	45,182
2010	64,224	189	390	2,074	66,876
2011	37,856	125	388	2,510	40,879
2012	54,465	149	445	2,837	57,896
2013	61,235	168	494	3,500	65,398
2014	47,660	134	374	3,079	51,246
2015	32,216	106	337	3,257	35,916
2016	34,356	107	773	3,049	38,285
2017	49,301	137	331	3,318	53,087

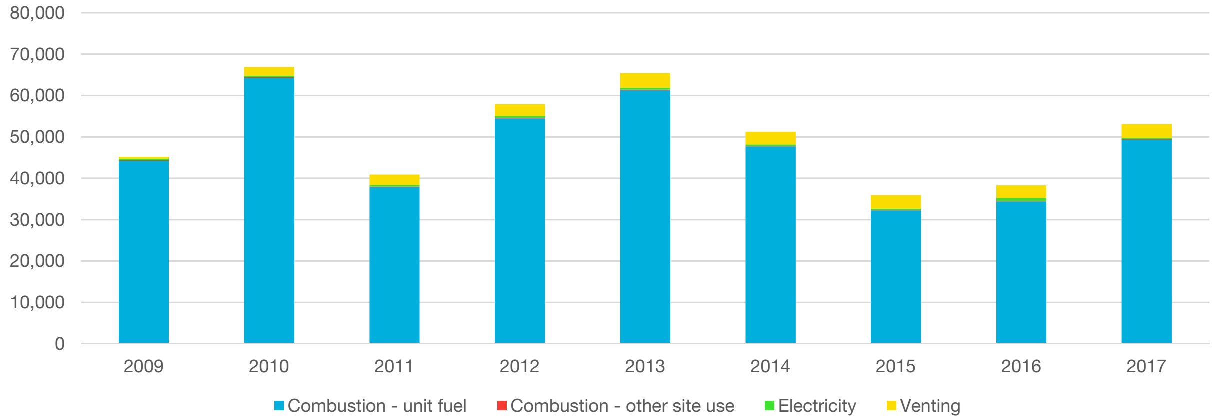
Notes

- 2009-2013 data taken from 2014 Peterborough Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Peterborough Compressor Station* Permit number: *UP3038LG*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	12	Avon 1533-75G	EAS1	Dresser Rand 36	Wet
B	GT	12	Avon 1533-75G	EAS1	Dresser Rand 36	Wet
C	GT	12	Avon 1533-75G	EAS1	Siemens DeLaval PV30/30	Wet

General description

Peterborough consists of 3 x Avon gas turbine units and the usual mode of operation is either one unit operating alone or two units operating in parallel with the remaining unit(s) providing standby. Peterborough is similar in some respects to Huntingdon (immediately to the south) and for some network conditions can be considered interchangeable although recent historical operation suggests increasing variance between Peterborough and Huntingdon operation, potentially caused by changes in wider network operation. Similarly to Hatton, its operation is affected in the same way by the flows from the terminals to the north, Bacton terminal (including the interconnectors) to the east, and LNG imports at Grain LNG in the south east. Operation has been mainly seasonal as the utilisation is largely affected by the system demand to the south.

Peterborough is increasingly becoming a central compressor station linking gas supplies from East and West NTS entry points. Peterborough is used to support Milford Haven entry and IUK flows. Peterborough can be used to move gas away from Bacton and the southeast generally and into the North West during periods of high Grain LNG flows as well for its more traditional role of moving gas into the South West and south east when Milford Haven and/or Grain flows are lower. Future interaction between west and east coast supplies as well as LNG transportation into the continent will continue to influence the utilisation of Peterborough compressor. The location & flexibility required of Peterborough is such that utilisation may increase to meet the changing operation of NTS supply points. Based on anticipated utilisation, Peterborough was identified as the next priority site for investment and evaluation of the investment solution and an investment programme is being delivered.

Status

High forecast utilisation site. Used in conjunction with Hatton, Huntingdon Compressor to move gas into the southern feeder and into the North West with high input from Milford Haven, Easington and Bacton IUK. The plan is to install two new units as part of ERP Phase 3.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *St Fergus Gas Terminal* Permit number: *PPC/A/1013002*

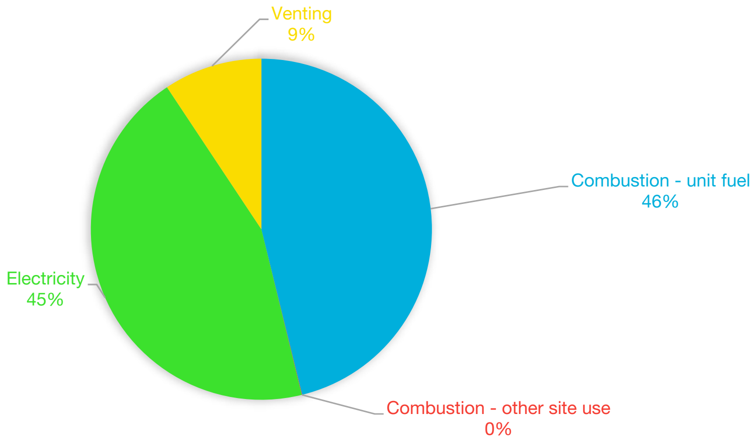
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	124,814	295	2,726	1,171	129,005
2010	131,083	166	2,497	7,922	141,668
2011	87,826	156	2,447	8,541	98,970
2012	92,518	83	2,012	9,335	103,948
2013	99,103	40	2,769	9,797	111,710
2014	68,451	38	2,948	9,287	80,725
2015	26,722	0	26,551	11,555	64,827
2016	29,666	42	36,127	8,008	73,842
2017	56,281	42	54,236	11,383	121,942

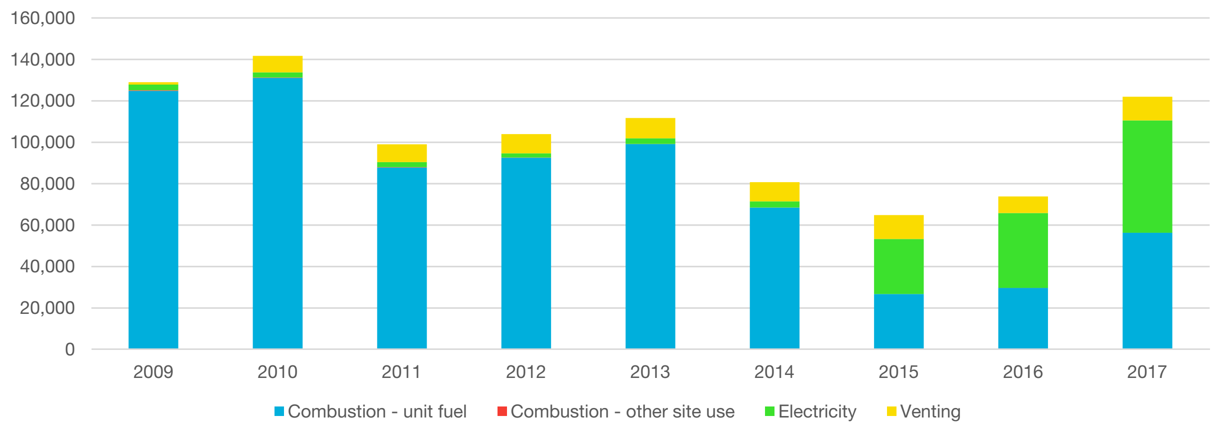
Notes

- 2009-2013 data taken from 2014 St Fergus Gas Terminal Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *St Fergus Gas Terminal* Permit number: *PPC/A/1013002*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
1A	GT	12	Avon 1533-75G	EAS1	Nuovo Pignone PCL 802-3/30	Wet
1B	GT	12	Avon 1533-75G	EAS1	Nuovo Pignone PCL 802-3/30	Wet
1C	GT	12	Avon 1533-75G	EAS1	Nuovo Pignone PCL 802-3/30	Wet
1D	GT	12	Avon 1533-75G	EAS1	Nuovo Pignone PCL 802-3/30	Wet
2A	GT	22.7	RB211-22	ERB1	Nuovo Pignone PCL 802-2/30	Wet
2B	GT	12	Avon 1533-75G	ERB1	Nuovo Pignone PCL 802-3/30	Wet
2C	0	0	No GG in berth.	No power turbine in berth.	Nuovo Pignone PCL 802	Wet
2D	GT	22.7	RB211-22	ERB1	Nuovo Pignone PCL 802-2/30	Wet
3A	EL	24	Siemens	N/A	Siemens STC/SV	Dry
3B	EL	24	Siemens	N/A	Siemens STC/SV	Dry

General description

The St Fergus Compressors are required to compress gas from the North Sea Midstream Partners (NSMP) sub terminal at St Fergus and as such the compression is required 365 days a year. Flows through NSMP are forecast to plateau as the slow decline in existing North Sea UKCS fields is offset by further UKCS field development and Norwegian gas supplies via the Vesterled pipeline. Additional flows from the West of Shetland field have commenced. As the highest single contributor to overall emissions on the NTS, the St Fergus Terminal was highlighted as a priority site for investment to reduce emissions and two 24MW Electric VSDs have been installed to handle the bulk duty. The two electric Variable Speed Drive (VSD) compressor trains have now been commissioned, are in commercial service and have provided the majority of the compression capacity since completion of commissioning activities Forecast duty has been allocated between the units based on planned outages and unit / plant capability.

Status

High forecast utilisation site, 2 electric drives commissioned. Two RB211’s not compliant with IED ELVs and entered into the limited lifetime derogation. The intention is to decommission one unit and abate the other, we are also proposing to replace one Avon, as part of the ERP4 element of the integrated plan. MCPD strategy for the Avons being developed.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Warrington Compressor Station* Permit number: *TP3234LS*

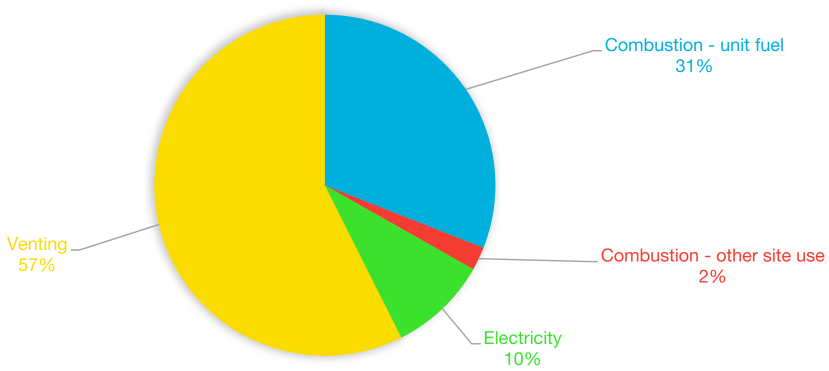
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	669	55	138	419	1,281
2010	119	51	173	803	1,147
2011	152	42	175	1,935	2,303
2012	37	38	192	809	1,076
2013	33	29	188	495	745
2014	240	26	169	772	1,207
2015	58	29	179	607	873
2016	46	28	194	717	985
2017	522	37	159	968	1,686

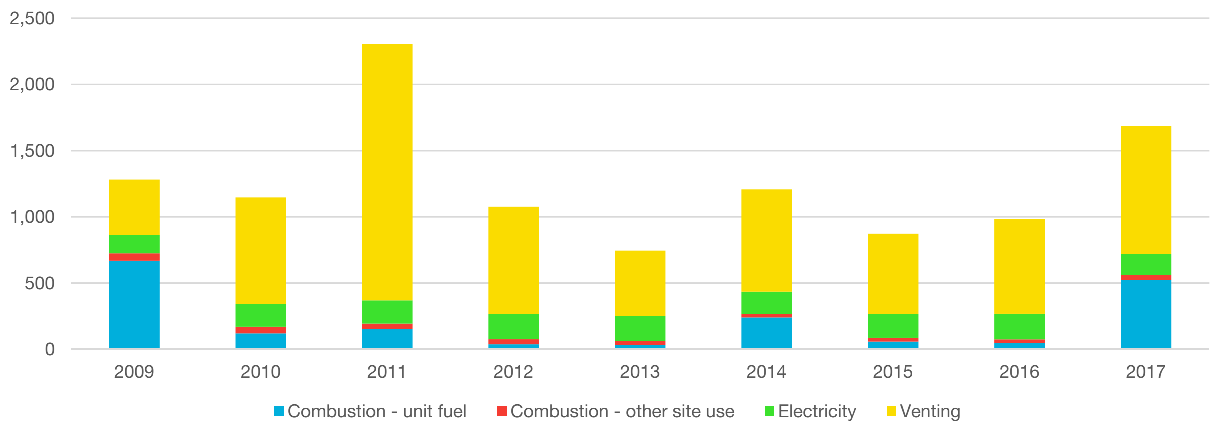
Notes

- 2009-2013 data taken from 2014 Warrington Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site:	*Warrington Compressor Station*	Permit number:	*TP3234LS*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	24.7	RB211-24C	Rolls Royce RT56	Rolls Royce RF36	Wet
B	GT	24.7	RB211-24C	Rolls Royce RT56	Rolls Royce RF36	Wet

General description

Warrington consists of 2 x RB211 gas turbine units and has traditionally been used to transport bulk gas flows through the North West to meet demand requirements in the West. The station currently has a low usage requirement. Forecast utilisation is anticipated to stay low.

Status

Low forecast utilisation site – monitor. The two RB211s are not compliant with IED ELVs and have been entered into the 500 hour derogation.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Wisbech Compressor Station* Permit number: *UP3538LW*

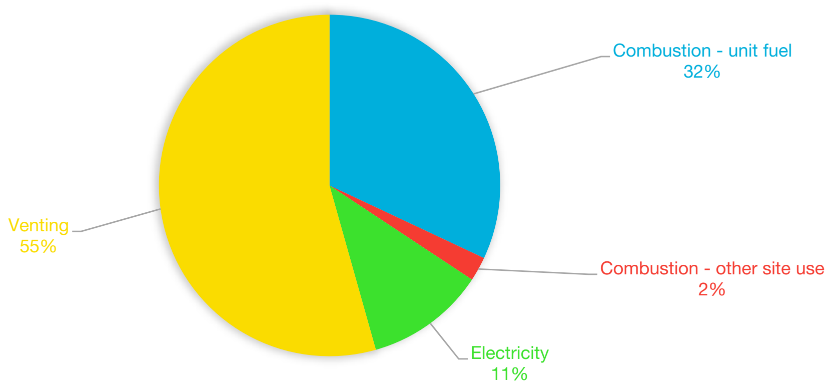
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	10	57	160	351	577
2010	120	61	156	411	749
2011	63	124	114	537	837
2012	1,594	122	183	1,559	3,458
2013	1,550	15	205	1,854	3,624
2014	317	17	208	877	1,420
2015	2,492	17	217	1,348	4,074
2016	6,166	50	201	1,380	7,796
2017	543	39	192	923	1,696

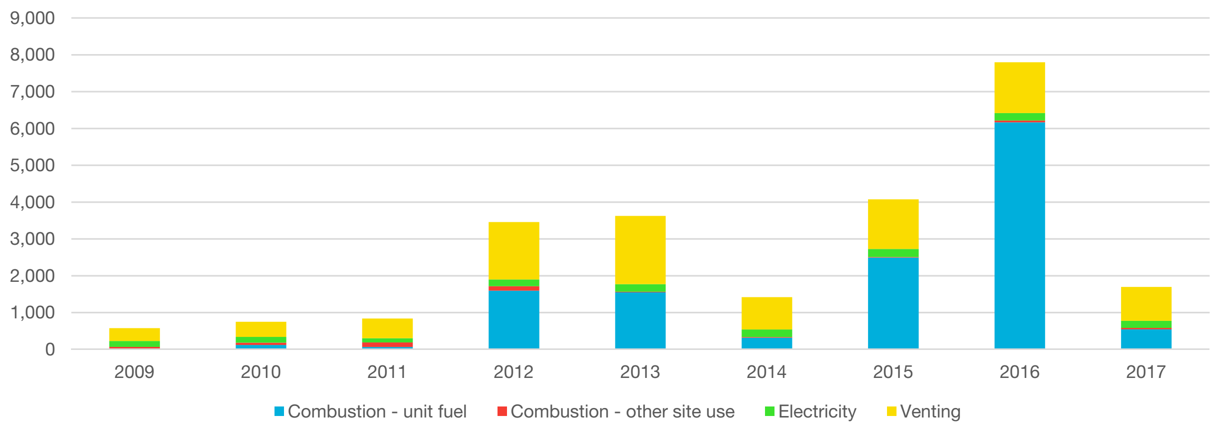
Notes

- 2009-2013 data taken from 2014 Wisbech Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site:	*Wisbech Compressor Station*	Permit number:	*UP3538LW*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	22.7	RB211-22	ERB1	Siemens DeLaval 2PB62	Wet
B	GT	12	Avon 1533-75G	ERB1	Siemens DeLaval 2PB62	Wet

General description

Wisbech consists of 1 x RB211 and 1 x Avon gas turbine units. Wisbech provides first line compression support into the South West in the event of loss of Peterborough or Huntingdon It may also be required under more extreme supply and demand scenarios and for within day operational requirements. It is likely that Wisbech may have a critical role to play during outages for construction work at Peterborough and/or Huntingdon. In December 2015 the existing Maxi Avon was replaced by a standard Avon.

Status

Low forecast utilisation site – monitor. The RB211 is not compliant with IED ELVs and has been entered into the 500 hour derogation. MCPD strategy for the Avon being developed.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Wooler Compressor Station* Permit number: *BT0596IS*

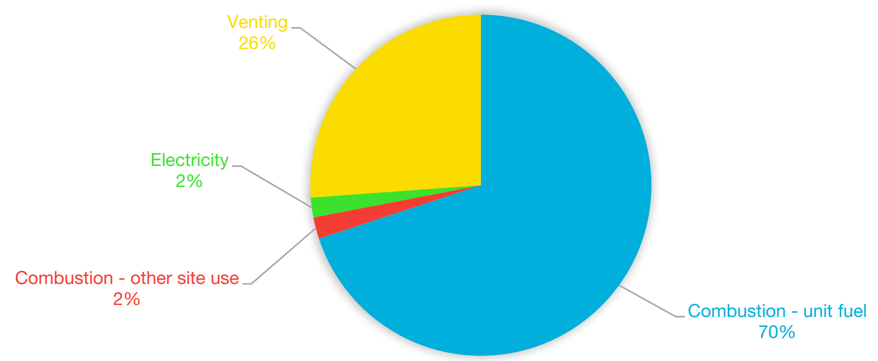
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	4,774	261	378	1,329	6,743
2010	2,561	210	305	3,187	6,263
2011	3,541	226	304	3,514	7,585
2012	3,792	806	114	1,931	6,643
2013	3,180	232	309	3,078	6,800
2014	1,052	197	261	1,768	3,277
2015	535	206	279	1,262	2,282
2016	11,920	268	304	6,438	18,930
2017	8,251	240	222	3,085	11,799

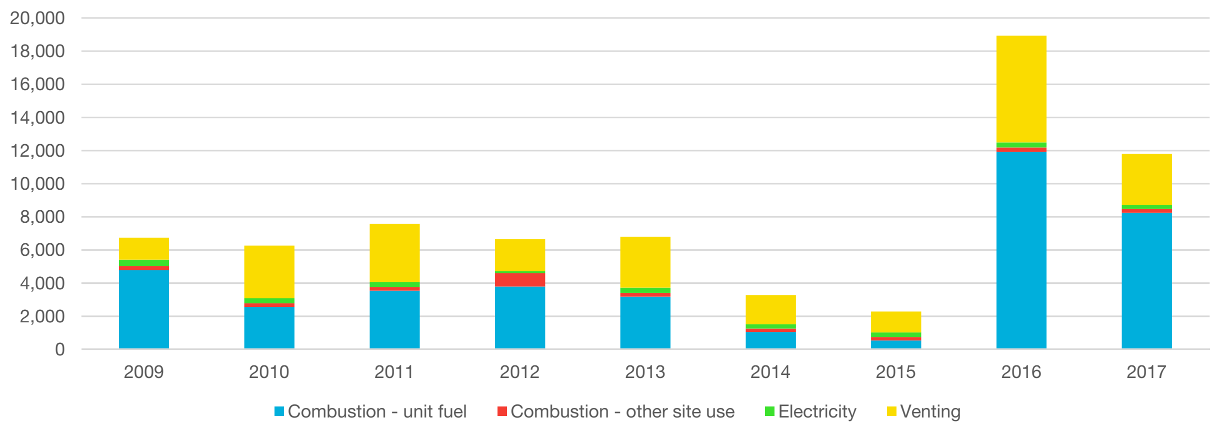
Notes

- 2009-2013 data taken from 2014 Wooler Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site:	*Wooler Compressor Station*	Permit number:	*BT0596IS*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	30.5	GE LM2500+DLE	Nuovo Pignone HS PGT 25	Nuovo Pignone PCL 802-1	Dry
B	GT	30.5	GE LM2500+DLE	Nuovo Pignone HS PGT 25	Nuovo Pignone PCL 802-1	Dry

General description

Wooler consists of 2x LM2500 DLE gas turbines and has historically been used for north to south bulk transmission of gas during periods of high St Fergus inputs coupled with low East NTS supplies as well as during periods of Aberdeen unavailability. With increased volumes of gas on the East Coast, predominantly Norwegian gas flows through the Easington reception terminal, there have been reduced gas flows down the east coast from Scotland. This has reduced the utilisation of Wooler significantly. Into the future the station is envisaged to be required to operate under traditional configurations and flow pattern scenarios (low Easington inputs, high St. Fergus supplies), during maintenance periods and to facilitate within day operational line pack movement.

Status

High forecast utilisation site, DLE gas turbine units – monitor.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

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National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Wormington Compressor Station* Permit number: *JP3735LM*

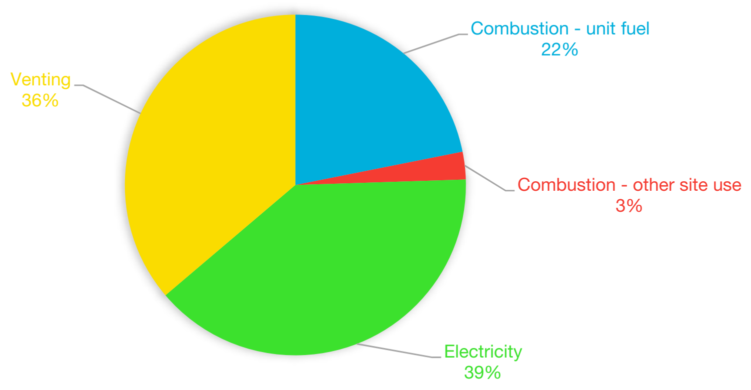
Emissions summary

Year	Combustion - unit fuel	Combustion - other site use	Electricity	Venting	Annual total
2009	2,887	185	0	615	3,687
2010	28,172	326	2,618	2,781	33,898
2011	44,658	384	13,057	4,589	62,688
2012	3,614	184	5,496	3,419	12,714
2013	357	175	4,547	2,148	7,227
2014	225	174	6,585	3,034	10,019
2015	558	172	10,603	3,932	15,266
2016	723	170	4,548	3,006	8,447
2017	1,538	184	2,764	2,547	7,033

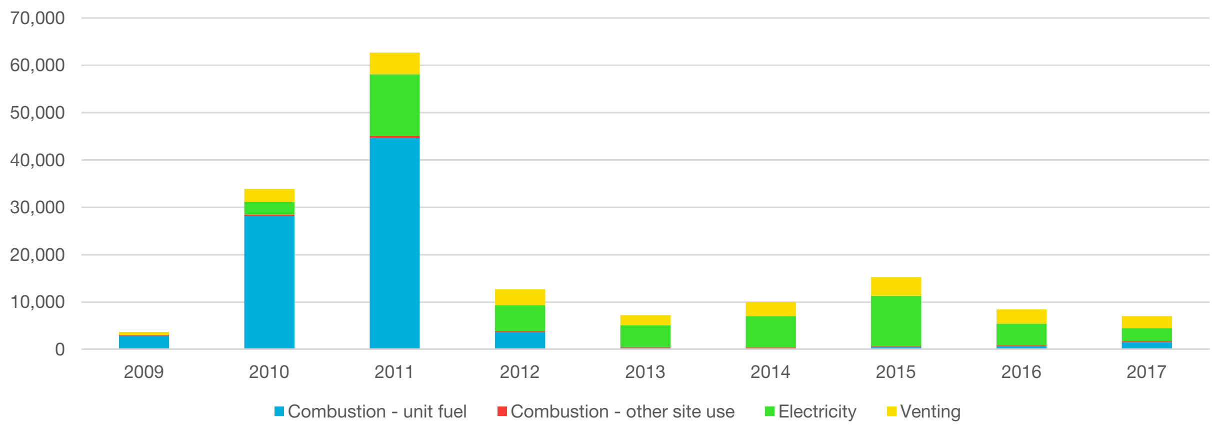
Notes

- 2009-2013 data taken from 2014 Wormington Compressor Station Compressor Station GHG Emissions Summary report

Emissions summary (2017)



Emissions summary (2009 - 2017)



nationalgrid

National Grid Gas - National Transmission System

Compressor Station GHG Emissions Summary

Site: *Wormington Compressor Station* Permit number: *JP3735LM*

Site configuration

Unit	Type	Shaft power	Engine	Power Turbine	Compressor	Seal
A	GT	12	Avon 1533-75G	EAS1	Siemens DeLaval 30/30	Dry
B	GT	12	Avon 1533-75G	EAS1	Siemens DeLaval 30/30	Dry
C	EL	15	Siemens	N/A	Siemens STC/SV	Dry

General description

Wormington currently consists of 2 x Avon gas turbine units and a 15MW electric drive VSD. The usual configuration is to operate the electric drive singly as the lead unit. The gas drives can also be operated singly or in parallel to meet gas process requirements outside the capability of the electric drive compressor. Wormington compressor station has recently become critical in supporting NTS gas entering through the Milford Haven terminal and utilisation is likely to remain high over a wide range of network conditions. Due to bi-directional flow capabilities it is also used to support the extremities in Wales when Milford Haven inputs are low. The electric drive is now established as the lead unit, taking up bulk duty within the limits of upstream process conditions.

Status

High forecast utilisation; electric VSD is the lead unit. MCPD strategy for the two Avons being developed.

References

Data/information	Source
Permit number	2010 Enviros reports
Site configuration data	16 Compressor Details_2016.pdf
Site configuration data - seals	Copy of Venting Calculator - A07.xls
Emissions summary	2014 - 2017 site CO2 Annual Report
Emissions summary	2014 - 2017 electricity usage
Emissions summary	2014 - 2017 venting data
General description text	2018 Network Review document from National Grid
Status text	2018 Network Review document from National Grid

Appendix 2 Detailed table of 2014 recommendations and status update

Table 1 Site-by-site 2014 recommendations and status update

Order	Location	Area	Measure	Forecast project life (years)	Gas venting saving (scm/y)	Gas combustion saving (scm/y)	Elec saving (MWh/y)	GHG saving (tCO2/y)	Operating cost saving estimate (£k/y)	Capital cost estimate (£k)	Payback (years)	MAC (£/tCO2e)	Adopted 2014-18?
1	Aberdeen	S2	Thermal Oxidation	15	511,682	-511,682	-265	6,144	-14	900	No pay-back	22	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
2	Aberdeen	S2	Vent Gas Recompression	15	261,427			3,731	51	210	4	-6	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
3	Aberdeen	S2	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
4	Kings Lynn	E4	Lube Oil Pumps VSD	10			5	3	0	9	36	481	Not implemented
5	Alrewas	W2	Thermal Oxidation	15	101,223	-101,223	-265	1,101	-14	900	No pay-back	120	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
6	Alrewas	W2	Vent Gas Recompression	15	43,912			627	9	210	25	30	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
7	Alrewas	W2	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
8	Warrington	W1	Vent Fans VSD	10			4	2	0	8	42	582	Not implemented
9	Warrington	W1	Lube Oil Pumps VSD	10			17	9	1	9	10	56	Not implemented
10	Warrington	W1	Fuel Gas Preheater - heat recovery	TBC		1,096		2	0	TBC			Not implemented
11	Avonbridge	S3	Thermal Oxidation	15	359,195	-359,195	-265	4,270	-14	900	No pay-back	31	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.

Order	Location	Area	Measure	Forecast project life (years)	Gas venting saving (scm/y)	Gas combustion saving (scm/y)	Elec saving (MWh/y)	GHG saving (tCO2/y)	Operating cost saving estimate (£k/y)	Capital cost estimate (£k)	Payback (years)	MAC (£/tCO2e)	Adopted 2014-18?
12	Avonbridge	S3	Vent Gas Recompression	15	176,667			2,522	34	280	8	1	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
13	Avonbridge	S3	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
14	Churchover	W2	Vent Fans VSD	10			9	5	1	3	6	3	Not implemented
15	Cambridge	E5	Lube Oil Pumps VSD	10			19	10	1	9	9	40	Not implemented
16	Avonbridge	S3	Voltage Optimisation	10			250	134	14	35	3	-58	Not implemented
17	Chelmsford	E5	Wet Seal Replacement	5	2,193			31	0	360	844	3,020	Not implemented, would only be addressed as part of major compressor upgrade
18	Aylesbury	W4	Thermal Oxidation	15	114,099	-114,099	-265	1,259	-14	900	No pay-back	105	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
19	Aylesbury	W4	Vent Gas Recompression	15	36,245		-4	515	7	140	20	22	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
20	Aylesbury	W4	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
21	Bishop Auckland	S4	Thermal Oxidation	15	240,521	-240,521	-265	2,812	-14	900	No pay-back	47	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.

Order	Location	Area	Measure	Forecast project life (years)	Gas venting saving (scm/y)	Gas combustion saving (scm/y)	Elec saving (MWh/y)	GHG saving (tCO2/y)	Operating cost saving estimate (£k/y)	Capital cost estimate (£k)	Payback (years)	MAC (£/tCO2e)	Adopted 2014-18?
22	Bishop Auckland	S4	Vent Gas Recompression	15	152,159			2,172	30	140	5	-5	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
23	Bishop Auckland	S4	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
24	Kings Lynn	E4	Vent Fans VSD	10			19	10	1	14	14	121	Not implemented
25	Wormington	W3	Lube Oil Pumps VSD	10			19	10	1	9	9	44	Not implemented
26	Alrewas	W2	Fuel Gas Preheater - heat recovery	TBC		2,100		4	0	TBC			Not implemented
27	Wisbech	E2	Wet Seal Replacement	5	2,297			33	0	360	806	2,884	Not implemented, would only be addressed as part of major compressor upgrade
28	Cambridge	E5	Thermal Oxidation	15	147,234	-147,234	-265	1,666	-14	900	No pay-back	80	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
29	Cambridge	E5	Vent Gas Recompression	15	79,686			1,137	15	210	14	11	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
30	Cambridge	E5	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
31	Bishop Auckland	S4	Lube Oil Pumps VSD	10			23	12	1	8	6	4	Not implemented
32	Bishop Auckland	S4	Fuel Gas Preheater - heat recovery	TBC		3,014		6	1	TBC.			Not implemented
33	Carnforth & Nether	W1	Thermal Oxidation	15	167,000	-167,000	-530	1,767	-29	1,800	No pay-back	150	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.

Order	Location	Area	Measure	Forecast project life (years)	Gas venting saving (scm/y)	Gas combustion saving (scm/y)	Elec saving (MWh/y)	GHG saving (tCO2/y)	Operating cost saving estimate (£k/y)	Capital cost estimate (£k)	Payback (years)	MAC (£/tCO2e)	Adopted 2014-18?
34	Carnforth & Nether	W1	Vent Gas Recompression	15	92,000			1,313	18	350	20	21	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
35	Carnforth & Nether	W1	Retaining Compressor Pressure		136,000		-650	1,592	-9	0	No pay-back		Major behavioural change programme has been implemented. Refer to main report Chapter 3 Review of previous recommendations.
36	Carnforth & Nether	W1	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
37	Huntingdon	E3	Vent Fans VSD	10			22	12	1	9	8	24	Not implemented. New Solar Titan currently being installed so no further invest in existing Avon units, other than priority asset health matters. Designers of new units specified simple fixed speed duty / standby fan configuration.
38	Chelmsford	E5	Lube Oil Pumps VSD	10			25	13	1	8	6	-4	Not implemented
39	Cambridge	E5	Wet Seal Replacement	5	12,202			174	2	360	152	532	Lead Unit C has dry gas seals, otherwise not implemented. Would only be addressed as part of major compressor upgrade
40	Chelmsford	E5	Thermal Oxidation	15	19,973	-19,973	-265	103	-14	900	No pay-back	1,287	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
41	Chelmsford	E5	Vent Gas Recompression	15	8,476			121	2	140	85	139	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
42	Chelmsford	E5	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
43	Moffat	S3	Lube Oil Pumps VSD	10			24	13	1	8	6	-1	Not implemented

Order	Location	Area	Measure	Forecast project life (years)	Gas venting saving (scm/y)	Gas combustion saving (scm/y)	Elec saving (MWh/y)	GHG saving (tCO2/y)	Operating cost saving estimate (£k/y)	Capital cost estimate (£k)	Payback (years)	MAC (£/tCO2e)	Adopted 2014-18?
44	Churchover	W2	Wet Seal Replacement	5	13,733			196	3	360	135	471	Orenda units decommissioned. Solar Titan Unit C and VSD have dry gas seals.
45	Churchover	W2	Thermal Oxidation	15	49,835	-49,835	-265	470	-14	900	No pay-back	282	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
46	Churchover	W2	Vent Gas Recompression	15	15,743			225	3	70	23	27	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
47	Churchover	W2	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
48	Kirriemuir	S2	Vent Fans VSD	10			55	30	3	12	4	-35	Not implemented
49	Aberdeen	S2	Lube Oil Pumps VSD	10			30	16	2	12	7	20	Not implemented
50	Kirriemuir	S2	Fuel Gas Preheater - heat recovery	TBC		6,189		12	1	TBC			Not implemented
51	Aylesbury	W4	Wet Seal Replacement	5	43,551			622	8	360	42	139	Not implemented, would only be addressed as part of major compressor upgrade
52	Diss	E4	Thermal Oxidation	15	77,572	-77,572	-265	811	-14	900	No pay-back	164	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
53	Diss	E4	Vent Gas Recompression	15	16,842			240	3	140	43	63	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
54	Diss	E4	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
55	Wooler	S4	Fuel Gas Preheater - heat recovery	TBC		9,213		18	2	TBC			Not implemented

Order	Location	Area	Measure	Forecast project life (years)	Gas venting saving (scm/y)	Gas combustion saving (scm/y)	Elec saving (MWh/y)	GHG saving (tCO2/y)	Operating cost saving estimate (£k/y)	Capital cost estimate (£k)	Payback (years)	MAC (£/tCO2e)	Adopted 2014-18?
56	Diss	E4	Office HVAC	10			44	24	2	15	6	3	Completed – Diss now has a full electric HVAC system throughout the buildings and the domestic gas supply has been disconnected
57	Felindre	W3	None										None identified
58	Hatton	E2	Thermal Oxidation	15	171,967	-171,967	-265	1,970	-14	900	No pay-back	67	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
59	Hatton	E2	Vent Gas Recompression	15	72,577			1,036	14	210	15	13	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
60	Hatton	E2	Retaining Compressor Pressure		107,128		-201	1,421	10	0	No pay-back		Major behavioural change programme has been implemented. Refer to main report Chapter 3 Review of previous recommendations.
61	Hatton	E2	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
62	Peterborough	E3	Vent Fans VSD	10			62	33	3	10	3	-54	Not implemented. New Solar Titan currently being installed so no further invest in existing Avon units, other than priority asset health matters. Designers of new units specified simple fixed speed duty / standby fan configuration.
63	Huntingdon	E3	Lube Oil Pumps VSD	10			36	19	2	12	6	1	New Solar Titan currently being installed so no further invest in existing Avon units, other than priority asset health matters. Pre/Post lube oil pump motors with variable frequency drive are being installed on the new Solar Titan Units D & E.
64	Cambridge	E5	Fuel Gas Preheater - heat recovery	TBC		9,734		19	2	TBC			Not implemented
65	Diss	E4	Wet Seal Replacement	5	44,024			628	9	540	63	213	Not implemented, would only be addressed as part of major compressor upgrade
66	Huntingdon	E3	Thermal Oxidation	15	250,869	-250,869	-265	2,940	-14	900	No pay-back	45	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.

Order	Location	Area	Measure	Forecast project life (years)	Gas venting saving (scm/y)	Gas combustion saving (scm/y)	Elec saving (MWh/y)	GHG saving (tCO2/y)	Operating cost saving estimate (£k/y)	Capital cost estimate (£k)	Payback (years)	MAC (£/tCO2e)	Adopted 2014-18?
67	Huntingdon	E3	Vent Gas Recompression	15	64,336			918	13	210	17	16	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
68	Huntingdon	E3	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
69	Hatton	E2	Vent Fans VSD	10			105	56	6	17	3	-52	Not implemented on existing gas turbine units A, B, C. Compressor upgrade will bring opportunities to consider VSD enclosure vent fans via a BAT assessment for new units.
70	Alrewas	W2	Lube Oil Pumps VSD	10			37	20	2	12	6	-2	Not implemented
71	Diss	E4	Fuel Gas Preheater - heat recovery	TBC		9,879		20	2	TBC			Not implemented
72	Kings Lynn	E4	Thermal Oxidation	15	160,556	-160,556	-265	1,830	-14	900	No pay-back	72	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
73	Kings Lynn	E4	Vent Gas Recompression	15	46,663			666	9	140	15	14	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
74	Kings Lynn	E4	Retaining Compressor Pressure		66,904			955	13	0	No pay-back		Major behavioural change programme has been implemented. Refer to main report Chapter 3 Review of previous recommendations. Also, Unit A has been mothballed, but at present remains part of the permitted installation.
75	Kings Lynn	E4	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
76	Wormington	W3	Vent Fans VSD	10			106	57	6	10	2	-73	Not implemented

Order	Location	Area	Measure	Forecast project life (years)	Gas venting saving (scm/y)	Gas combustion saving (scm/y)	Elec saving (MWh/y)	GHG saving (tCO2/y)	Operating cost saving estimate (£k/y)	Capital cost estimate (£k)	Payback (years)	MAC (£/tCO2e)	Adopted 2014-18?
77	Kings Lynn	E4	Mothball Units		57,152	29,000		873	17	0	No pay-back		Unit A has been mothballed, but at present remains part of the permitted installation.
78	Churchover	W2	Lube Oil Pumps VSD	10			48	26	3	12	5	-25	Not implemented
79	Huntingdon	E3	Wet Seal Replacement	5	127,782			1,824	25	360	14	38	New Solar Titan lead gas units will have dry gas seals - this is a now a formal requirement in National Grid engineering specifications. Unit C (Avon) also has dry gas seals. No investment plans other than critical asset health works on remaining Avon units.
80	Kirriemuir	S2	Thermal Oxidation	15	432,387	-432,387	-265	5,169	-14	900	No pay-back	26	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
81	Kirriemuir	S2	Vent Gas Recompression	15	78,632			1,122	15	280	18	19	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
82	Kirriemuir	S2	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
83	Bishop Auckland	S4	Vent Fans VSD	10			116	62	6	24	4	-38	Not implemented
84	Peterborough	E3	Lube Oil Pumps VSD	10			78	42	4	12	3	-54	New Solar Titan currently being installed so no further invest in existing Avon units, other than priority asset health matters. Pre/Post lube oil pump motors with variable frequency drive are being installed on the new Solar Titan Units D & E.
85	Moffat	S3	Fuel Gas Preheater - heat recovery	TBC		10,477		21	2	TBC			Not implemented
86	Kirriemuir	S2	Wet Seal Replacement	5	269,065			3,840	52	360	7	11	Lead VSD unit has dry gas seals, otherwise not implemented. Would only be addressed as part of major compressor upgrade
87	Moffat	S3	Thermal Oxidation	15	469,086	-469,086	-265	5,620	-14	900	No pay-back	24	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.

Order	Location	Area	Measure	Forecast project life (years)	Gas venting saving (scm/y)	Gas combustion saving (scm/y)	Elec saving (MWh/y)	GHG saving (tCO2/y)	Operating cost saving estimate (£k/y)	Capital cost estimate (£k)	Payback (years)	MAC (£/tCO2e)	Adopted 2014-18?
88	Moffat	S3	Vent Gas Recompression	15	49,018			700	10	140	15	13	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
89	Moffat	S3	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
90	Kirriemuir	S2	Lube Oil Pumps VSD	10			83	45	4	18	4	-35	Not implemented
91	Wisbech	E2	Fuel Gas Preheater - heat recovery	TBC		12,739		25	2	TBC			Not implemented
92	Moffat	S3	Wet Seal Replacement	5	356,362			5,086	69	360	5	5	Not implemented, would only be addressed as part of major compressor upgrade
93	Peterborough	E3	Thermal Oxidation	15	684,876	-684,876	-265	8,271	-14	900	No pay-back	16	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
94	Peterborough	E3	Vent Gas Recompression	15	34,586			494	7	210	31	42	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
95	Peterborough	E3	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
96	Alrewas	W2	Vent Fans VSD	10			154	83	8	42	5	-18	Not implemented
97	Avonbridge	S3	Lube Oil Pumps VSD	10			89	48	5	16	3	-46	Not implemented
98	Churchover	W2	Fuel Gas Preheater - heat recovery	TBC		16,419		33	3	TBC			Orenda units decommissioned. No work being undertaken on Solar Titan Unit C

Order	Location	Area	Measure	Forecast project life (years)	Gas venting saving (scm/y)	Gas combustion saving (scm/y)	Elec saving (MWh/y)	GHG saving (tCO2/y)	Operating cost saving estimate (£k/y)	Capital cost estimate (£k)	Payback (years)	MAC (£/tCO2e)	Adopted 2014-18?
99	Peterborough	E3	Wet Seal Replacement	5	547,946			7,821	107	540	5	5	New Solar Titan lead gas units will have dry gas seals - this is a now a formal requirement in National Grid engineering specifications. No investment plans other than critical asset health works on remaining Avon units.
100	St Fergus	S1	Thermal Oxidation	15	169,660	-169,660	-265	1,942	-14	900	No pay-back	68	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
101	St Fergus	S1	Vent Gas Recompression	15	82,610			1,179	16	490	30	41	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
102	St Fergus	S1	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
103	Wooler	S4	Vent Fans VSD	10			166	89	9	48	5	-13	Not implemented
104	Hatton	E2	Lube Oil Pumps VSD	10			98	53	5	25	5	-25	Not implemented on existing gas turbine units A, B, C. Compressor upgrade will bring opportunities to consider VSD lube oil pumps via a BAT assessment for new units.
105	Warrington	W1	Vent Gas Recompression	15	19,191			274	4	70	19	20	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
106	Warrington	W1	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
107	Avonbridge	S3	Vent Fans VSD	10			193	104	10	40	4	-38	Not implemented
108	Carnforth & Nether	W1	Lube Oil Pumps VSD	10			290	156	16	20	1	-80	Not implemented

Order	Location	Area	Measure	Forecast project life (years)	Gas venting saving (scm/y)	Gas combustion saving (scm/y)	Elec saving (MWh/y)	GHG saving (tCO2/y)	Operating cost saving estimate (£k/y)	Capital cost estimate (£k)	Payback (years)	MAC (£/tCO2e)	Adopted 2014-18?
109	Hatton	E2	Fuel Gas Preheater - heat recovery	TBC		24,817		49	5	TBC			Project ongoing - expectation is that fuel gas preheat will be implemented (subject to site specific BAT assessment) on new gas turbine units
110	Wormington	W3	Wet Seal Replacement	5	630,743			9,003	123	360	3	-3	All units have dry gas seals (A & B Avon, C VSD)
111	Wisbech	E2	Thermal Oxidation	15	25,772	-25,772	-265	174	-14	900	No pay-back	761	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
112	Wisbech	E2	Vent Gas Recompression	15	13,416			191	3	140	54	82	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
113	Wisbech	E2	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
114	Huntingdon	E3	Fuel Gas Preheater - heat recovery	TBC		25,166		50	5	TBC			Yes - new Solar Titan 130 units being implemented with fuel gas preheat. Commission 2020
115	Wooler	S4	Thermal Oxidation	15	190,043	-190,043	-265	2,192	-14	900	No pay-back	61	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
116	Wooler	S4	Vent Gas Recompression	15	76,590			1,093	15	140	9	3	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
117	Wooler	S4	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
118	Carnforth & Nether	W1	Vent Fans VSD	10			330	177	18	53	3	-52	Carnforth Unit B has VSD vent fans installed. No other implementation.
119	Peterborough	E3	Fuel Gas Preheater - heat recovery	TBC		37,540		75	7	TBC			Yes - new Solar Titan 130 units being implemented with fuel gas preheat. Commission 2020

Order	Location	Area	Measure	Forecast project life (years)	Gas venting saving (scm/y)	Gas combustion saving (scm/y)	Elec saving (MWh/y)	GHG saving (tCO2/y)	Operating cost saving estimate (£k/y)	Capital cost estimate (£k)	Payback (years)	MAC (£/tCO2e)	Adopted 2014-18?
120	St Fergus	S1	Wet Seal Replacement	5	2,103,225			30,019	409	1,260	3	-3	New gas units will have dry gas seals - this is a now a formal requirement in National Grid engineering specifications.
121	Wormington	W3	Thermal Oxidation	15	733,175	-733,175	-265	8,865	-14	900	No pay-back	15	No uptake of thermal oxidation. Refer to main report, Chapter 4 - Opportunities and recommendations 2019-2022.
122	Wormington	W3	Vent Gas Recompression	15	41,746			596	8	210	26	33	Recompression of routine venting is not available on operational and safety grounds due to need to evacuate gas promptly maximising dispersion. Refer to main report Chapter 3 Review of Previous Recommendations for successes with regard to planned pipework venting and also enhanced management practices to reduce venting.
123	Wormington	W3	Ultrasonic Leak Detection	5	5,700			81	-1	1	No pay-back	13	GHGIM project successfully implemented; further enhancements under investigation
124	St Fergus	S1	Vent Fans VSD	10			396	213	21	32	1	-76	Compressor upgrade - opportunities to consider VSD enclosure vent fans via a BAT assessment for new units
125	St Fergus	S1	Lube Oil Pumps VSD	10			409	220	22	28	1	-80	Not implemented on existing gas turbine units. Compressor upgrade will bring opportunities to consider VSD lube oil pumps via a BAT assessment for new units.
	Total				**11.179.254**	**-4.879.342**		**148.207**	**1.020**	**29.230**		**12.147**	

Appendix 3 NTS energy consumption charts

Figure 22 and ***Figure 23*** show emissions from combustion and electricity use between 2009 and 2017. The totals demonstrate a generally constant and low amount of emissions by minor combustion across the NTS but declining major combustion emissions from gas (more noticeable on the second chart where total emissions by year are shown as absolute percentages), with a corresponding increase in electricity emissions. This reflects a move across the NTS to more electric VSD units in place of older gas CMT equipped units.

Figure 22 Major combustion emissions by year

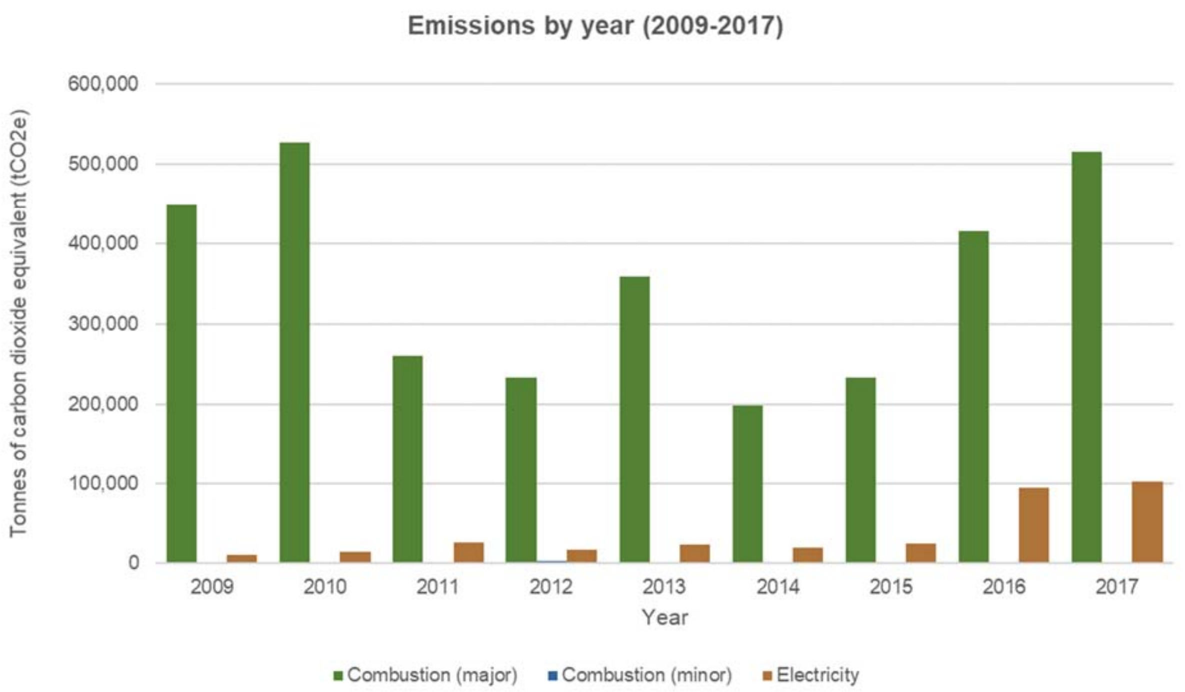


Figure 23 Emissions by year

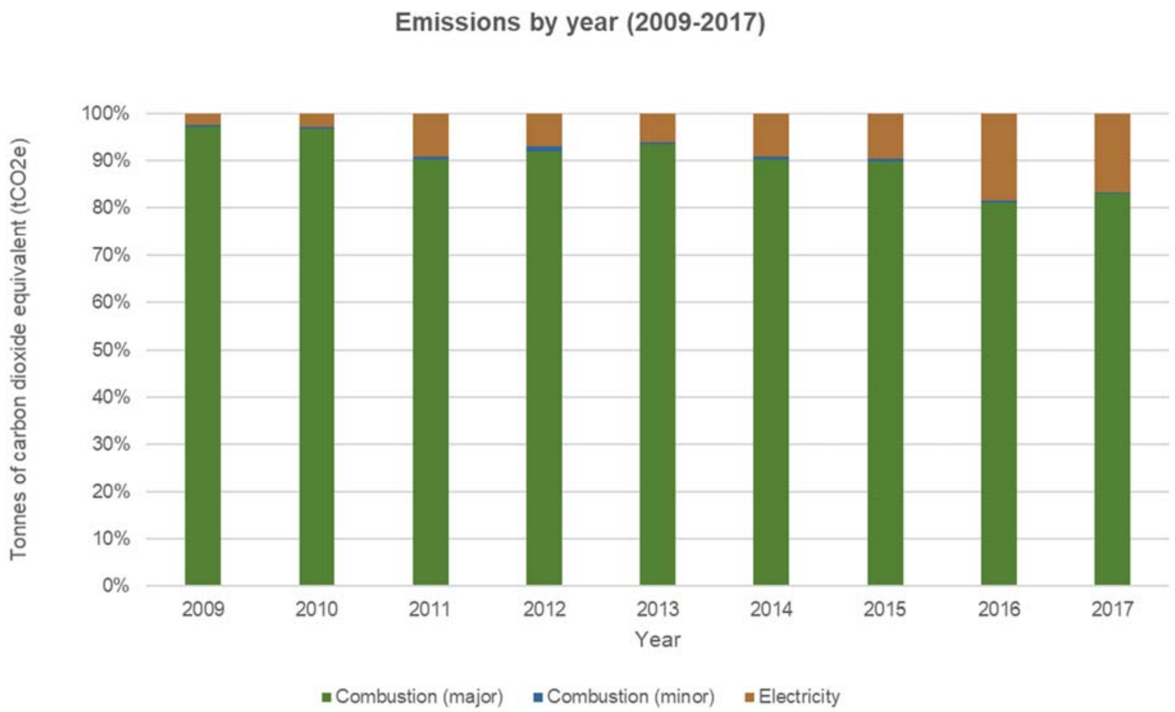


Figure 24 and ***Figure 25*** show emissions from combustion and electricity use between 2009 and 2017 for National Grid's NTS zone as illustrated in ***Figure 1***. As discussed in Section 2.3 these charts show higher emissions associated with zones S1 – S3, the NTS zones in Scotland. This reflects the higher flow of gas into the zone at St Fergus and flows of gas from the north to the rest of the UK. The low emissions in zones W1 – W4 reflect the relatively low flow of gas through the west NTS zones.

Figure 24 Major combustion emissions by year

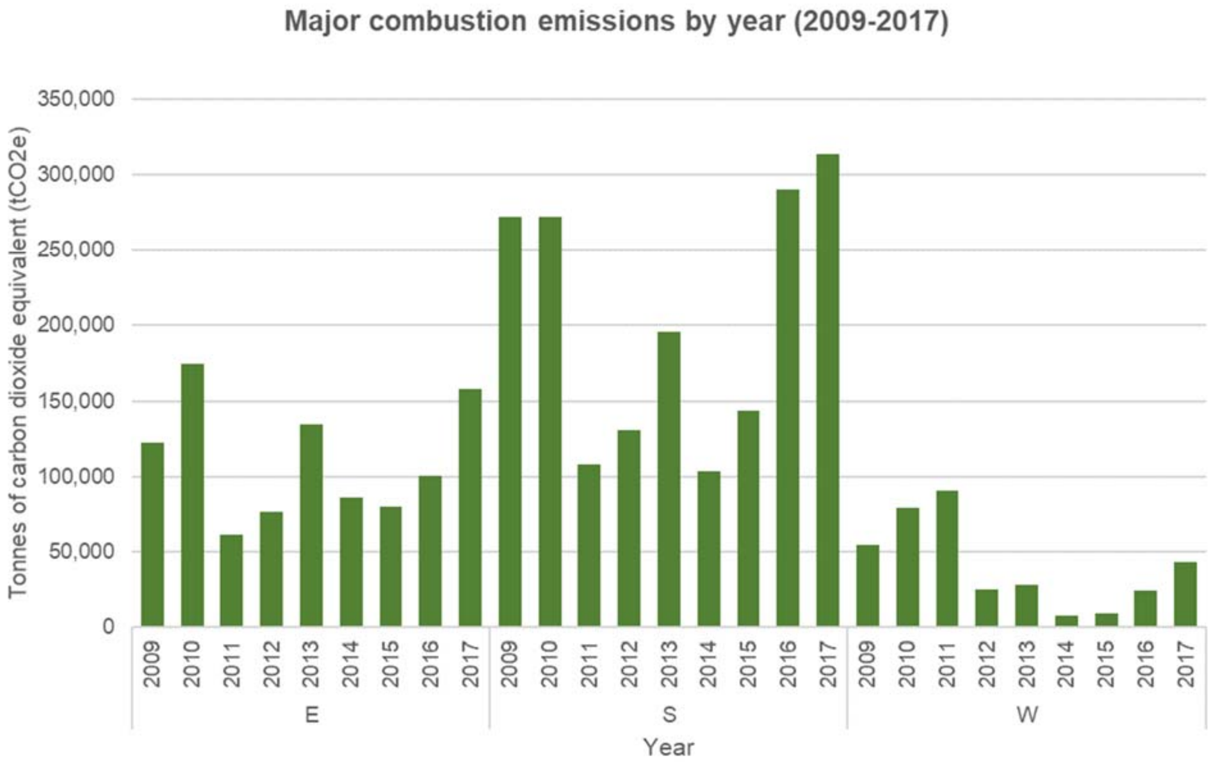


Figure 25 Total emissions by zone