King’s Lynn Preliminary BAT assessment – output summary

King’s Lynn Compressor Station

National Grid Gas plc

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FINAL VERSION

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Contents

List of acronyms

BAT	Best Available Techniques
BREF	BAT Reference Document
CAPEX	Capital expenditure
CBA	Cost Benefit Analysis
CSRP	Control System Restricted Performance
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DLE	Dry Low Emissions
EA	Environment Agency
ELV	Emission Limit Values
FEED	Front End Engineering Design
FES	Future Energy Scenario
FOSR	Final Option Selection Report
GT	Gas Turbine
MCPD	Medium Combustion Plant Directive
NOx	Oxides of Nitrogen
NPV	Net Present Value
NTS	National Transmission System
OEM	Original Equipment Manufacturer
PDS	Process Duty Specification
SEPA	Scottish Environment Protection Agency
Totex	Total whole life modelled cost
SCR	Selective Catalytic Reduction
VSD	Variable Speed Drive

Introduction

This report is a summary of the preliminary Best Available Techniques (BAT) assessment for King's Lynn Compressor Station. The assessment has been undertaken using investment options identified in the FEED (Front End Engineering Design) Feasibility Study and National Grid Cost Benefit Analysis (CBA). Its purpose is to support decision making and accompanies the Final Option Selection Report (FOSR), to demonstrate the investment case for an upgrade at King's Lynn Compressor Station.

Investment is required for the site to comply with the requirements of the Medium Combustion Plant Directive (MCPD) and ensure that network capability requirements are maintained. The assessment has been undertaken independently from the CBA Tool analysis using a different methodological approach[1]; it does however incorporate common assumptions on cost and network capability requirement predictions.

This is a preliminary assessment informed by the FEED Feasibility study, ongoing technology studies and cost estimates described in the FOSR. The BAT assessment will be updated at the project procurement stage, with information provided by equipment suppliers (Original Equipment Manufacturers (OEMs)).

BAT methodology overview

The BAT assessment approach is a stepwise process underpinned by an environmental cost-benefit analysis methodology, which draws together environmental and operational priorities to support decision making. It has been used to assess different gas compressor unit combinations ('BAT candidate options') that could potentially be used to deliver future process condition requirements at King's Lynn. Figure 1, overleaf, illustrates the key steps within the BAT assessment.

[1] As defined in National Grid Specification Procedure T/SP/ENV/21 (v2) Specification for Best Available Techniques (BAT) assessment for Compressor Machinery Train

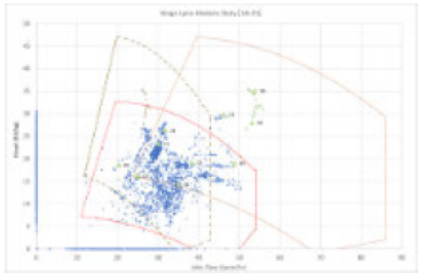
Figure 1 King's Lynn preliminary BAT assessment, method overview

1 Historical data analysis of process flow and duty

2 Identify PDS points reflecting current usage and future flow scenarios.

8 PDS points, hours apportioned to each

3 Identify he primary sensitivities including the compressor train performance characteristics for the PDS points



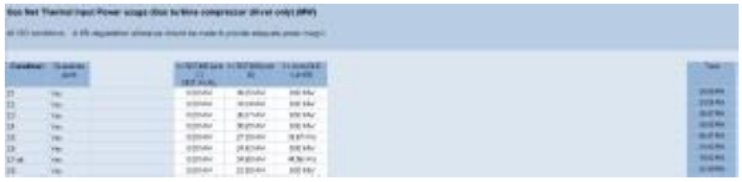
4 Initial high level screening based on CBA to identify candidate options (combinations of units) from known market based solu ions

Option	Lead configuration	Backup configuration
Option 1	2 x SGT400	1 x SGT400 + 1 x Avon 500 hrs
Option 2	2 x SGT400	1 x SGT400 + 1 x Avon CSRP
Option 3	2 x SGT400	1 x SGT400 + 1 x Avon SCR
Option 4	2 x SGT400	1 x SGT400 + 1 x Avon DLE
Option 5	1 x New GT + 1 x SGT400	2 x SGT400
Option 6	Two new GT units	
Option 7	One new GT unit + one derogated Avon (500 hours)	
Option 8	Decommission Avon	

5 Map the load split ing between units in each candidate, and iden ify the shaft / NTI required to achieve the PDS points, and associated emissions

Example for one combination in one option

6 Complete BAT inputs sheets for each solution in a backup configuration



Example from BAT input tool

7 Combine op ions in BAT assessment tool, with technical scoring evaluation results and cost data

Example for one BAT assessment tool

Preliminary BAT results

Key features of the BAT models

The following summarises the key features of the BAT model:

- The models are populated with data validated by the business on process conditions, capital costs and maintenance (ongoing asset health) costs.
- Representative business stakeholders identified the following technical/environmental criteria used to qualitatively score the options and the weighting applied to each criterion. Collectively these criteria have a weighting of 65% of the total combined technical and environmental scores.

Table 1 Qualitative Criteria Description (Technical & Environmental)

Qualitative Criteria Description (Technical & Environmental)	Weighting
Versatility - extent and useability of an MCPD emissions compliant compressor envelope	15%
Future proofing – headroom above current emission limit values (ELVs) and performance against anticipated energy efficiency levels which may be contained in a future MCPD BAT Reference Document (BREF)[2]	15%
Ownership – maintenance complexity and availability of spares for the compressor plant	13%
Constructability – ease of construction and likely disruption to existing site operations	7%
Environmental amenity – potential for visual and noise concerns	10%
Hazard – remaining environment risks	5%
	65%

- Oxides of nitrogen (NOx), carbon dioxide (CO_2) and carbon monoxide (CO) emissions are quantitatively evaluated and scored, based on predicted emissions and have a weighting of 20%, 10% and 5% respectively (35% overall).

[2] The UK environmental agencies have indicated that any forthcoming BREF for MCDP will contain energy efficiency targets.

- The BAT model assesses a 20-year period, over which total emissions and whole life operating costs (including fuel) are calculated. The time period for this King's Lynn assessment is 20 years for installed costs, with ongoing asset health and emissions calculated for 2030-2050 when the options are fully operational. Capital costs are rebased to FY18/19 in line with the CBA requirements for consistency.

Future Process Duty Specification (PDS) points and running hours

The BAT assessment was undertaken on the potential compressor configuration options (referred to from now on as 'candidate BAT Options').

The table below illustrates the eight PDS points identified from historical running data and the estimated running hours. The total running hours for the Basis of Design for the station are estimated as 3,000 hours for the BAT assessment, noting that some PDS points will require parallel running, increasing the PDS run hours. No sensitivity analyses were carried out on operating hours in the BAT assessment.

Table 2 Future Process Duty Specification (PDS) points and running hours

Duty	Station Flow (mscm/d)	Station Inlet Temp (deg C)	Unit Inlet Pressure (barg)	Unit Outlet Pressure (barg)	Station Running Hours/Year (est. 2030)
C1	42.75	10.00	50.12	61.37	400
C2	42.85	8.91	47.68	59.85	400
C3	58.25	10.00	53.26	63.03	800
C4	61.04	2.28	57.83	66.07	1,000
C5	84.14	1.04	56.93	67.94	200
C6	39.41	11.21	55.45	63.92	100
C7	72.34	10.00	54.73	70.90	50
C8	30.00	12.61	52.86	62.12	50

Identification of candidate BAT options

The two existing SGT400s are already compliant with the emission limit requirements of the MCPD. When one of these units is unavailable, the existing operational Avon unit (Unit B) is required to provide backup compression, operating in parallel with the remaining SGT400 (or on its own when neither is available). Note that a second Avon is present at King's Lynn (Unit A), but this is not operational and is disconnected and partially dismantled, therefore reference to the Avon unit throughout this document assumes the operational Unit B. Under certain operating conditions the Avon unit could exceed the NOx limits of the MCPD. The FEED study identified compressor investment options for King's Lynn that enable the site to be MCPD compliant and to meet future gas compression requirements.

Options included:

- The 'counterfactual' of no changes to the units aside from 're-lifing' (where the Avon unit will be restricted to 500 hrs[3] running per annum under the MCPD derogation).
- Retaining the operational Avon unit but installing Control System Restricted Performance (CSRP) to restrict power to a level where the MCPD NOx emission limit cannot be breached, allowing the unit to operate without any hours restrictions[4].
- The installation of retrofit Selective Catalytic Reduction (SCR) equipment to the Avon to lower NOx emissions and bring it into compliance with the MCPD.
- The installation of retrofit Dry Low Emissions (DLE) technology to the Avon (engine model 1533), which would also allow the unit to meet MCPD ELVs.
- The installation of either one or two new MCPD compliant gas turbine (GT) units or electric Variable Speed Drive (VSD) compressors, to replace the Avon.
- The installation of one new GT unit or VSD whilst retaining the Avon which would be retained under the 500 hrs derogation.
- Decommission the operational Avon retaining only the two current SGT400s.

BAT candidate options were developed based on the current SGT400s being available as the lead units or a new GT available as the lead unit in combination with an SGT400. For all options it has been assumed that the existing SGT400 units will be re-wheeled (replacement of the impeller bundle to better match forecast requirements). Whilst a new VSD unit would offer emissions improvements over a GT unit, the VSD option is seen to carry a higher risk compared to GT driven options (assessed as part of the risk workshop reported in 203513C-001-RT-0200). At this stage VSD has not been included in the BAT assessment and a further option selection exercise will be undertaken to decide between VSD or GT drivers if a new compressor option is agreed.

All options at King's Lynn could be accommodated within the existing land ownership boundary and are therefore considered to be brownfield options, not requiring greenfield land.

[3] 5 year rolling average
[4] Subject to Environment Agency approval via a variation to the site's Environmental Permit.

The following table summarises the lead and backup configurations, only the backup configurations are included in the BAT assessment as it is considered that there will be no significant difference between all options in a lead configuration.

Table 3 Lead and backup configuration

Option Number	Lead configuration	Backup configuration	Option included in BAT Assessment?
Option 1	2 x SGT400	1 x SGT400 + 1 x Avon 500 hrs	Yes
Option 2	2 x SGT400	1 x SGT400 + 1 x Avon CSRP	Yes
Option 3	2 x SGT400	1 x SGT400 + 1 x Avon SCR	Yes
Option 4	2 x SGT400	1 x SGT400 + 1 x Avon DLE	Yes
Option 5*	1 x New GT + 1 x SGT400	1 x New GT + 1 x SGT400	Yes – this backup configuration assumes one of the SGT400s is unavailable (as a result of the age of the units requiring more maintenance and that the new unit is assumed to be more reliable). An alternative backup configuration would be 2 x SGT400s when the new unit is unavailable; this option will score similarly to the primary backup option shown and is therefore not included for clarity as less likely to be the backup arrangement.
Additional options			
Option 6*	Two new GT units		No – 4 unit options have not been included in the BAT assessment.
Option 7	One new GT unit + one derogated Avon (500 hrs)		No – 4 unit options have not been included in the BAT assessment.
Option 8*	Decommission Avon		No – not included in BAT assessment as there is no backup when 2 units are required to be operated in parallel.

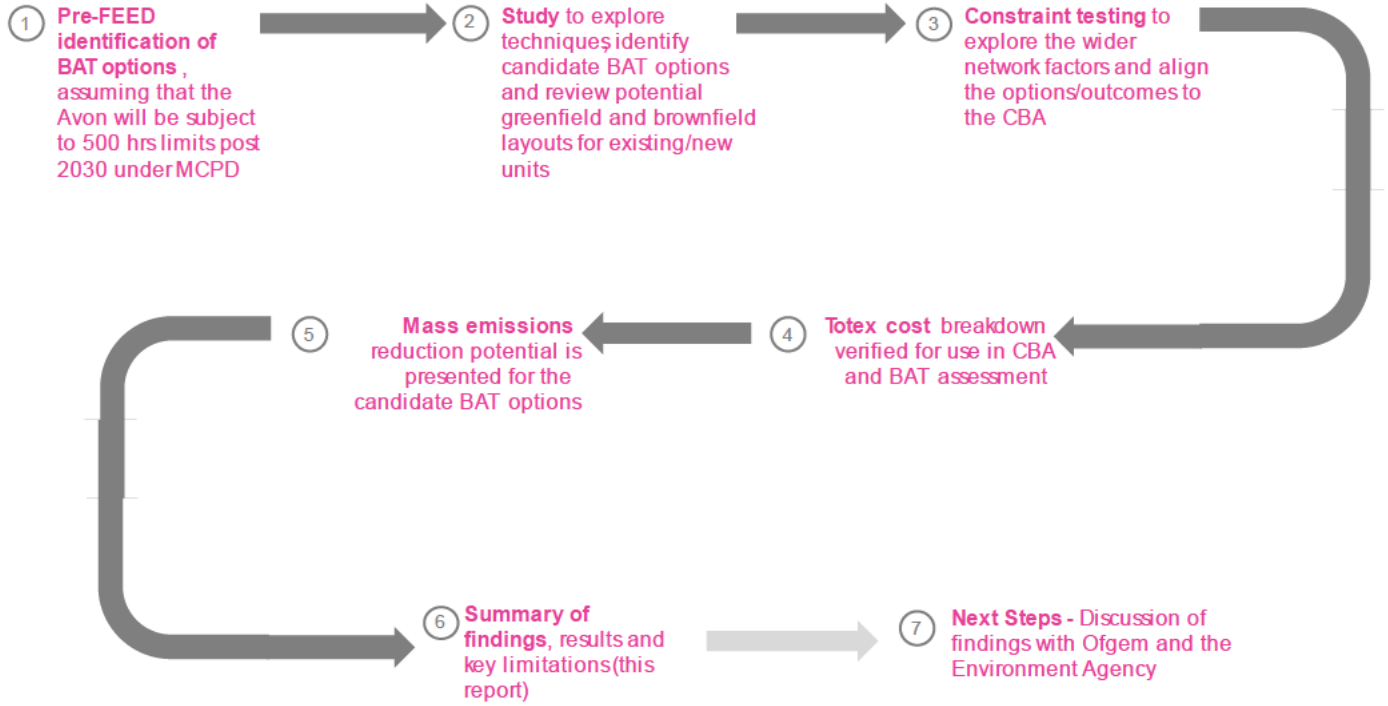
*Option includes decommission of Avon unit

Additional options 6 and 7 are assessed in the CBA, these represent a 4-unit station providing additional compressor resilience over the 3-unit site options (Options 1-5). These high resilience options have not been included in this BAT assessment but they are considered in the CBA, since it is better able to quantify the benefits that additional resilience can provide. Option 8 involves decommissioning the remaining Avon resulting in a site consisting of 2-units. This option has also been excluded from the BAT assessment as it does not provide sufficient resilience.

Stepwise approach to the BAT assessment

The flow chart below illustrates the phased approach to exploring the opportunities and constraints through the BAT assessment, in order to produce preliminary results on the candidate BAT options for King's Lynn.

Figure 2 Stepwise approach to BAT assessment and findings narrative



Qualitative Technical Scores for candidate BAT options

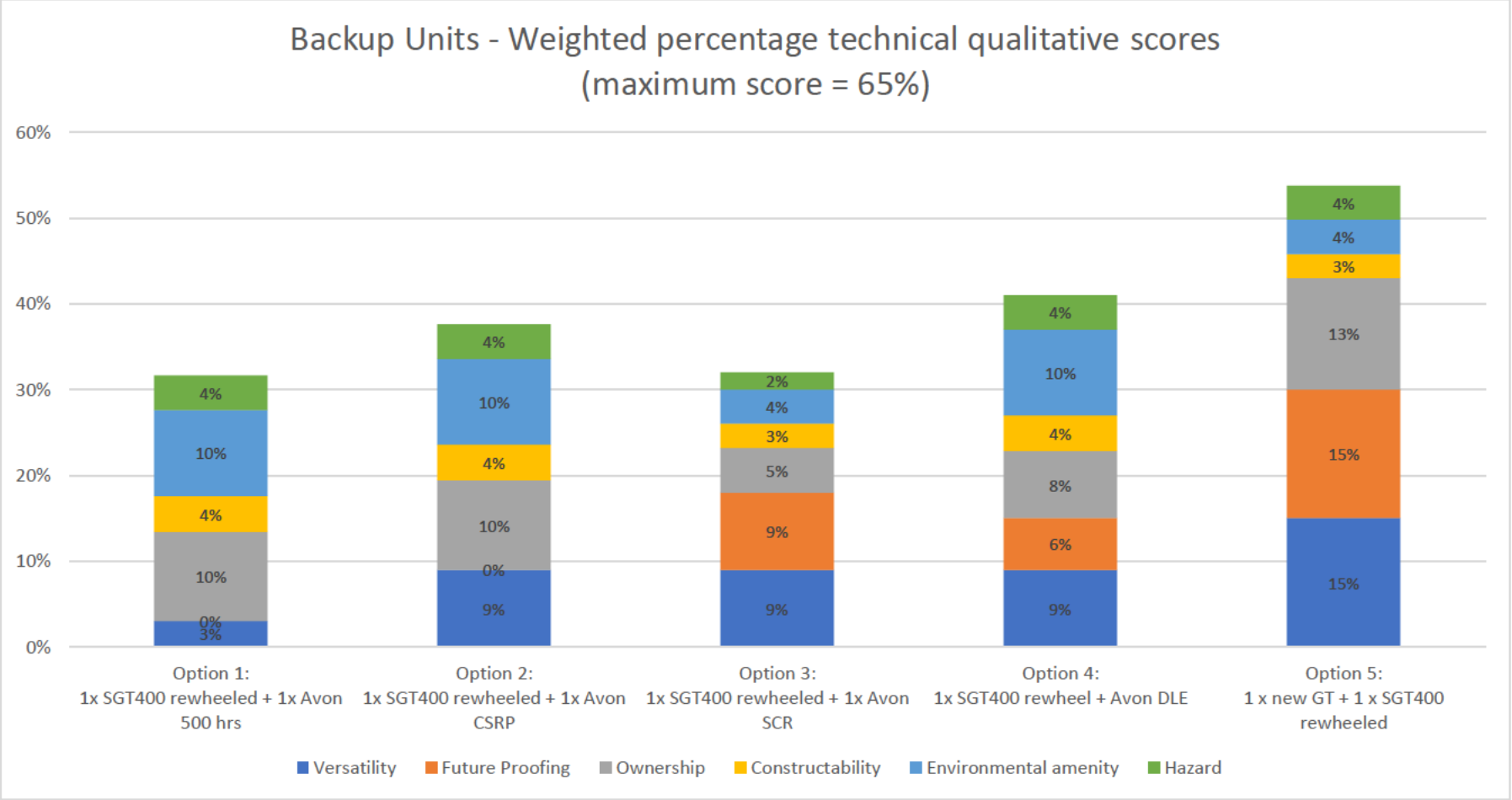
Table 4 provides the technical/environmental qualitative criteria weighted percentage scores for each candidate BAT option and is summarised as follows:

- The derogated solution (Option 1) has the lowest score for versatility and future proofing, but scores better in constructability. This option (Option 1): has restricted running hours as a result of the Avon 500 hrs derogation limit; is already likely to exceed NOx limits under certain operational conditions or would not withstand a tightening of the NOx limit.
- The CSRP solution (Option 2) also has the lowest score for future proofing, this option would not withstand a tightening of the NOx limit and has restricted power availability.
- Option 3 (Avon SCR) has similar energy efficiency to Option 4 (Avon DLE) which reduces their future proofing score should efficiency be introduced as a requirement for MCPD, although Option 3 has greater emissions headroom than Option 4 and therefore has a higher score for future proofing. Conversely, the new GT based solution (Option 5) scores more highly in terms of versatility and future proofing but is more complex to build.
- For Option 5, full versatility and future proofing is provided for when the new GT is operating with an SGT400.
- The emission abatement solutions represent the middle ground, with DLE retrofit scoring more highly for constructability than SCR retrofit.

Table 4 Technical/environmental qualitative criteria weighted percentage scores

Option Number	Backup configuration	Versatility	Future Proofing	Ownership	Constructability	Environmental amenity	Hazard	Total
Option 1	1 x SGT400 + 1 x Avon 500 hrs	3.0%	0.0%	10.4%	4.2%	10.0%	4.0%	31.6%
Option 2	1 x SGT400 + 1 x Avon CSRP	9.0%	0.0%	10.4%	4.2%	10.0%	4.0%	37.6%
Option 3	1 x SGT400 + 1 x Avon SCR	9.0%	9.0%	5.2%	2.8%	4.0%	2.0%	32.0%
Option 4	1 x SGT400 + 1 x Avon DLE	9.0%	6.0%	7.8%	4.2%	10.0%	4.0%	41.0%
Option 5	1 x new GT + 1 x SGT400	15.0%	15.0%	13.0%	2.8%	4.0%	4.0%	53.8%
Maximum weighted score available (65%)	N/A	15% / 65%	15% / 65%	13% / 65%	7% / 65%	10% / 65%	5% / 65%	*65%*

Figure 3 Qualitative technical scores summary



Note % scores rounded to the nearest whole number in the chart above for clarity.

Quantitative Emissions Scores for candidate BAT options

The quantitative assessment of the candidate BAT options is based on the estimated expected tonnes of NOx, CO_2 and CO emitted from the operation of the compressors for the assumed running hours over the 20 year model period; the emissions data are presented later in this report. The total tonnes of emissions for each candidate BAT option are scored relative to each other, with the least polluting option achieving 100% of the available score. The table below illustrates the quantitative environmental assessment scores for the candidate BAT options.

Table 5 Quantitative environmental assessment scores for the candidate BAT options

Option Number	Backup configuration	NOx	CO_2	CO	Total
Option 1	1 x SGT400 + 1 x Avon 500 hrs	9%	10%	1%	20%
Option 2	1 x SGT400 + 1 x Avon CSRP	9%	10%	1%	20%
Option 3	1 x SGT400 + 1 x Avon SCR	14%	10%	2%	26%
Option 4	1 x SGT400 + 1 x Avon DLE	13%	10%	2%	25%
Option 5	1 x new GT + 1 x SGT400	20%	10%	5%	35%
Maximum weighted score available (35%)	N/A	20% / 35%	10% / 35%	5% / 35%	**35%**

Combined Technical and Emissions Scores for candidate BAT options

The following table provides the combined technical/environmental and predicted emissions criteria weighted percentage scores for each candidate BAT option. The highest scoring option is Option 5 and the lowest scoring option is Option 1.

Table 6 Combined technical/environmental and predicted emissions criteria weighted percentage score

Option Number	Backup configuration	Technical/Environmental Score based on (qualitative assessment)	Environmental Score based on (quantitative assessment)	Total Score
Option 1	1 x SGT400 + 1 x Avon 500 hrs	31.6%	19.8%	51.4%
Option 2	1 x SGT400 + 1 x Avon CSRP	37.6%	19.8%	57.4%
Option 3	1 x SGT400 + 1 x Avon SCR	32.0%	25.6%	57.6%
Option 4	1 x SGT400 + 1 x Avon DLE	41.0%	25.2%	66.2%
Option 5	1 x new GT + 1 x SGT400	53.8%	34.5%	88.3%
Maximum weighted score available	N/A	65%	35%	100%

BAT Results

The current Avon at King's Lynn would be subject to the existing unit requirements of the MCPD due to the NOx emissions having the potential to exceed 150 mg/Nm^3. As such, for the Avon to form part of a viable site solution, it would need to operate within the 500 hrs derogation limit post 2030. However, for the assessment, it is assumed the Avon would run for as many hours as necessary to deliver compression requirements to illustrate the impact of unmitigated NOx emissions. Alternatively, Avon emissions would need to be restricted using CSRP or emissions mitigated using retrofit DLE or SCR techniques. It is assumed that the current SGT400s will continue to be the lead units in the future running of the compressor station except if a new GT is installed, in which case this will become one of the lead units alongside one of the SGT400s to meet all or part of the compression requirements.

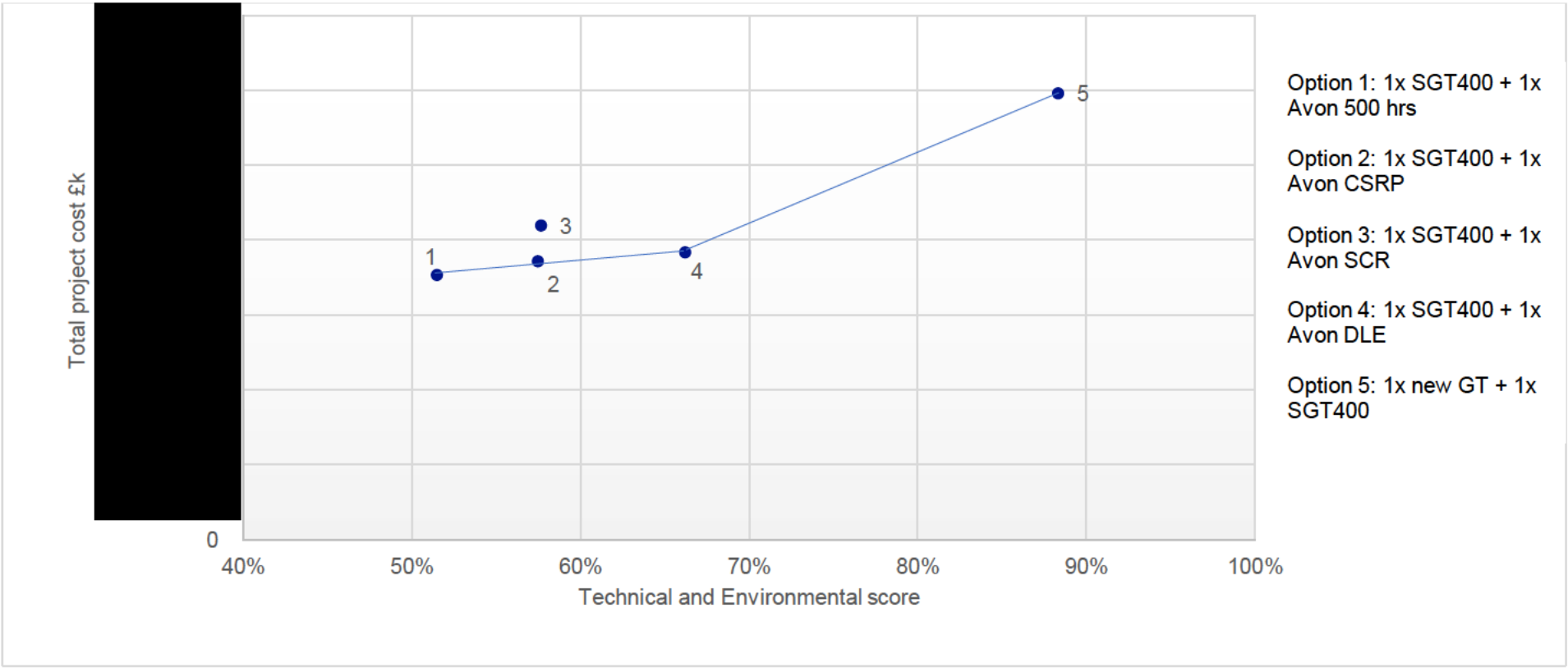
The next chart illustrates the cost-benefit BAT model results. The Y axis represents the modelled total project cost over 20 years; the X axis is the combined technical and environmental score derived by the BAT model for the options.

BAT appraisal – lead SGT unit unavailable

For Options 1 to 4, the normal site running configuration is 2 x SGT400s. When one of these units is unavailable compression capability will be provided by the other SGT400 unit plus the Avon backup unit. In Option 5 when a new GT is proposed, the normal site running configuration is 1 x new GT and 1 x SGT400. It is assumed that the new GT will have a higher availability than an SGT400 and this would therefore be the lead unit. The backup configuration will be 1 x new GT and 1 x SGT400, utilising the other SGT400 on site. An alternative backup configuration would be 2 x SGT400, which would have a similar environmental/technical performance.

The chart below illustrates the BAT results for the backup configuration options at King's Lynn.

Figure 4 BAT – future operations; backup configuration options



Key observations from the assessment are as follows:

- The chart illustrates that the option which retains an unmitigated Avon (Option 1) has the lowest estimated whole life cost but also has the lowest technical/environmental score. This option has higher emissions and scores low for versatility and future proofing[5]. This option offers a poor cost-benefit for this reason.
- Option 2 using CSRP also has a low overall performance; the reduction in power caused by CSRP is expected to limit the available compressor envelope and reduces compression capability. The technique only provides regulatory compliance with the emission limits of the MCPD and does not result in any material reduction in emissions (i.e. all points of the compressor envelope for the Avon will have the same emissions but the envelope will be smaller resulting in loss of unit capability which, if required, will need to be picked up by another unit or another site and so therefore no material reduction in emissions from the overall National Transmission System (NTS) operation). All operating conditions used in this assessment can by met by Option 2 therefore total NOx emissions are assumed to be the same as an unabated Avon, contributing to a lower technical/environmental performance compared to options with emissions abatement techniques/new GT.
- The options that include investment in emissions abatement techniques of SCR and retrofit DLE on the Avon unit achieved a higher performance score compared with the option that includes CSRP (Option 2). Option 4 using Avon DLE has a lower environmental amenity impact and lower ownership risk compared to SCR, resulting in a 8% point improvement in performance.
- Option 3 SCR has a slightly higher whole life cost compared with the Avon DLE option and scored less for ease of construction. It should be noted though that retrofitting SCR solutions to gas turbines (including Avons), is proven in use, whereas the other retrofit solutions considered in this BAT study cannot yet demonstrate real world applications, but nonetheless they are assumed to be available at this stage.
- Option 5, which includes a single new GT (which is assumed to be available in a backup configuration) and decommissioned Avon. The new GT and an SGT400 would provide the backup solution when one of the SGT400s is unavailable. The new GT option is more costly but offers considerable environment/technical gain over all options that retain an Avon unit (at least 22% points more) however, the benefit of this option over alternative solutions is dependent on how often the backup unit is required to support parallel compressor operation.
- In considering the conclusions in this section, it should be noted that this is the backup configuration scenario which would only be utilised when one of the lead units is unavailable and parallel operation of 2 compressors is required. Given the high availability of the lead units, as noted in the site availability models, this backup scenario would be utilised relatively infrequently. It is however of importance in the investment decision as it is under backup scenarios that the site operations would be under greatest pressure to undertake required duty and remain in legal compliance with emissions limits. Further detail on resilience requirements and 1-in-20 obligations for this critical site is provided in the FOSR.
- For the operating conditions used in this assessment, parallel running is considered to be required for the high station flow points of C5 and C7, assumed to be required for an estimated 8.3% of total station running hours (250 of the estimated 3,000 station run hours per annum). Based on this requirement

[5] Scoring of the future proofing scoring was undertaken on the lowest performing unit in the option.

and the high likely availability of lead units (either an SGT400 or new GT), the retrofit options could be considered to offer good versatility and lower NOx emissions, which would increase their technical/environmental score.

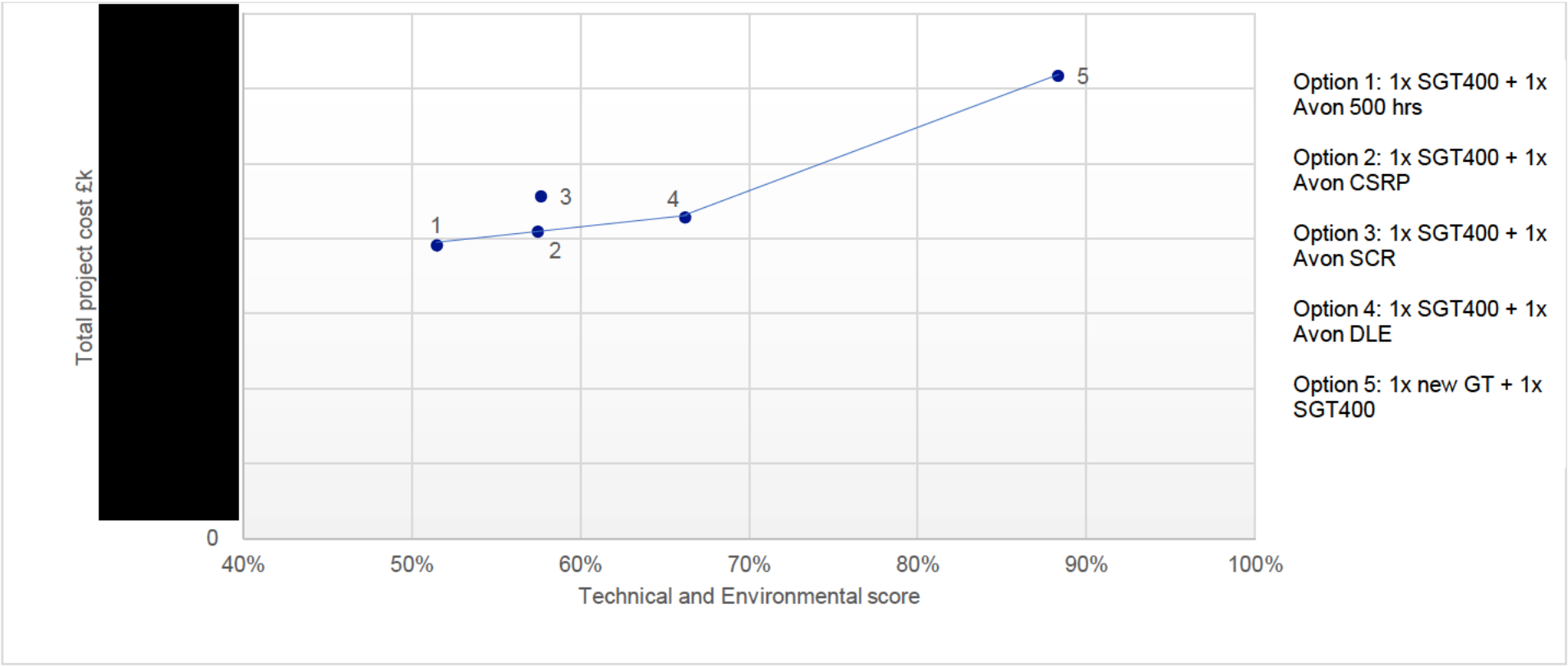
Constraint testing

The CBA calculates constraint costs to accommodate circumstances when the units are unavailable. These include penalties placed on the business such as buying gas on the day or buying back capacity from end users. These costs include risk factors associated with capability of the site and techniques within the options.

Typically, constraint costs are excluded from the initial stages of the BAT assessment but are added in where relevant as a sensitivity. With King's Lynn being a strategically critical site (supporting bi-directional flow to resolve supply/demand imbalance for south east England) and to aid comparison with the CBA, a sensitivity assessment was undertaken on the candidate BAT options through inclusion of the constraints costs in order to take into account these wider network factors. For this assessment the addition of constraint costs has not had a material influence on the BAT results and is not considered to be a significant factor in investment decision making.

Figure 4 illustrates the addition of constraint costs in the BAT assessment for the backup configurations. It can be observed that, with the addition of constraint costs, there is very little difference from the assessment without the constraint costs added. Option 4 (DLE) has the highest associated constraint costs (which is a direct result of applying the 5% penalty for availability) and the option including the new GT (Option 5) has the lowest associated constraint costs. The cost gap between the Avon DLE and the new GT options is slightly reduced, however the new GT option is still modelled to be [redacted] more costly over a 20 year period.

Figure 5 BAT – future operations; backup configuration options; with constraint costs



Totex cost

The total whole life modelled cost (totex) breakdown for the 20-year period of the BAT model is explored for the candidate BAT options to show the breakdown of key cost components, rounded to the nearest hundred pounds. A chart is provided for the backup configuration, and with no constraint costs added.

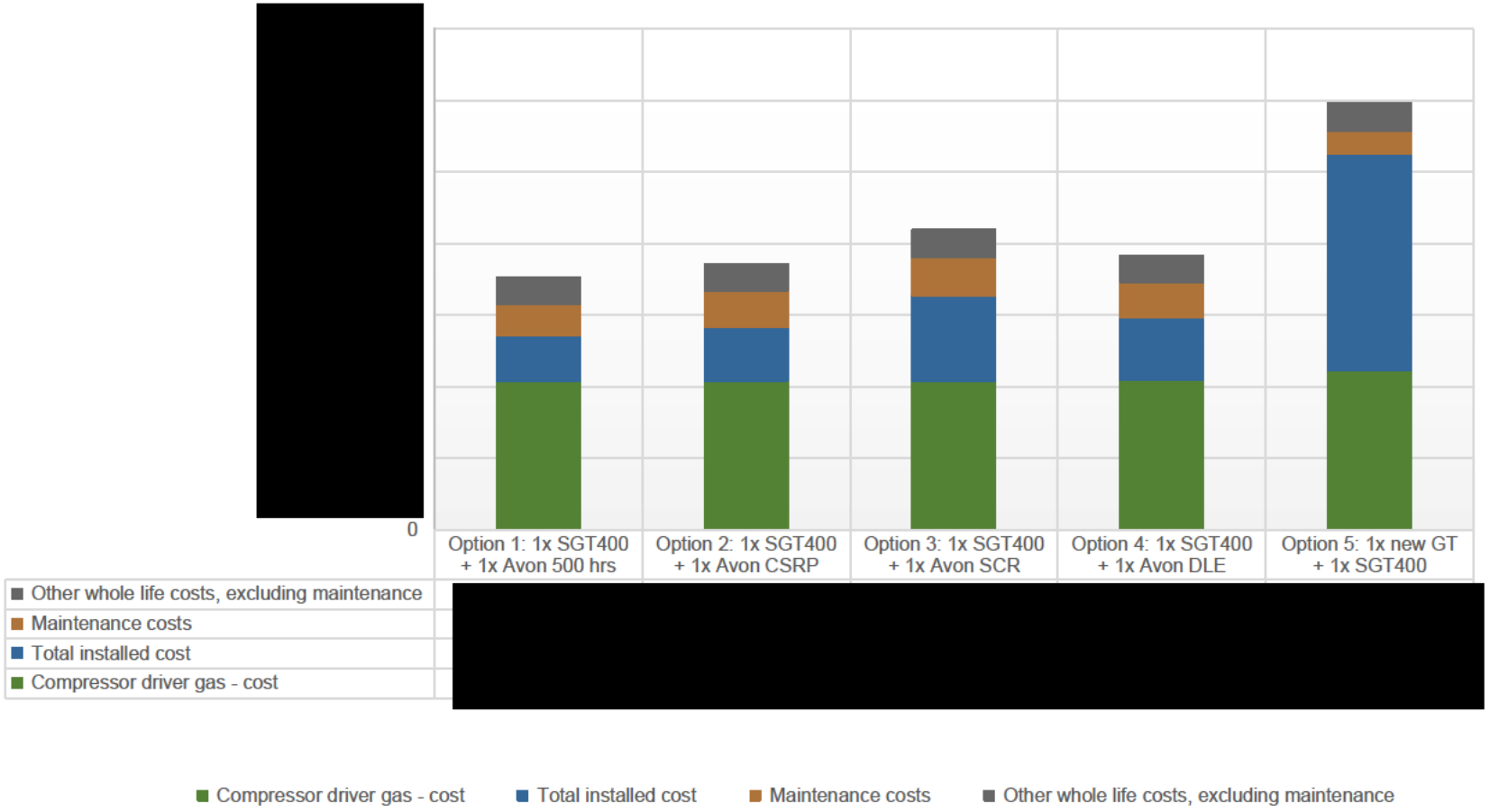
Key points to note when interpreting the chart are as follows:

- The BAT model uses a simplified spend profile for total installed costs so discounted costs will not completely align to the CBA, however they are not materially different. The same UK Government Green Book discounting factor of 3.5% is used in the CBA and the BAT model.
- Gas prices are based on published data, with the same source data used in the CBA and BAT model[6].
- Additional costs for reagent are added for Option 3 SCR but there are no additional operating costs associated with replacement of the SCR catalyst as this is not required based on running hours. However, catalyst does deteriorate even without use, e.g. contaminants in rain which will enter via the stack. If appropriate, a cost per fired hour allowance could be made in later iterations of the assessment.

The chart illustrates that total energy costs are reasonably comparable across all options, with Option 5 (including a new GT) being slightly higher. For the new GT option, installed capex costs comprise approximately 51% of total project cost. Maintenance costs (ongoing asset health and overhauls) are reasonably comparable across all options, with Option 5 (including a new GT) being slightly lower.

[6] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2019

Figure 6 Total costs for backup configuration options

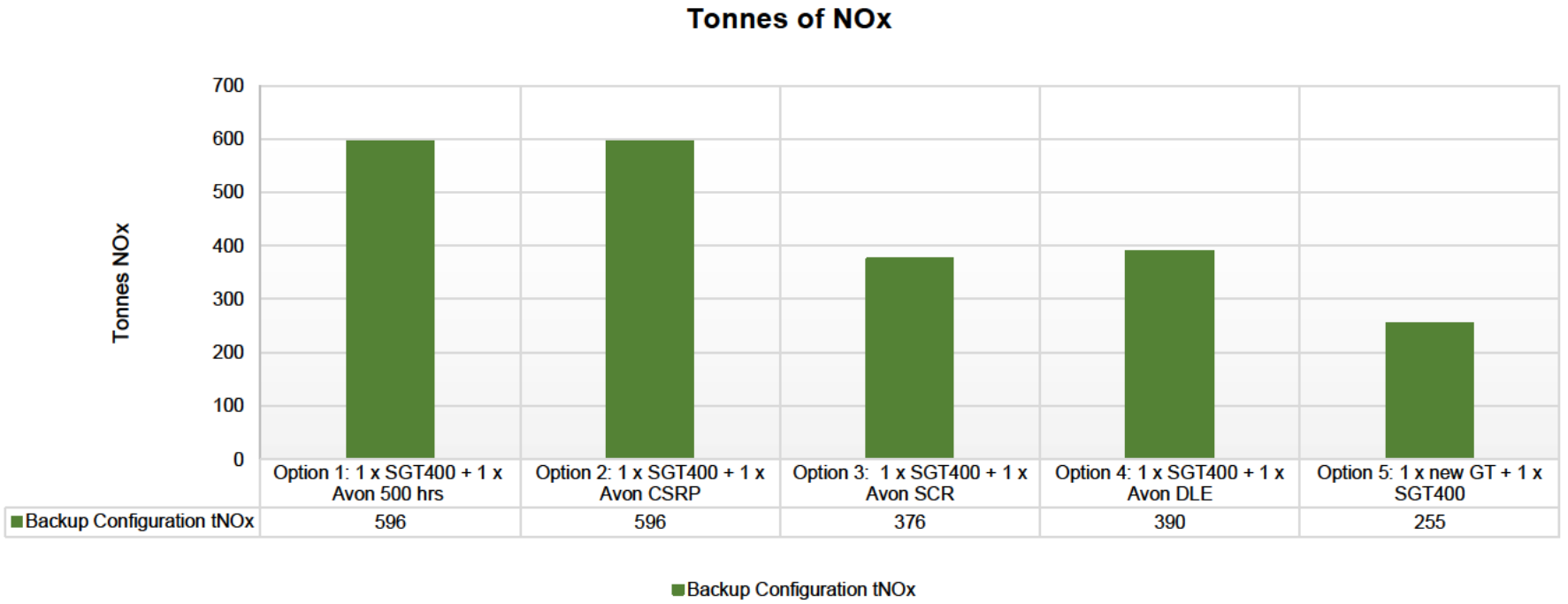


Mass emissions

The potential for the candidate BAT options to reduce total mass emissions is presented in the following charts. The charts illustrate total tonnes emitted over the 20-year period of the BAT model. The new GT option along with the SCR and DLE options provide the greatest potential to reduce emissions compared with the current arrangements on site. The NOx emissions for the counterfactual and CSRP option are assumed to be the same. This is because all operating conditions included in this assessment can be met by Option 2 and the CSRP technique does not reduce emissions.

It should be noted that emission calculations for the Avon DLE options assume certain emissions factors provided by an OEM developing a technique for the 1533 engine models, which is not proven at engine scale and may be subject to future change. It should also be noted that emissions calculations for the SCR option include certain emissions factors and assumptions which may be subject to change.

Figure 7 tNOx emissions



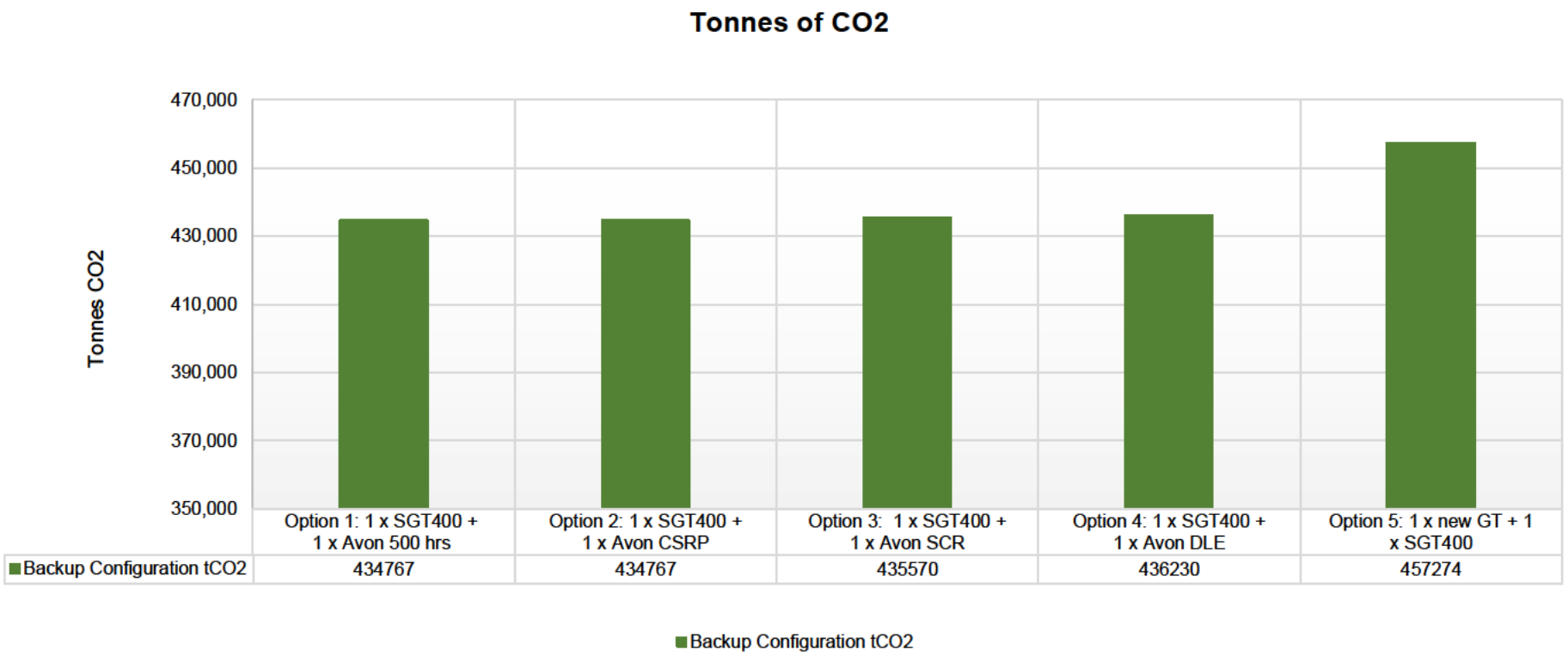
The chart illustrates that the options which retain an Avon on 500 hrs and the Avon CSRP have the highest NOx levels as they have no abatement technique and perform poorly in terms of emissions.

The Avon SCR, Avon DLE options produce comparable NOx with the new GT option offering lower emissions, and all represent a significant improvement in NOx performance compared to an unabated Avon.

The principle of BAT underpins the Industrial Emissions Directive, and is used as the basis for permit conditions for industry. The BAT assessment process used by National Grid was developed in consultation with the EA and SEPA. The two existing SGT400 units are MCPD-compliant and all process conditions can be met. It was considered that there will be no significant difference between all options in a lead configuration. It is only by assessing the impact of running the backup configuration options that the performance of the different techniques can be fully assessed.

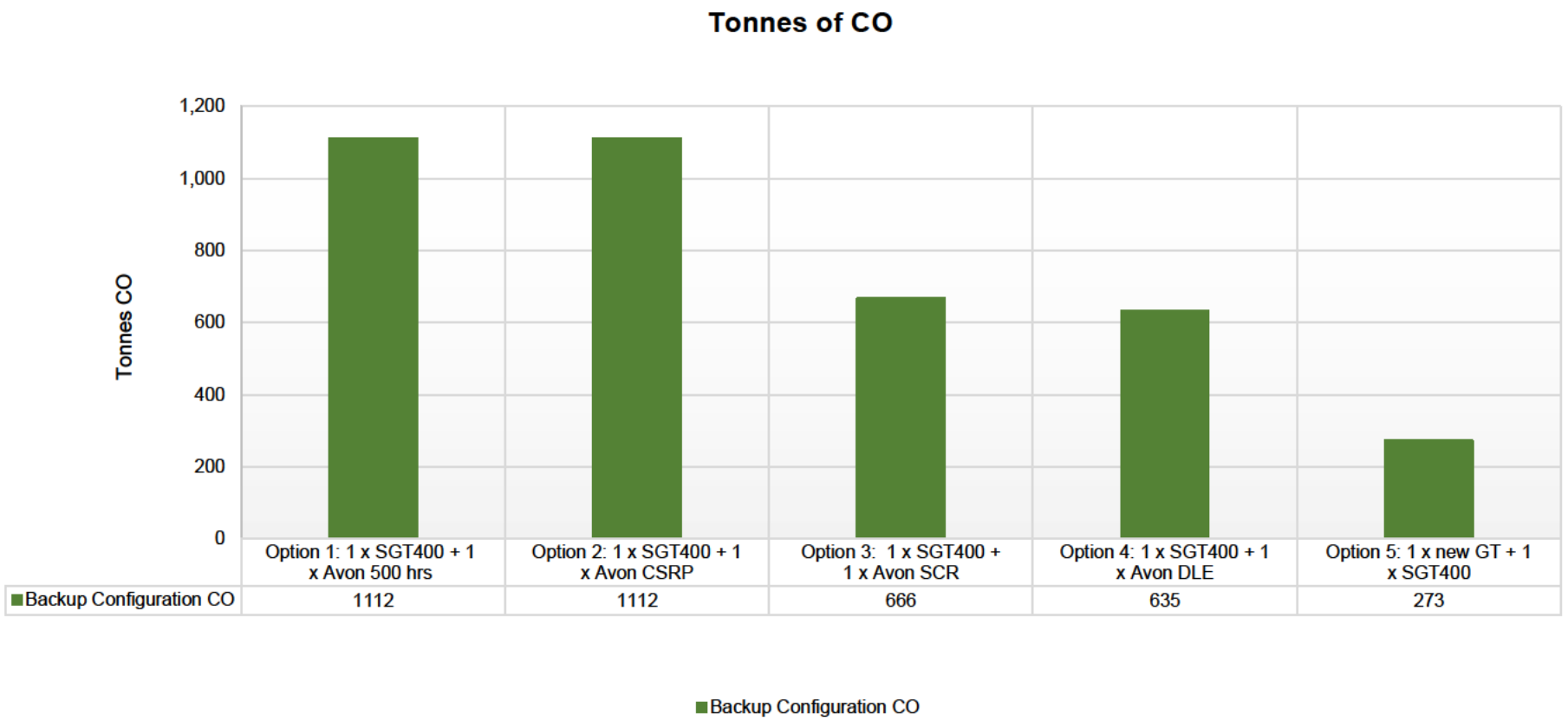
It should again be noted though that the site would not operate in the backup configuration for a 20 year period (the BAT model period). This is a necessary assumption made in conducting a BAT assessment of the backup scenario. The realised emissions will depend on the likely percentage availability of the lead units and the need to run the backup configuration. Given the high availability of the lead units and low number of parallel running hours, the resulting NOx emissions from a backup unit are likely to be relatively low.

Figure 8 tCO_2 emissions



Performance data for a Solar T130 was used to estimate the likely emissions data for the new GT in the BAT assessment. Unlike the existing SGT400, this unit was not optimised for the process conditions assumed for King's Lynn. Option 5, running 1x new GT + 1x SGT400 in a backup configuration (noting that the T130 is the lead unit) produces marginally higher CO_2 emissions in this BAT assessment, compared to other options. During the FEED procurement stage, different new unit options would be assessed, both GT and VSD technologies.

Figure 9 tCO emissions



The Avon 500 hrs and Avon CSRP options have the highest emissions. CO emissions are lowest for the option which includes a new GT, reflecting the better combustion controls associated with newer GTs which would be run in the backup configuration.

The Avon DLE option assumes certain emissions factors provided by an OEM developing a technique for the 1533 engine models, which is not proven at engine scale and may be subject to future change. The Avon SCR includes a catalyst that reduces CO, hence emissions are lower.

Summary of findings

Key findings

- Analysis of the compression capability of the candidate BAT options identified that, when the lead unit is available, there is sufficient capability available to meet all of the duty requirements assumed for this assessment either using a single unit or with two units run in parallel. It was considered that there will be no significant difference between all options in a lead configuration. Lead configurations have therefore not been BAT assessed.
- For future gas compressor running scenarios, where the lead unit is unavailable, a backup compressor unit is required to meet some of the duty requirements for the station. Options for backup configurations have varying performance and associated costs and have been included in the BAT assessment.
- Options retaining an Avon on 500 hrs or with CSRP have lower technical/environmental scores than options utilising Avon DLE/SCR retrofit technology or investment in a new GT. This is due to their reduced versatility as a result of limited running hours or a restricted compressor envelope, no future proofing against potential tightening of emissions legislation and no NOx emissions abatement.
- Option 3 (SCR) is a proven technique in the gas transmission sector (but not yet on the UK National Transmission System). Whilst expected to offer an acceptable performance it is considered likely to be more costly than the Avon DLE technique. The site footprint requirements are greater for SCR but this would not be significant given available space at King's Lynn.
- In the backup configuration, Option 4 (DLE) could potentially represent a BAT solution since the performance is substantially better than other Avon-based options and costs are not materially different or are slightly lower. However, the retrofit DLE technique is not proven on the network; this limitation is noted below.
- CSRP could be considered as a potential BAT option, if the site/NTS could tolerate the loss of versatility caused by engine power restrictions and there was high availability of the SGT400s/low predicted use of the Avon CSRP unit. The ultimate acceptability of CSRP does remain to be tested with the UK environmental regulators via a formal variation to a site's environmental permit.
- Option 5 includes a new GT and has the highest overall cost. However, this option provides significant technical/environmental gain over Avon-based solutions. However, the benefit of this option over alternative solutions is dependent on how often the backup unit is required to support parallel compressor operation. As noted above the analysis discussed in this report focusses on the back-up configuration as there is no significant difference between options in a lead configuration.
- When constraint costs are included there is no material difference in the BAT cost benefit rankings between the candidate options. However, the cost gap between the Avon DLE and the new GT options is slightly reduced, however the new GT option is still modelled to be [redacted] more costly over a 20 year period. This indicates that constraint costs are not a material consideration in this BAT assessment.
- The BAT assessment process described herein should only be considered as a decision support process, not a decision making process. Full justification for option selection, considering BAT and CBA outputs is described in the Formal Option Selection Report (FOSR).

- A number of assumptions and estimates have been made in the underlying data input points, these should be reviewed in making final decisions based on these findings.

Limitations and assumptions

- Although the retrofit Avon DLE option was assessed to provide technical advantages, this technique is not fully proven in site-based operations. Site-based trials are proposed for the Avon DLE 1533 technique in 2023.
- It should be noted that emissions calculations for the SCR option include certain emissions factors and assumptions which may be subject to change.
- A key difference between the CBA and the BAT assessment is that the BAT assessment takes into consideration NOx emissions. This difference is most apparent when comparing the results for the CSRP option. As a technique, CSRP is considered to be an option that will enable NOx emissions to be maintained below 150mg/Nm^3. It is currently expected that the environmental regulators will view this technique as suitable to gain compliance with the MCPD Directive emission limits, however no definitive response from the regulators is currently available. CSRP however does not:
    - Materially reduce overall NOx mass emissions (from the overall NTS operation).
    - Provide any level of future proofing should emissions limits tighten.
    - For these reasons, CSRP solutions may be viewed by environmental regulators as being more suited to backup or low utilisation applications.
    - These issues result in the option with CSRP achieving a lower technical/environmental score in the BAT assessment compared with Avon retrofit emissions abatement solutions/new GTs. Since these factors are not evaluated in the CBA, CSRP options perform relatively better in the CBA compared with the BAT assessment.
- The energy price data (from FES) does not take account of current gas prices and it should be noted that this may have implications in several years to come. However, all options have been treated equally using consistent data within the BAT assessment.
- At this stage there has been no consideration of seal leakage data or venting for emissions. This could be added in a subsequent iteration if data to confirm numbers of seals and vents are available, along with an estimate of pressured hours per annum.
- At this stage, costs have not included any ancillary electricity consumption. This will not be a material differentiator, but SCR has a higher electrical energy usage, as do modern GTs compared to Avons. This could be added in a subsequent iteration if required and would need an estimate for number of start per annum.
- Net present value (NPV) calculations have been undertaken for Capex and asset health. It is also noted that no costs are included for inspections specified under National Grid maintenance procedure T/PM/MAINT/6.
- The BAT assessment has only considered the basis of design case as this represents the highest run hours and therefore the worst case scenario for costs and emissions.