Independent Review of National Grid's IED Investments: Ofgem Submission

Client: Ofgem

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Contents

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Revision and Change Control History

Revision	Date	No. of Pages	Summary of Changes
0	12/06/2015	22	Draft Submission
1	24/06/2015	23	Final Submission

REDACTED VERSION:

Redacted text

1. Executive Summary

National Grid Gas Transmission (NGGT) has supplied Ofgem with a proposal regarding continued investment into the National Transmission System (NTS) compressor units in order to comply with the Industrial Emissions Directive (IED). Penspen have been tasked, by Ofgem, to analyse the proposal to corroborate NGGT's conclusions from a technical and cost perspective.

A brief overview of the relevant legislation is given, and the NGGT decision process used within their proposal is outlined and critiqued. The NGGT proposed solutions for the affected stations are presented and technically analysed, and alternatives are given where applicable.

In terms of the facilities which fall under the LCP (Large Combustion Plant legislation), there is not enough technical information available to confirm that the most appropriate solution has been chosen for each station. However, many of the final decisions which NGGT has made to derogate could be acceptable if the historic running hours are low and the useful design life of the unit is nearing its end.

In terms of IPPC Phase 4 proposal there is not enough evidence to support the choice of stations to upgrade, and no analysis is provided to support the decision to replace the units.

Generally, where replacements have been proposed NGGT have not presented a thorough assessment of alternative options. Under the IED regulation NGGT should have performed BAT (Best available Techniques) assessments to identify the best options for each unit, which it would then take forward to the stakeholder consultation stage. There is not enough evidence in the submission to justify the rejection of DLN/DLE (Dry Low NOx/Dry Low Emissions) retrofit and SCR (Selective Catalytic Reduction) solutions, especially since they are considered BAT in the BREF (Best Available Techniques Reference document). Quotes for retrofit should have been obtained, and SCR should have been considered for each unit individually. There is no emissions data available to support the NGGT decision to only use CO (Carbon Monoxide) catalysis at the Aylesbury site.

Savings of over £90 million are predicted if SCR or retrofit technologies are utilised at the Hatton site instead of replacement. Please note that this prediction is made within the limitations of this report based on incomplete information.

The total NGGT estimated costs are presented and interpolation is used to corroborate them, with any discrepancies highlighted. Replacement costs are compared with figures for the construction of Felindre Compressor Station on the Milford Haven Pipeline Project, and there is general agreement between the two. NGGT have provided a reasonable representation of potential expenditure **for the works which it proposes**. Exceptions to this include Hatton which may have additional expenses, and the 100% contingency used for the Kirriemuir and the IPPC phase 4 facilities.

2. Introduction

National Grid Gas Transmission has presented its plan for compliance of the National Transmission System (NTS) compressor units with the Industrial Emissions Directive (IED).
The purpose of this report is to establish if NGGT has exercised due diligence in the technical and economic decisions which it has made.

NGGT has indicated costs in the region of £400-500m under the programme of work considered necessary to comply with the Industrial Emissions Directive. Penspen will assess the NGGT proposal received, along with available supplementary documentation available within the public domain, and provide Ofgem with views as to whether the proposed costs for individual units and specific modifications are appropriate along with a review of the proposed methods identified by NGGT for complying with the IED and the chosen solutions suitability for each station.
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Thanks must be given to Ofgem for awarding this review to Penspen, and to the employees at both Ofgem and NGGT who have been helpful in providing us with background information.

2.1 Definitions

AFW	Amec Foster Wheeler
BAT	Best Available Techniques
BREF	Best Available Techniques Reference Document [4]
CCGT	Combined Cycle Gas Turbines
CO	Carbon Monoxide
DLE	Dry Low Emissions
DLN	Dry Low NOx
DN	Distribution Network
EA	Environment Agency
ELV	Emission Limit Values
FES	Future Engineering Scenarios
IED	Industrial Emissions Directive [3]
IPPC	Integrated Pollution Prevention and Control
IPPC Phase 4	4^{th} round of the NGGT/EA/SEPA compressor fleet annual review strategy
LCP	Large Combustion Plant directive
MCP	Medium Combustion Plant directive
MW	Mega Watt
MW_e	Mega Watts of electrical output
MW_{th}	Mega Watts of thermal input
NDP	Network Development Process
NGGT	National Grid Gas Transmission
NO_x	Nitrogen Oxides
NTS	National Transmission System
Ofgem	Office of Gas and Electricity Markets
RIIO	Ofgem's framework for setting price controls for network companies (Revenue = Incentives + Innovation + Outputs)
RIIO-T1	The first price control reviews to use the RIIO framework: RIIO-T1 (gas and electricity transmission)
RIIO-T2	The second phase of transmission price control reviews
RPE	Real Price Effects
RPI	Retail Prices Index
SBG	Stand-By Generator
SFA	Supplementary Firing Apparatus
SCR	Selective Catalytic Reduction (NOx removal technology)
SEPA	Scottish Environment Protection Agency
TSO	Transmission Systems Operator

2.2 References

[1] IED Investments Ofgem Submission FINAL (1)
[2] IED Investments Ofgem Submission Appendix II - Cost Summaries
[3] DIRECTIVE 2010/75/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL ON INDUSTRIAL EMISSIONS (integrated pollution prevention and control), 24/10/2010
[4] Best Available Techniques (BAT) Reference Document for the Large Combustion Plants, European IPPC Bureau, Draft 1 (June 2013)
[5] Draft EPR Guidance on Chapter III (large combustion plants) of the industrial emissions Directive (March 2011) (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/82618/industrial-emissions-lpc-draft-epr-guidance-120312.pdf)
[6] NGGT Stakeholder Presentation (Sep 2014) (http://consense.opendebate.co.uk/files/nationalgrid/transmission/September_Workshop_Slide_Pack2.pdf)
[7] SCR_BAT_Draft_v1.pdf
[8] http://consense.opendebate.co.uk/files/nationalgrid/transmission/IED_Investments_Initial_Consultation_Feedback.pdf

2.3 Relevant Legislation

1. DIRECTIVE 2010/75/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL ON INDUSTRIAL EMISSIONS (integrated pollution prevention and control), 24/10/2010

3. Overview of the National Grid Proposal

3.1 Legislative Background

In 2010 the EU promulgated the Industrial Emissions Directive (IED). It brought together a number of previous legislative documents, and introduced some new legislation. The specific areas which impact NGGT are summarised below:

1) The use of permits for installations
2) Establishment of BAT Reference documents
3) Large Combustion Plant (LCP) - The updating of Emission Limit Values (ELVs) on nitrogen oxides (NO_{x}) and carbon monoxide (CO) for installations above 50 MW

3.1.1 Large Combustion Plant (LCP)

This applies to all combustion plants with an aggregate thermal input of 50MW or more. In this context if a number of turbines do (or could) use the same exhaust stack then they must be considered together and if the aggregate heat input is above 50MW then they must all comply with the LCP regulation.

The LCP defines ELV for the level of NOx and CO in the plant exhaust. The emissions limits are higher for existing installations than for new build.

There are also a number of derogations presented in the IED which allow plants to continue operating with emissions above the ELV:

- Limited Lifetime Derogation (maximum 17500 hours or until 2023)
- Emergency Use Derogation (maximum 500 hours per year)
- 1,500 hours Derogation (1,500 hours per year as a rolling average over 5 years)

It is expected that future legislation will include ELVs for Medium size Combustion Plants (MCP).

3.1.2 Integrated Pollution Prevention and Control (IPPC)

Under the IPPC any installation with a high pollution potential is required to have a permit. One of the prerequisites for this permit is that Best Available Techniques (BAT) are used to minimise the emission of these pollutants and that a BAT assessment of a site should be carried out when developing solutions. As such the design, build, maintenance, operation and decommissioning of a plant should all be considered when making adjustments.

The IED also introduces an increased emphasis on the status of the BAT Reference (BREF) documents. These BREF documents draw conclusions on what the BAT is for each sector to comply with the requirements of IED. The BREF for LCP [4] is currently in draft form but is due to be finalised in 2016.

3.2 Summary of the NGGT Response

As a result of the new legislation NGGT has reviewed its compressor fleet to establish if it complies. In summary it has found that 16 out of its 64 compressor units will be in breach of the new regulations which come into force on the 31st December 2015 unless further action is taken.

NGGT undertook a benchmarking study with other European TSOs to establish best practice. They also conducted a number of stakeholder meetings and presentations and incorporated stakeholder feedback into the review process.

They identify a number of potential solutions for each compressor turbine which are summarised below:

1) Retain under the Limited Life Derogation and subsequently decommission
2) Retain under the Emergency Use Derogation
3) Retrofit
4) Catalytic Converter
5) Replace with the same capability
6) Replace with different capability

At this stage NGGT reject both compressor retrofit options and Selective Catalytic Reduction (SCR) technology. (The reasons for this are detailed in Section 4.1.3.)

A number of options are then presented for those stations which will be in contravention of the law. The options mostly consider combinations of derogating and replacing machines. The assessment criteria for the different options are based on what stakeholders identified as being important through the development of the Gas Transmission Network Strategy scorecard.

Each option is rated against these criteria and a preferred option is presented based on which performed best.

A further section deals with the proposed IPPC Phase 4 changes. NGGT selects three plants for upgrade, which according to its analysis are the most polluting. These are Peterborough, Huntingdon and St. Fergus, all of which previously received funding under IPPC Phases 1-3.

A draft schedule is presented for the anticipated programme of works and outages, and finally the approximate impact on customer bills is given.

4. Analysis of the NGGT Decision Process

Section 4 follows the structure of the NGGT report. The NGGT decision making process is reviewed along with the technical information presented.

4.1 Potential Solutions

Within this section there are a number of potential solutions which are dismissed with little discussion or evidence of investigation. Some solutions which are considered BAT in the Draft BRE document [4] are not mentioned at all. Each of these solutions are presented here and discussed in turn.

Generally it would have been expected that NGGT should do BAT assessments for each site and each technology. If a technology was obviously not applicable then it could be eliminated before this stage.

4.1.1 Retain under the Limited Life Derogation and subsequently decommission

This option is given in the IED and is definitely a valid consideration; however a technical assessment is not given here. One major technical benefit to derogating is that if a machine is nearing the end of its design life it may not be economical to upgrade it to meet the ELV for the remainder of its working life.

There may also be an advantage in terms of waiting to see how the legislation progresses further before committing to new capital expenditure; however this is not a technical issue.

It is suggested (in the 'replace with the same capability' option) that the operating envelope of a derogated machine could be larger than an equivalent new machine due to the more stringent ELVs placed on new turbines. It follows from this that derogating turbines will allow more system flexibility. This is a slightly erroneous argument as the IED places no ELV restrictions on machines operating below 70% flow rate (See 4.1.5 below).

The downside of keeping older machines running are the higher maintenance costs and potentially lower efficiency than a newer model, leading to comparatively higher running costs. The machine may also be less reliable, but this must be contrasted with the downtime associated with installing a new machine. In terms of the overall system flexibility it may not be feasible to limit the running hours, but discussion of this is beyond the scope of this report.

4.1.2 Retain under the Emergency Use Derogation

This generally shares the same benefits and disadvantages as the limited life derogation. The very limited operating hours mean that it can't be applied to any turbine which is critical to the overall system operation and flexibility.

"If the regulator is satisfied that standby generators will be used only in the case of an emergency or breakdown of other equipment, such that they replace the thermal input of that part for which they are substituting, their rated thermal input should not be counted towards calculation of the total. However, if the SBGs or SFAs are used to boost performance in certain cases (as well as, at times, substituting), they will need to be counted towards the total rated thermal input." [5]

It is assumed that where the emergency use derogation has been invoked it has been discussed with the relevant environmental agency, and they have agreed to its use. However, no evidence is presented in the proposal to this effect.

4.1.3 Retrofit

The option to retrofit is briefly discussed in the NGGT submission. NGGT refer to detailed studies which they made of compressor retrofit options, however these are not currently available for review. The BREF document [4] gives a number of retrofitting options which are considered BAT for reducing NOx emissions, but these are not mentioned here. These rely on reducing the overall combustion temperature inside the turbine. Broadly they can be categorised based on whether they are dry or wet.

Dry methods include DLE and DLN. DLE technology has been used to upgrade the existing engines at Aylesbury and so it is not clear why this is not considered elsewhere.

Wet methods include steam or water injection, which may be preheated with the turbine exhaust gases (e.g. Cheng cycle). The wet systems have the disadvantage of reducing the life of the turbine, but can be effective in reducing NOx.

NGGT reject this option based on their stated findings that retrofit is only minimally less expensive than replacement. In fact retrofitting costs for DLN vary considerably between manufacturer and model, [4]. Therefore NGGT should have obtained retrofit quotes for the specific turbine makes and models involved in order to justify their conclusions. However, there is no mention of any such quotes obtained.

4.1.4 Catalytic Converter

Oxidation of CO

The most accepted gas turbine technology uses a catalyst in the exhaust stack which aids the oxidation of CO with oxygen, converting it to CO_2. It is appropriate that this technology is included here, and that it is not rejected, as it is accepted as BAT. However, NGGT only propose it as a solution at one facility (Aylesbury). NGGT state that the reason for this is that Aylesbury is the only site which meets the NOx ELV, but not the CO ELV [8]. This technology could be applied usefully at other sites if the CO emissions were above the ELV, independent of the level of NOx. However, there is no emissions data available to check if other units do have elevated CO levels.

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Reduction of NOx

In their analysis NGGT rightly mention the hazardous nature of the reducing agents. Ammonia can be stored and used as a dilute solution in water which makes it less hazardous. The actual storage volumes needed vary depending on the size of the plant and running hours. However, general space constraints are important in determining if SCR can be implemented.

NGGT assert that this technology is more suitable for units with low running hours. This would have to assume that the supply and storage of the reducing agent is significantly more costly than fitting a catalyst bed into the exhaust stack. This is possible, but sounds unlikely. In fact BREF (p773) [4] describes the technique as not being applicable to emergency plants due to their intermittent operation. This may include many of the smaller MCP units.

NGGT describe how the technology is not yet proven or demonstrated for this application. In fact the BREF document [4] refers to a number of countries which are using them:

"Many gas turbines currently only use primary measures to reduce NOX emissions, but secondary systems, such as SCR systems have been installed at some gas turbines in Austria, Japan, Italy, the Netherlands, and in the US (especially in California). It is estimated that approximately 300 gas turbines worldwide are equipped with SCR systems." [4]

The SCR BAT [7] which was produced for NGGT is a very general document. It doesn't provide an individual BAT assessment for each site.

It is apparent from Figure 1, reproduced from the SCR BAT report [7], that the SCR options are given a similar cost to the base case of doing nothing. This is because most of the costs are associated with the maintenance of the existing RB211 turbine.

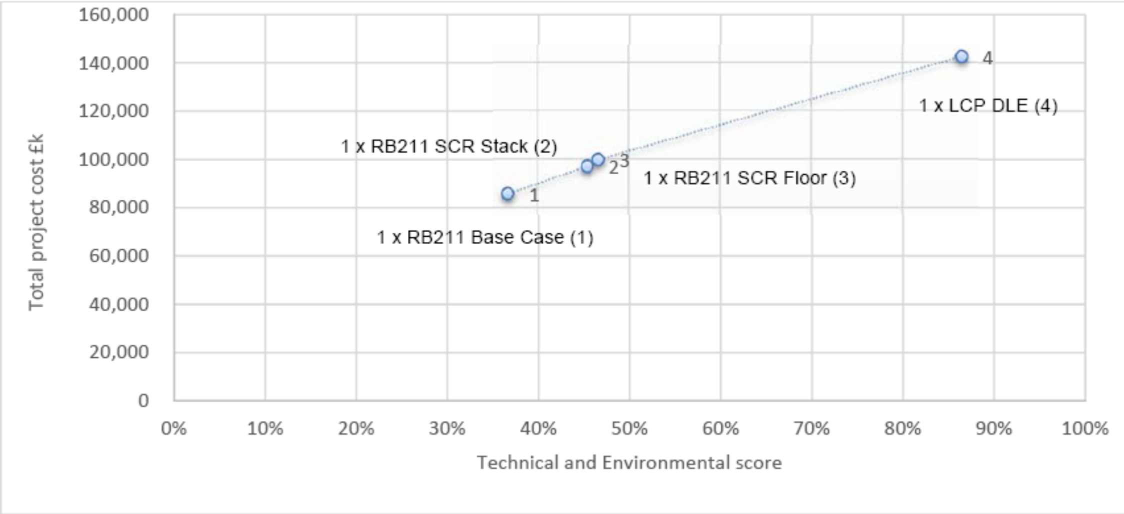

Figure 1 – Cost Benefit Analysis 1500 [sic] Hours LCP Case (Actually 3000 hours case) [7]

It states in the SCR BAT report that:

"RB211 and Avon maintenance costs (base case and catalyst options) are likely to be an overestimate of the true cost of maintaining these units." [7]

Thus the actual cost of an SCR solution may be considerably lower than estimated.

4.1.5 Replace with the same capability

It is suggested that the operating envelope of an older machine will be larger than an equivalent new machine due to the more stringent ELVs placed on new turbines, thus allowing more system flexibility. This is a slightly erroneous argument as the IED places no ELV restrictions on machines operating below 70% flow rate.

"For gas turbines (including CCGT), the NOx and CO emission limit values set out in the table contained in this point apply only above 70 % load." [3]

Load is equivalent to flow. Operation at 70% load is operation at 70% of the maximum possible flow. NGGT state in a recent stakeholder presentation [6] that **deliberately** running under 70% to avoid compliance with limits is illegal. However, using the full operating envelope when required to enhance system flexibility should be completely acceptable.

Figure 2 below is adapted from the NGGT submission [1]. It shows the 70% load line superimposed on the NGGT potential new operating envelope. This means that the only area where emissions are likely to be above the ELV is inside the small area bounded by blue, not the whole of the grey area.

Technically this draws into question the stated need to replace a single large unit with multiple smaller units.

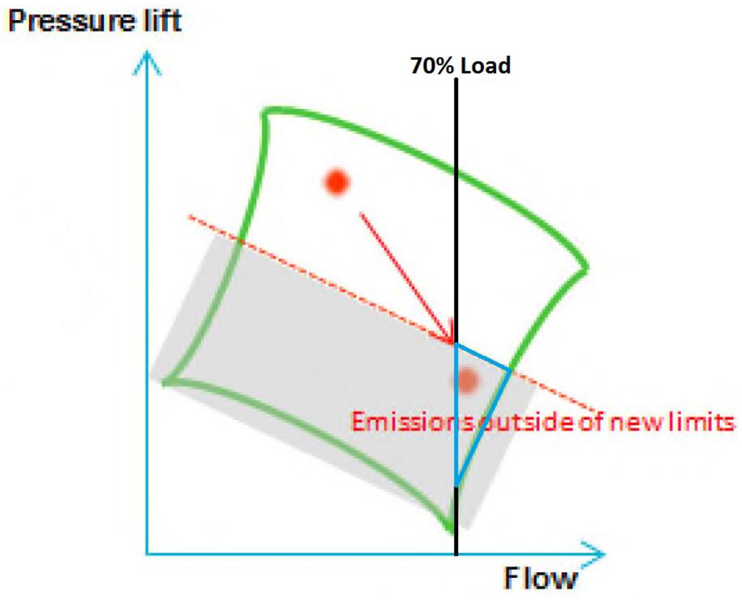

Figure 2 – NGGT example of a potential operating envelope for a new compressor with the 70% load line superimposed (the blue bordered area is likely to be above the ELV).

4.1.6 Replace with different capability

The discussion in the previous section is also relevant here in terms of choosing to install multiple units or one larger one.

Electric Drives can also be used on new units. These are outside of the IED emissions requirements.

Looking at changes in the overall forecast flows and operating strategy is important, but is beyond the scope of this report.

4.1.7 Additional Solutions

Exchanging small units between sites could reduce the aggregate thermal input below the 50MW LCP limit. However, when the MCP regulations are introduced this approach would not be adequate. In reality there appear to be no opportunities to do this.

4.2 Assessment of Options under LCP

Network Development Process (NDP)

At this stage in the NGGT methodology the options presented largely consist of combinations of derogation and replacement of turbine units. The criteria against which the options are assessed are listed below along with an analysis of whether they are appropriate. It should be noted that NGGT decided the basic criteria, and then obtained feedback from the stakeholders to determine the weighting applied to each criterion.

1. Does this option allow National Grid to meet future flexibility requirements?
System flexibility is measured against the Future Energy Scenarios (FES) which NGGT predicted in 2014. These were based on two variables: economic growth and the level of environmental legislation (sustainability). By combining these two variables four scenarios were

generated. Each scenario considers the supply of gas coming from different sources, and therefore entering the national grid at different locations.

Due to interactions in the network it is difficult to apply this for an individual station. On a basic level this is a range of potential pressures and flowrates which a station can operate at. From this perspective it is a valid criterion. The effect of limiting operating hours with derogations must also be considered.

2. Does this option remove barrier for encouraging new investment?
This question relates to capability. Additional capability is only useful if it is flexible enough to cope with possible future scenarios. Therefore this question is best combined with question 1.

3. Does this option have a negligible impact on customer charges?
This is a valid criterion, but it is only calculated based on capital and maintenance costs. Operating costs may have a significant impact on the figures given.

4. Is this option future proof? (flexibility is covered above so this deals with legislation i.e. BREF and MCP)
This is in the scope of the forthcoming Poyry report, and so is not addressed here.

5. Can National Grid meet Exit Capacity obligations considering this option?
NGGT has an obligation to meet certain exit capacities, so this is a valid criterion.

6. Does this option allow National Grid to retain current capability?
Capability is defined as the physical limit of the NTS to flow a volume of gas under a given set of conditions; this may be higher or lower than the capacity rights at a given exit or entry point.

It is more important to meet the obligatory entry and exit capacities covered in questions 5 and 8, than to retain current capability which may either be wasted or insufficient to meet demand.

NGGT have decided the possible answers to question 6, and they all refer to the FES. The FES relates to future capability; this means that question 6 overlaps with question 1.

7. Does this option represent an appropriate level of resilience on the network?
This is an important consideration which may warrant splitting into two separate questions relating to the redundancy within each station and the level of redundancy with interacting stations.

8. Can National Grid meet Entry Capacity obligations considering this option?
NGGT has an obligation to meet certain entry capacities, so this is a valid criterion.

9. Does this option allow the network to be operated in sensitivities beyond FES?
This is essentially an extension of question 1.

In conclusion questions 9 and 6 could be removed as they do not improve the assessment. Question 2 only has context when combined with question 1. Many of these questions are more appropriate when considering the network as a whole, not an individual station. These questions are mostly qualitative in nature. There are technical aspects related to individual stations such as reliability and efficiency which are not considered.

4.3 Options Chosen for Each Station

The figures which are presented relate to the compressor operating hours per year. This is useful in determining if a limited operating hour derogation may be suitable for a particular compressor. In order to evaluate the options effectively it is necessary to review the required operating conditions of the compressors (e.g. flowrates, supply & discharge pressures). These are not currently available. In this analysis it is assumed that the works proposed in the previous phases of IPPC are proceeding as planned.

4.3.1 St Fergus

Option 1: 17,500 hour derogation on units 2A and 2D and then decommission by 31st December 2023.

The affected units were built in 1980. There is no indication of the design life of the units or their condition. No rated capacity or range of discharge and suction pressures is given. No indication of the space available for retrofitting or the installation of catalysts is given. No emissions data has been made available.

Assuming that the units are near the end of their design life after 35 years of service then derogation becomes an attractive option. An expected continuing drop in the UKCS flowrates also supports this decision.

4.3.2 Kirriemuir

Option 5: Unit D - 17,500 hour derogation and then decommission.
Unit E – de-rate and re-wheel (electric unit)
Unit C – Decommission and install one new unit (MCP unit)

The affected unit was built in 1985. There is no indication of the design life of the units or their condition, but 10 years continued service is not unreasonable to expect. No rated capacity or range of discharge and suction pressures is given, or indication of the space available for retrofitting or the installation of catalysts. No emissions data has been made available.

If there is sufficient space available then DLE, Wet Low NOx or SCR technology could be considered for Unit D as an alternative to derogation and decommissioning, but the unit may not have enough operational life left to make this worthwhile.

It is assumed that the new unit will incorporate DLE technology as stated on p18 of the NGGT submission [1] (supplied as standard on all new gas turbines NGGT are considering). This is a necessity.

It is assumed that system flexibility requirements dictate the proposed re-wheeling of unit E. Commenting on system flexibility is beyond the scope of this report.

The proposed option also includes the decommissioning and replacement of unit C. NGGT justify this decision with the poor condition of the Avon units. There is no way for us to assess this, but the decision to replace could be delayed until the MCP legislation has been introduced.

4.3.3 Moffat

Option 3: 500 hour derogation both units

The affected units are two RB211 21.2 MW machines (units A and B). They were constructed in 1980. There is no indication of their design life or their condition. No rated capacity or range of discharge and suction pressures is given, or indication of the space available for retrofitting. No emissions data has been made available.

Due to the low number of hours operation of this unit SCR is not a recommended option.

Based on the previous yearly operating hours of the Moffat station it rarely operates above 500 hours per year. Therefore the 500 hour derogation is a reasonable solution.

4.3.4 Carnforth

Option 4: Unit A - 17,500 hour derogation and then decommission.
Unit B – 500 hour derogation
Site reconfiguration

The affected units are two RB211 25.3 MW machines (units A and B). They were installed in 1989. There is no indication of their design life or their condition. No rated capacity or range of discharge and suction pressures is given, or indication of the space available for retrofitting or the installation of catalysts. Unit A is not currently operational. No cost is given for the remedial works to bring it into operation. No emissions data has been made available.

There is no option given for entering both Unit A and B into the 500 hours emergency derogation and leaving unit A out of service. This has the advantage that there is no requirement to decommission A by the end of 2023. Site reconfiguration could also take place under this option. Cost savings from this alternative option could be considerable.

4.3.5 Hatton

Option 4: 17,500 hour derogation on 3 affected units and then decommission by 31st December 2023. Install three medium sized units.

The affected units are three RB211 25.3 MW machines (A, B and C). They were installed in 1989. There is no indication of their design life or their condition. No rated capacity or range of discharge and suction pressures is given, or indication of the space available for retrofitting or the installation of catalysts. No emissions data has been made available.

There is a necessity to keep capability at this station, and the units are also relatively young. This makes retrofit or SCR more attractive as options.

As such retrofit and SCR options for this station should not have been discounted by NGGT. NGGT should have conducted a BAT assessment of the available options.

Since there is no detailed evidence to the contrary, we must assume that the following are viable alternatives:

Option 5: Utilise the 17,500 hour derogation on A, B & C until the electric drive is operationally proven, and then **retrofit** A, B & C.

Option 6: Utilise the 17,500 hour derogation on A, B & C until the electric drive is operationally proven, and then add **SCR** to A, B & C.

Further Discussion of Option 4

In terms of the proposed option 4 replacement it will not provide the same system capability as the existing units.

Option	Arrangement	Total Power (MW)
Current	3 x 25MW	75
Option 4	3 x 15MW	45

Table 1 – Current and proposed Hatton gas driven compressor arrangements

As outlined in Section 4.1.5 there is little benefit in using smaller compressors. An arrangement of 2 x 25MW compressors would likely be cheaper than the proposed 3 x 15 MW and would have a higher total power output.

Alternative Options

Option 4

The cost of this option is £100m+, as per the NGGT submission.

Option 5

The draft BREF document gives approximate figures for the cost of retrofitting DLN technology to a turbine:

"Investment costs for retrofitting can be estimated as EUR 20 – 40/kWe. Retrofits cost approx. from EUR 2 million to EUR 4 million for a 140 MWth gas turbine for modern dry low NOX burner, depending on the original/final situations and on the type of plant/retrofit, and operation and maintenance cost is approx. EUR 500 k/year." [4]

For a conservative estimate of capital cost assume that the conversion to electrical power is 100% efficient, and use the EUR 40/kWe figure.

For a single 25.3MW unit the capital cost is:

25.3MW x (1000kW/MW) x EUR 40 / kW	=	EUR 1 million
For all three units	=	EUR 3 million (maximum)
	=	£2.2 million (maximum)

NGGT should have obtained a quote for a DLN/DLE retrofit for the specific turbine make and model.

Water or steam injection is also possible, but dry retrofit with DLN/DLE technology is preferred.

Option 6

The draft BREF document [4] has a method for estimating the capital cost of an SCR:

"The capital costs of an SCR for gas turbines or internal combustion engines are in the range of EUR 10 to 50/kW (based on electrical output)." [4]

For a conservative estimate of capital cost assume that the conversion to electrical power is 100% efficient, and use the EUR 50/kW figure.
For a single 25.3MW unit the capital cost is:

25.3MW x (1000kW/MW) x EUR 50 / kW	=	EUR 1.3 million
For all three units	=	EUR 3.9 million (maximum)
	=	£2.9 million (maximum)

The draft BREF document also gives a method for estimating operating costs:

"Operating costs for the reducing agent are approximately EUR 75 per tonne NOX for anhydrous ammonia or EUR 125 per tonne of NOX for a 40 % urea solution." [4]

Please note, an estimate of the operating costs for the reducing agent (ammonia or urea) is not currently possible as the emissions data has not been made available.

4.3.6 Warrington

Option 3: 500 hour derogation both units

The affected units are two RB211 22.3 MW machines (units A & B). The Warrington station was constructed in 1983. There is no indication of their design life or their condition. No rated capacity or range of discharge and suction pressures is given, or indication of the space available for retrofitting. No emissions data has been made available.

Due to the low number of hours operation of this unit SCR is not a recommended option.

Given the low running hours of these units the 500 hour derogation is a logical option. If the system requirements change in the future then this could be reviewed.

4.3.7 Wisbech

Option 3: Unit A - Maxi Avon conversion to Avon
Unit B – 500 hour derogation

The affected units are one RB211 21 MW machine (unit A) and one Avon 1534 13.97 MW machine (unit B). These units were constructed in 1980. There is no indication of their design life or their condition. No rated capacity or range of discharge and suction pressures is given, or indication of the space available for retrofitting or the installation of catalysts. No emissions data has been made available.

Due to the low number of hours operation of this unit SCR is not a recommended option.

Due to the historic low running hours of the two units a 500 hour derogation on both units is definitely attractive. Option 3 also includes the downgrading of an Avon 1534 to the previous model 1533. The reason for this downgrade is to reduce the total heat input of this unit to below 50MW, and thus to bring it outside of the scope of the current legislation.

It is not clear if the conversion of the maxi Avon to an Avon involves the re-use of the maxi Avon parts. The appendix to the NGGT report [1] states that the conversion involves an engine change out and refurbishment. Elsewhere in the document [1] it mentions replacement. It does not explain where the parts are from, and it is not clear how much of the existing turbine is reused. If it involves a complete replacement then the cost of option 3 could potentially be reduced if the resale or reuse of the maxi Avon 1534 was considered. Additionally, if the 1533 Avon is already owned by National Grid and is unused then purchase costs for it should not be included. Generally NGGT has not demonstrated the use of strategic spares to reduce costs.

4.4 IED – IPPC Phase 4

As part of their RIIO submission NGGT proposed undertaking works to reduce emissions at the three most polluting sites. There is no justification of this in the report or explanation of the IPPC Phase 4 agreement with Ofgem, and Ofgem indicate that there is no agreement for NGGT to undertake works at three sites. In this section NGGT do not consider units which are covered by the LCP legislation. It appears that all of the units proposed for IPPC Phase 4 investment are MCP. NGGT are effectively using IPPC Phase 4 to prepare for the introduction of the MCP legislation. No power ratings are given for the units under discussion, and no actual emissions data is provided (other than operating hours). This limits our ability to technically assess this section.

4.4.1 Greatest Emissions

Table 2 below is reproduced from the NGGT submission [1]. NGGT use the data in Table 2 to determine the most polluting units in service. NGGT assume that the total running hours of a unit directly correlates with the level of emissions which it produces. This is an over simplification, but may be adequate since all of the units are Avon type 1533.

There are a number of units highlighted in red within Table 2. NGGT maintain that these units hold the most potential "for replacement under IPPC Phase 4, due to their size and emissions performance" [1]. There is no measureable proof to back this up within the available documentation.

NGGT identify replacement of units at St Fergus, Peterborough and Huntingdon as the most likely to provide the greatest emissions production. With the information available we cannot confirm that this is the case.

The decision to carry out adjustments at Peterborough and Huntingdon is been brought into question given that NGGT are in the process of installing a new 15.3 MW gas turbine at each site under IPPC 3 (already funded) and they were not considered as options in initial negotiations with Ofgem. NGGT still propose as part of IPPC phase 4 that two of the smaller units are replaced at each site in order to retain redundancy at operation at turndown.

Compressor station	Units	Running Hours					
		2010	2011	2012	2013	2014	5 year average
Alrewas	A and B (Avon 1533s)	1061	305	258	146	66	367
	C (Solar Titan DLE)	1091	1209	28	120	50	500
Cambridge	A and B (Avon 1533s)	117	18	40	42	49	53
	C (Cyclone DLE)	4	21	44	26	27	24
Chelmsford	A and B (Avon 1533s)	28	15	27	553	10	127
Diss	A, B and C (Avon 1533s)	432	15	19	918	45	285
Kings Lynn	A and B (Avon 1533s)	14	8	21	66	7	23
	C and D (Siemens SGT400)	1392	505	69	1723	42	746
Kirriemuir	A, B and C (Avon 1533s)	891	499	997	457	169	603
	D (RB211)	3127	795	1756	157	176	1202
	E (Electric VSD)	N/A	N/A	N/A	N/A	N/A	N/A
St. Fergus	5 Avon 1533 Units	6346	8816	6987	6902	6647	7140
	2 RB211 Units	8645	2916	4255	5893	2605	4863
	Electric VSD Unit	N/A	N/A	N/A	N/A	N/A	N/A
Wormington	A and B (Avon 1533s)	3746	5053	541	81	62	1897
	C (Electric VSD)	1098	2021	961	926	1455	1292
*Peterborough	A, B and C (Avon 1533s)	8268	4958	6621	7448	5785	6616
*Huntingdon	A, B and C (Avon 1533s)	6201	1444	842	4586	2503	3115

* One new unit to be installed as part of IPPC Phase 3

Table 2: Running hours at each site provided, with relevant breakdowns by unit. [1]

4.4.2 Decision to replace

It is also not clear how the decision to replace the units was reached. There is no evidence of any analysis done to reach this conclusion. Retrofitting the existing units with DLE/DLN technology is a possibility; this could improve emissions at a reduced cost. As there are no further details available for these units it is not possible to critically evaluate the NGGT proposal. Suffice to say that if the condition of the units was poor then replacement must be considered.

In short there is not enough supporting evidence to be able to confirm the decision on a technical level. However, given that the three sites chosen are key network stations, it makes sense to keep them in good condition as well as improving emissions and so they provide a practical solution for the improvement of future transmission activities.

If the units are to be replaced then a thorough investigation of the probable requirements of the forthcoming MCP legislation should be made. This ensures that any replacement units are future-proof. If this cannot be guaranteed then NGGT should consider delaying the replacement.

5. Overall Cost Analysis

5.1 Introduction

NGGT presented a Cost/Allowance Assessment in Appendix 1 of IED Investment Proposal dated May 2015. This Appendix identified that for such items as compressor unit replacement, allowances have been generated from the unit costs set as part of the RIIO-T1 deal. Where unit prices were not set as part of RIIO-T1, for example for decommissioning, refurbishment and asset health costs, budget prices were obtained from Amec Foster Wheeler (AFW) and others,.

The summary funding request Included on page 81 of NGGTs Appendix 1 is reproduced below:

Assessed Cost/Allowances are generally presented at 2009/10 prices and these have been converted to Outturn Costs by factoring in latest RPI data, actuals and forecast, and the RPEs as set out in the National Grid Licence.

In summary, National Grid are requesting £342.79m at 2009/10 prices, £467.88m at outturn prices

Summary Funding Request

[redacted]

5.2 Holistic Assessment

NGGT presented a Holistic Assessment of the IED proposals and the anticipated outturn costs on page 64 of the IED Proposal, reproduced below:

Taken at face value, the range of estimated outturn costs for individual sites provided in this table could be aggregated and the overall price expressed as ranging from a minimum of circa £335m to a maximum of circa £600m assuming Hatton costs are capped at £130m rather than £100+ as quoted in the summary table[1].

The Summary Funding Request for £467.88m total outturn price falls almost exactly in the middle of the overall price range quoted in the holistic analysis, +/- circa £133m, or +/- 28%.

The table below summarises for each station the recommended option.

Station	Recommended option	Recommended option - anticipated allowance (outturn prices)
St Fergus (LCP)	17,500 hour derogation on units 2A and 2D and then decommission by 31st December 2023	<£10m
Kirriemuir	Unit D - 17,500 hour derogation and then decommission Unit E – De-rate and re-wheel (electric unit) Unit C – Decommission and install one new unit (MCP unit)	£50-100m
Moffat	500 hour derogation both units	£10-20m
Carnforth	Unit A - 17,500 hour derogation and then decommission Unit B – 500 hour derogation Site reconfiguration	£10-20m
Hatton	17,500 hour derogation on 3 affected units and then decommission by 31st December 2023. Install three medium sized units	£100m+
Warrington	500 hour derogation both units	<£10m
Wisbech	Unit A - 500 hour derogation Unit B – Maxi Avon conversion to Avon	<£10m
St Fergus (IPPC)	Two replacement units and decommission two units	£50-100m
Peterborough (IPPC)	Two replacement units and decommission three units	£50-100m
Huntingdon (IPPC)	Two replacement units and decommission three units	£50-100m

5.3 Penspen Interpolation

Other than by worksite, an exact detailed breakdown of the NGGT funding request was not provided in the IED Proposal.

For instance, the Appendix identified how the National Grid and Project Services costs have been developed on a "bottom up basis" but nowhere are these costs actually separately identified. Footnote 11 on page 77 confirms that the unit cost for decommissioning includes for National Grid and project Services costs and the presentation given to Ofgem on 3 June 2015 goes further to identify that these costs have also been added to the Kirriemuir and Wisbech refurbishment quotations.

[redacted]

Penspen have therefore attempted to re-create a detailed cost breakdown by interpolation from the information actually provided by NGGT and to summarise it in a more logical sequence.

It is concluded that NGGT propose to undertake the following activities at the ten compressor stations identified in the Proposal at a total cost of £342.79m (2009/10 prices):

1. **An allowance of [redacted] install a total of ten replacement units at Kirriemuir (1), Hatton (3), St Fergus (2), Peterborough (2) and Huntingdon (2) accounting for [redacted] of the total cost of the proposals.**
2. **An allowance of £20.1m for decommissioning of the original ten units identified in item 1 above, plus one more unit each at Kirriemuir, Peterborough and Huntingdon and two more units at St Fergus (LCP) accounting for 6% of the total cost of the proposals.**
3. **Allowance of £7.9m for decommissioning one unit and site reconfiguration (reverse flow modifications) at Carnforth accounting for 2% of the total cost of the proposals.**
4. **Allowance of £3.4m for de-rating and re-wheeling of one unit at Kirriemuir plus conversion of one unit at Wisbech accounting for 1% of the total cost of the proposals.**
5. **Allowance of £22.9m for Asset Health costs at Moffat, Carnforth, Warrington and Wisbech accounting for 7% of the total cost of the proposals.**
6. **The above allowances items 2 to 5 above are inclusive of Project Services and National Grid Costs, Budget prices obtained from AFW and others have been uplifted by circa 4%.**
7. **An uplift equivalent to average 36.5% has been applied to obtain outturn prices from the 2009/10 estimated costs.**

5.4 Discussion on Replacement Unit Costs

As described on page 75 of the IED Proposals, NGGT have used unit costs set as part of the RIIO-T1 deal to evaluate the cost of the ten replacement units proposed. Although elegant, it is a very simple method on which to estimate 84% of the overall cost of the proposals.

Presumably, the unit costs set as part of the RIIO-T1 deal were based on accurate verified cost data and would be broadly applicable to the works now proposed by NGGT.

For an alternative comparison, Penspen have previously reviewed the outturn costs collated by NGGT for the construction of Felindre Compressor Station on the Milford Haven Pipeline Project.

[redacted]

It is therefore concluded that the method of calculation chosen by NGGT for the estimated cost of replacement units appears reasonable.

Nevertheless, it is noted here that 90% of the cost of the IED Proposals, (Items 1 and 2 in Section 5.3 above) are associated with decommissioning existing units and replacement with new units having lower emissions. It would appear that although potentially cheaper alternative methods to reduce emissions associated with existing units have been identified, they have been largely discounted by NGGT.

5.5 Discussion on Decommissioning Costs

Item 2 in Section 5.3 above identified an allowance of £20.1m decommissioning costs for fifteen units. The allowance for decommissioning appears to be based on the 2014/15 budget prices provided by AFW, ref estimates 2, 3 and 4 in NGGT Appendix II. NGGT appear to have used the budget price plus the identified risk allowance. According to the presentation made to Ofgem on 3 June 2015, NGGT have added circa 4% (estimated by interpolation) of the budget cost to cover National Grid and Project Services costs.
NGGT does not appear to have attempted to convert the 2014/15 budget prices to 2009/10 prices. It is also noted that there are a further five units with proposed derogation for which no decommissioning costs have been identified in the IED Proposal.

5.6 Discussion on other Modification Costs

Items 3 and 4 in Section 5.3 above identified an allowance of £11.3m decommissioning, site re-configuration (for reverse flow), de-rating and re-wheeling of an existing unit. The allowance for these smaller value proposals appear to be based on the 2014/15 budget prices provided by AFW, Siemens and RWG, estimates 1, 9 and 10 in NGGT Appendix II with circa 4% added for National Grid and Project Services costs.

The 2014/15 budget costs provided by Siemens and RWG do not appear to have been converted to 2009/10 prices but neither has any risk allowance been included. However, the total allowances for these modifications account for only 3% of the total cost of the proposals and the apparent omission of some risk allowance is unlikely to affect the total funding requested.

5.7 Discussion on Asset Health Costs

Item 5 in Section 5.3 above identified an allowance of £22.9m for Asset Health costs. The total allowance appears to be based on the 2014/15 budget prices provided by AFW, estimates 5, 6, 7 and 8 in NGGT Appendix II, plus the identified risk allowance for each site and a mark-up for National Grid and Project Services costs, assumed circa 4%.

NGGT does not appear to have attempted to convert the 2014/15 budget prices to 2009/10 prices. It also appears that NGGT have included additional sums of £0.72m and £0.64m in the Carnforth and Wisbech estimates that are not otherwise accounted for.

There is minimal information provided in the Appendices to identify what is exactly included under "Asset Health" as only the generic parts of the AFW estimate sheets have been included in NGGT Appendix II.

5.8 Discussion on Outturn Costs

Item 6 in Section 5.3 above identified that an overall average uplift equivalent to 36.5% of the total funding request (2009/10 prices) has been used to convert 2009/10 prices to outturn prices.

For individual stations, this uplift percentage varies from minimum of circa 30% for Wisbech where spend profile occurs during years 2015/16 to 2018/19, to a maximum of circa 48% for St Fergus (LCP) where spend profile occurs much later in years 2020/21 and 2021/22.

5.9 Discussion on Holistic Assessment

In Section 5.2 above, it was identified that the overall outturn price is expected to range from circa £335m to £600m and that the Summary Funding Request for £467.88m total outturn price falls almost exactly in the middle of the overall price range quoted in the holistic analysis, +/- circa £133m, or +/- 28%.

Looking at the individual compressor sites, it is evident that most estimated outturn prices are also close to the midpoint of the range quoted in the holistic analysis but with two exceptions:

- For Kirriemuir, the estimated outturn price of [redacted] is at the bottom end of the range £50m - £100m
- For Hatton, the estimated outturn price of [redacted] appears inconsistent with the quoted summary figure of £100m+ although presumably, the + signifies that a much higher upper figure could be interpreted. This apparent discrepancy was subject to a formal Question and Answer, which received a non-committal response from NGGT, reported in Footnote 1. It would appear that for Hatton, the estimated outturn price of [redacted] is in fact at the top end of the range interpolated as [redacted] but reported by NGGT as £100m+.

NGGT have not explained the significance of the ranges illustrated in the Holistic Assessment.

It is assumed that the upper range is intended to provide circa £133m, or 28% additional contingency for Risks not already allowed for. It is noted that if the equivalent contingency was applied to Hatton then the Holistic Assessment upper range figure for this site might increase by circa £37m to £165m and the overall contingency for all sites might increase to circa £170m. Based on previous NGGT experiences, cost escalation could consume this contingency.

Of concern is the that in its IED Proposals NGGT may have failed to identify the real cost of providing replacement units at the affected sites and that only by careful interpolation can the breakdown of proposed estimated costs be identified.

Further evidence is provided by reference to the draft IED proposals published in March 2015. The technical proposals for Hatton are unchanged from the draft with three replacement units proposed but with an anticipated outturn cost of £50m - £100m in the draft.

As each new unit has been simply priced at [redacted](09/10 prices) and with circa [redacted] average uplift to convert to outturn prices, NGGT must have already known prior to March 2015 that Hatton costs would exceed £100m.

6. Conclusion

In terms of the LCP, there is not enough technical information available to confirm that the most appropriate solution has been chosen for each station. However, many of the final decisions which NGGT has made appear to be reasonable. This is because derogation is the most appealing option when historic running hours are low and the useful design life of the unit is nearing its end.

In terms of IPPC Phase 4 proposal there is not enough evidence to support the choice of stations to upgrade, and no analysis is provided to support the decision to replace the units.

Generally, where replacements have been proposed NGGT have not presented a thorough assessment of alternative options. Under the IED regulation NGGT should have performed BAT assessments to identify the best options for each unit, which it would then take forward to the stakeholder consultation stage. There is not enough evidence in the submission to justify the rejection of DLN/DLE retrofit and SCR solutions, especially since they are considered BAT in the BREF. Quotes for retrofit should have been obtained, and SCR should have been considered for each unit individually. There is no emissions data available to support the NGGT decision to only use CO catalysis at the Aylesbury site.

Savings of over £90 million are predicted if SCR or retrofit technologies are utilised at the Hatton site instead of replacement. Please note that this prediction is made within the limitations of this report based on incomplete information.

NGGT have provided a reasonable representation of potential expenditure **for the works which it proposes**. Exceptions to this include Hatton which may have additional expenses, and the 100% contingency used for the Kirriemuir and the IPPC phase 4 facilities.