# Peterborough Preliminary BAT assessment – output summary

## Peterborough Compressor Station

## National Grid Gas plc

January 2023

FINAL VERSION - CONFIDENTIAL

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| Client name | National Grid Gas plc |
| Client address | National Grid House<br>Warwick Technology Park<br>Gallows Hill<br>Warwick<br>CV34 6DA |

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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 Peterborough Compressor Station Medium Combustion Plant Directive (MCPD) project. 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 Peterborough Compressor Station. This assessment and project is separate from the in-flight Peterborough Emissions Reduction Project (Phase 3) (ERP3).

Investment is required for the site to comply with the requirements of the 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 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)).

It is noted that Peterborough and Huntingdon compressor stations have significant interaction on the National Transmission System (NTS) gas network, and can operate independently, or together, to meet supply and demand. However, as effective independent operation is essential, the strategy for the Avons at Huntingdon will be considered independently and is not included in this BAT assessment for Peterborough.

## 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 Peterborough. 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 Peterborough preliminary BAT assessment, method overview*

① Historical data analysis of process flow and duty

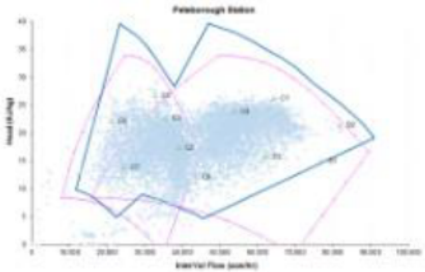
② Identify PDS points reflecting current usage and future flow scenarios.

*Table 5: Peterborough preliminary PDS Points*

| Duty | Est. Running hours (Base Case – Cold Winter) | Est. running hours (S1 – Warm Winter) | Unit Suction Pressure (Barg) | Unit Discharge Pressure (Barg) | Station Flow (mcmd @ (288.15K, 101.325kPa | Unit Suction Temperature (Deg C) | Number of Units Required (typical) |
|---|---|---|---|---|---|---|---|
| C1 | 1,200 | 1,000 | 51.63 | 64.46 | 94.80 | 7.73 | 2 |
| C2 | 1,500 | 900 | 52.64 | 61.10 | 58.80 | 8.01 | 1 |
| C3 | 100 | 100 | 51.78 | 62.30 | 50.57 | 15.49 | 1 |
| C4 | 400 | 500 | 54.82 | 67.20 | 84.42 | 8.68 | 2 |
| C5 | 400 | 300 | 59.25 | 67.80 | 105.04 | 11.04 | 2 |
| C6 | 200 | 100 | 59.22 | 65.80 | 73.89 | 10.01 | 2 |
| C7 | 150 | 50 | 51.98 | 58.30 | 34.93 | 15.22 | 1 |
| C8 | 75 | 25 | 46.43 | 55.79 | 27.40 | 10.50 | 1 |
| C9 | 75 | 25 | 50.46 | 63.13 | 46.78 | 9.04 | 1 |
| S1 | 25 | 25 | 58.36 | 66.68 | 132.16 | 5.00 | 2 |
| S2 | 25 | 25 | 46.95 | 56.38 | 109.70 | 6.00 | 2 |

***11 PDS points, hours apportioned to each***

③ Iden ify the primary sensitivities including the compressor train performance characteristics for the PDS points



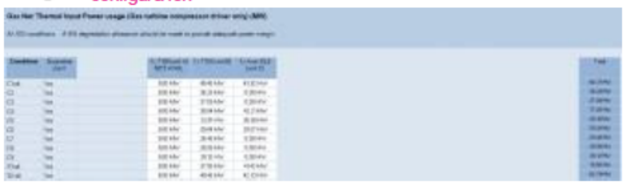
④ Initial high level screening based on CBA to identify candidate op ions (combinations of units) from known market based solutions

| Option | Lead configuration | Back up configuration |
|---|---|---|
| 1 | 2x T130 | 1x T130 + Avon 500 hrs |
| 2 | 2x T130 | 1x T130 + Avon CSRP |
| 3 | 2x T130 | 1x T130 + Avon DLE |
| 4 | 2x T130 | 1x T130 + Avon SCR |
| 5 | 2x T130 | 2x T130 |
| 6 | 2x T130 | 1x T130 (no back-up) |

⑤ Map he load split ing between units in each candidate, and identify he 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 configura ion



***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

 [redacted]

### *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).
- 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 Peterborough 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.

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

 [redacted]

### *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 eleven 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 3,950 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 | 94.80 | 7.73 | 51.63 | 64.46 | 1,200 |
| C2 | 58.80 | 8.01 | 52.64 | 61.10 | 1,300 |
| C3 | 50.57 | 15.49 | 51.78 | 62.30 | 100 |
| C4 | 84.42 | 8.68 | 54.82 | 67.20 | 400 |
| C5 | 105.04 | 11.04 | 59.25 | 67.80 | 400 |
| C6 | 73.89 | 10.01 | 59.22 | 65.80 | 200 |
| C7 | 34.93 | 15.22 | 51.98 | 58.30 | 150 |
| C8 | 27.40 | 10.50 | 46.43 | 55.79 | 75 |
| C9 | 46.78 | 9.04 | 50.46 | 63.13 | 75 |
| S1 | 132.16 | 5.00 | 58.36 | 66.68 | 25 |
| S1 | 109.70 | 6.00 | 46.95 | 56.38 | 25 |

*Identification of candidate BAT options*

Two Solar Titan 130 (T130) compressor machinery trains are being installed and commissioned under the ERP3 programme; these will be compliant with the emission limit requirements of the MCPD. These units will take over from the legacy Avon units at the site when commissioned. When one of the ERP3 T130 units is unavailable, one of the existing operational Avon units A, B or C (assumed to be Unit A – although this is to be confirmed based on further surveys and assessments at later stages) will provide backup compression and resilience. Under certain operating conditions the Avon units could exceed the NOx limits of the MCPD, and thus the Avon will, as a minimum, be required to run under a limited running hours derogation. The FEED study identified compressor investment options for Peterborough 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 hours[3] running per annum under the MCPD derogation).
- Retaining one 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 one Avon to lower NOx emissions and bring it into compliance with the MCPD.
- The installation of retrofit Dry Low Emissions (DLE) technology to one Avon (engine model 1533), which would also allow the unit to meet MCPD ELVs.
- The installation of either one new MCPD compliant gas turbine (GT) (assumed to be another T130) unit or one electric Variable Speed Drive (VSD) compressor, to replace the Avon.
- Decommission all existing Avons retaining only the two T130s being installed under ERP3.

BAT candidate options were developed based on the ERP3 T130s being available as the lead units. 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-002-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 Peterborough 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 | 2x T130 (ERP3) | 1x T130 (ERP3) + 1x Avon 500 hrs | Yes |
| Option 2 | 2x T130 (ERP3) | 1x T130 (ERP3) + 1x Avon CSRP | Yes |
| Option 3 | 2x T130 (ERP3) | 1x T130 (ERP3) + 1x Avon DLE | Yes |
| Option 4 | 2x T130 (ERP3) | 1x T130 (ERP3) + 1x Avon SCR | Yes |
| Option 5* | 2x T130 (ERP3) | 1x T130 (ERP3) + 1x New GT (T130) | Yes |
| **Additional options** | | | |
| Option 6* | Decommission Avons | | No – not included in BAT assessment as there is no available backup. |

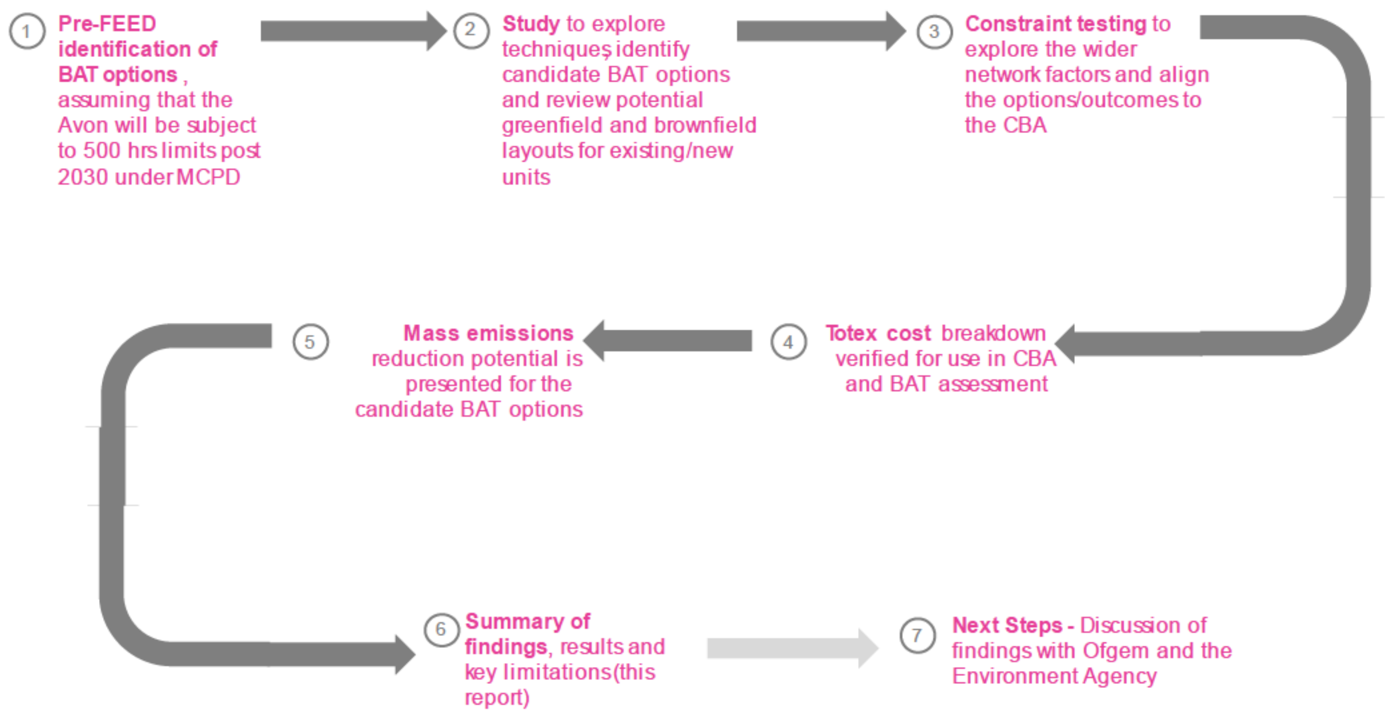
*Option includes decommission of all Avon units

Additional Option 6 has also been assessed in the CBA but it was agreed not to include in the BAT assessment as it offers no backup solution for the station.

# 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 Peterborough.

*Figure 2 Stepwise approach to BAT assessment and findings narrative*



## Qualitative Technical Scores for candidate BAT options

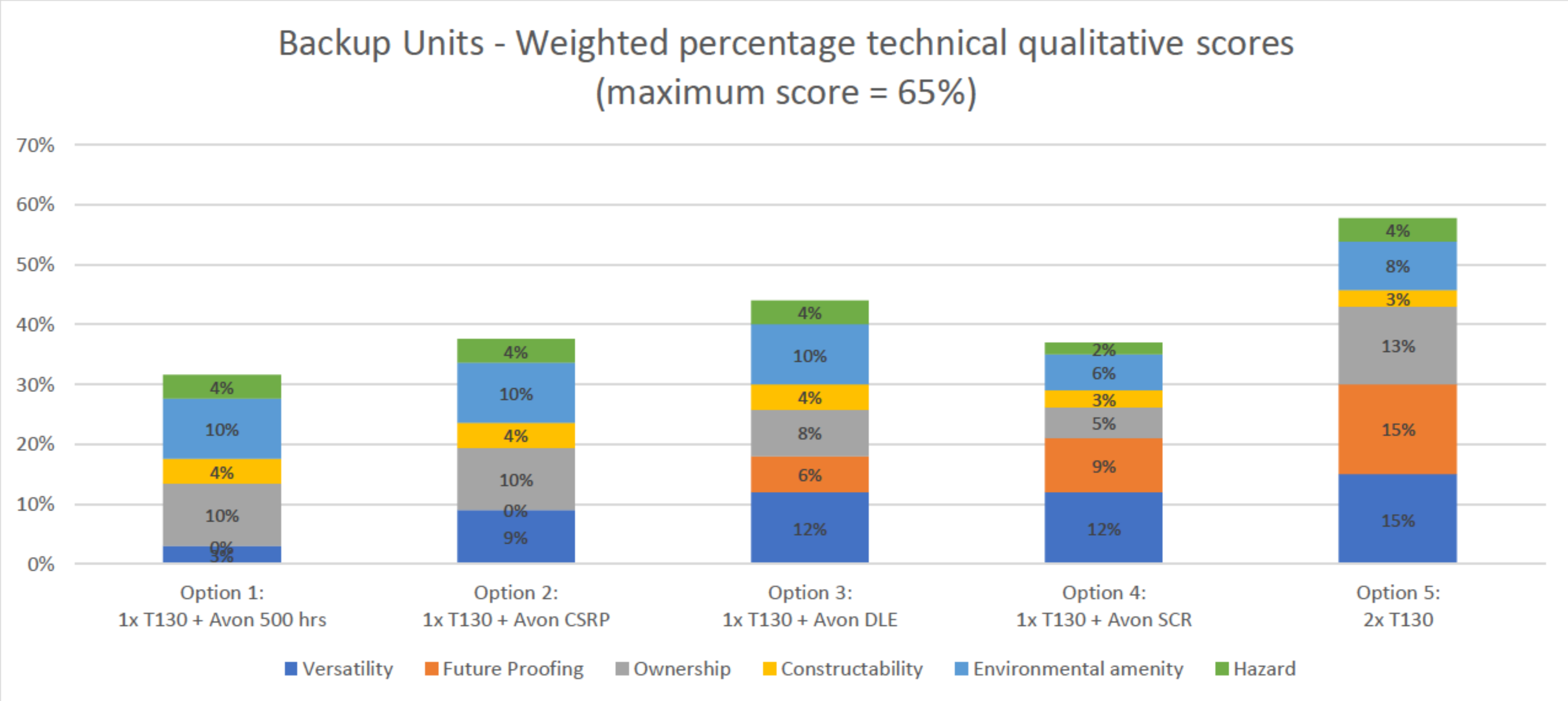
The following table provides the technical/environmental qualitative criteria weighted percentage scores for each candidate BAT option and is summarised as follows.

- 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 500h 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 4 (Avon SCR) has similar energy efficiency to Option 3 (Avon DLE) which reduces their future proofing score should efficiency be introduced as a future requirement under the expected MCPD BAT Reference (BREF) document, although Option 4 has greater emissions headroom than Option 3 and therefore has a higher score for future proofing. Conversely, the new GT based solution (Option 5) scores higher in terms of versatility and future proofing but is more complex to build, noting also that the score differential between Option 5 and the other options is reduced because much of the preliminary construction works for a new GT have already been completed under the ERP3 project.
- The emission abatement solutions represent the middle ground, with DLE retrofit scoring higher 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 | 1x T130 (ERP3) + 1x Avon 500 hrs | 3% | 0% | 10% | 4% | 10% | 4% | 32% |
| Option 2 | 1x T130 (ERP3) + 1x Avon CSRP | 9% | 0% | 10% | 4% | 10% | 4% | 38% |
| Option 3 | 1x T130 (ERP3) + 1x Avon DLE | 12% | 6% | 8% | 4% | 10% | 4% | 44% |
| Option 4 | 1x T130 (ERP3) + 1x Avon SCR | 12% | 9% | 5% | 3% | 6% | 2% | 37% |
| Option 5 | 1x T130 (ERP3) + 1x new GT (T130) | 15% | 15% | 13% | 3% | 8% | 4% | 58% |
| 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*



# 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 | 1x T130 (ERP3) + Avon 500 hrs | 3% | 10% | 0% | 13% |
| Option 2 | 1x T130 (ERP3) + Avon CSRP | 3% | 10% | 0% | 13% |
| Option 3 | 1x T130 (ERP3) + Avon DLE | 13% | 9% | 2% | 25% |
| Option 4 | 1x T130 (ERP3) + Avon SCR | 16% | 9% | 2% | 28% |
| Option 5 | 1x T130 (ERP3) + 1x new GT (T130) | 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 | 1x T130 (ERP3) + Avon 500 hrs | 32% | 13% | 45% |
| Option 2 | 1x T130 (ERP3) + Avon CSRP | 38% | 13% | 51% |
| Option 3 | 1x T130 (ERP3) + Avon DLE | 44% | 25% | 69% |
| Option 4 | 1x T130 (ERP3) + Avon SCR | 37% | 28% | 65% |
| Option 5 | 1x T130 (ERP3) + 1x new GT (T130) | 58% | 35% | 93% |
| Maximum weighted score available | N/A | 65% | 35% | 100% |

# BAT Results

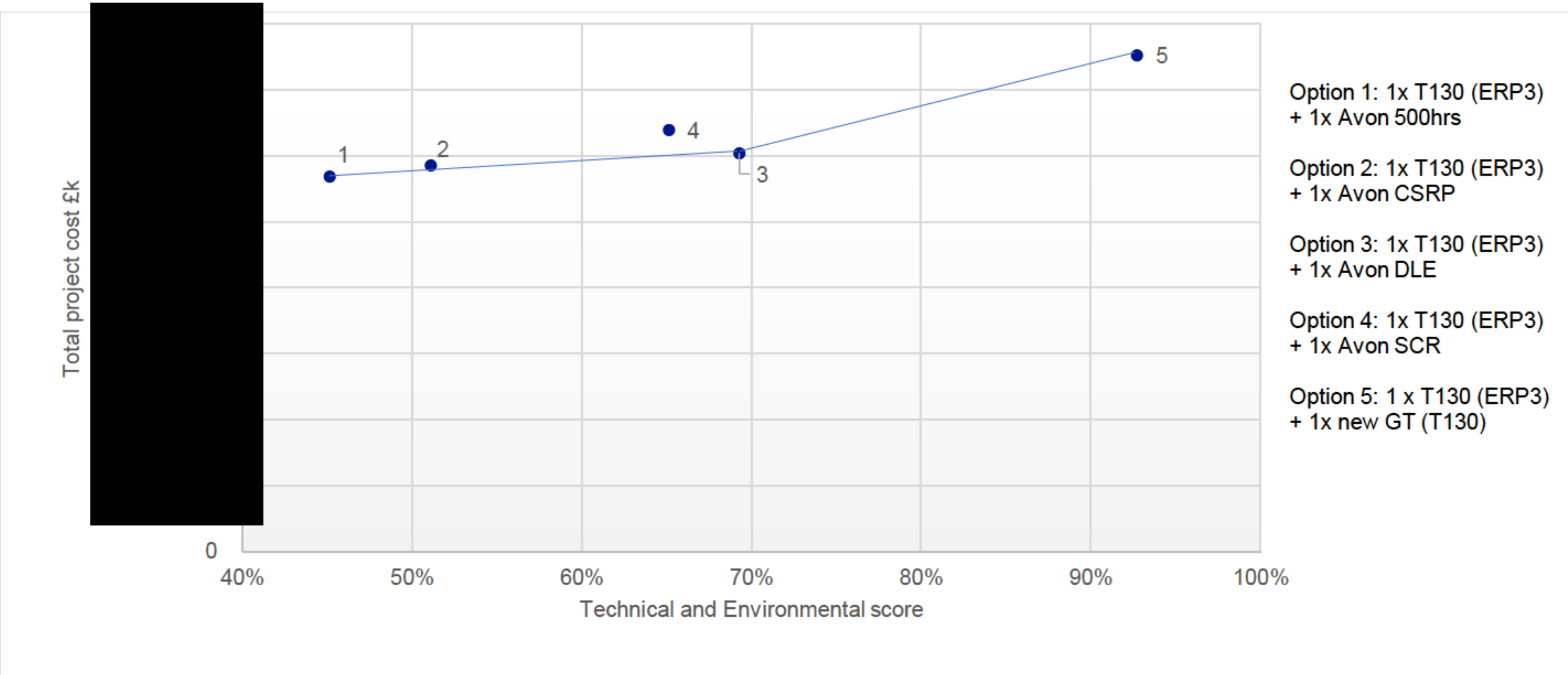
The retained Avon at Peterborough would be subject to the existing unit requirements of the MCPD due to the NOx emissions having the potential to exceed 150 mg/Nm$^3$. As such, for the Avon to form part of a viable site solution, it would need to operate within the 500 hours derogation limit post 2030. 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 ERP3 T130s will continue to be the lead units in the future running of the compressor station.

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 unit unavailable*

When a lead unit is unavailable (in this case either of the ERP3 T130s), compression capability will be provided by the unit that usually supports the lead unit plus the backup unit. The chart below illustrates the BAT results for when the lead unit is not operational.

*Figure 4 BAT – future operations; lead unit unavailable*



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 3 using Avon DLE has a lower environmental amenity impact and lower ownership risk compared to SCR, resulting in a 4% point improvement in performance.
- Option 4 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, includes a single new GT and all Avons decommissioned so the backup configuration would be the same as the lead configuration. The new GT option is more costly but offers considerable environment/technical gain over all options that retain an Avon unit (at least 24% points more).
- 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 C1, C4, C5, C6, S1 and S2, assumed to be required for an estimated 56.9% of total station running hours (2,250 of the estimated 3,950 station run hours per annum). Parallel running backup arrangements could only run for a short time before the 500 hours derogation would be exceeded. Based on the high likely parallel running hours for the site, using the CSRP option could potentially result in relatively high NOx emissions and a reduced versatility associated

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

with a reduced compressor envelope. There is current uncertainty regarding the EA regulatory position regarding applicability of CSRP as a BAT solution. Based on this requirement and the high likely availability of lead units, the retrofit NOx abatement options could be considered to offer good versatility and lower NOx emissions, which would increase their technical/environmental score.

 [redacted]

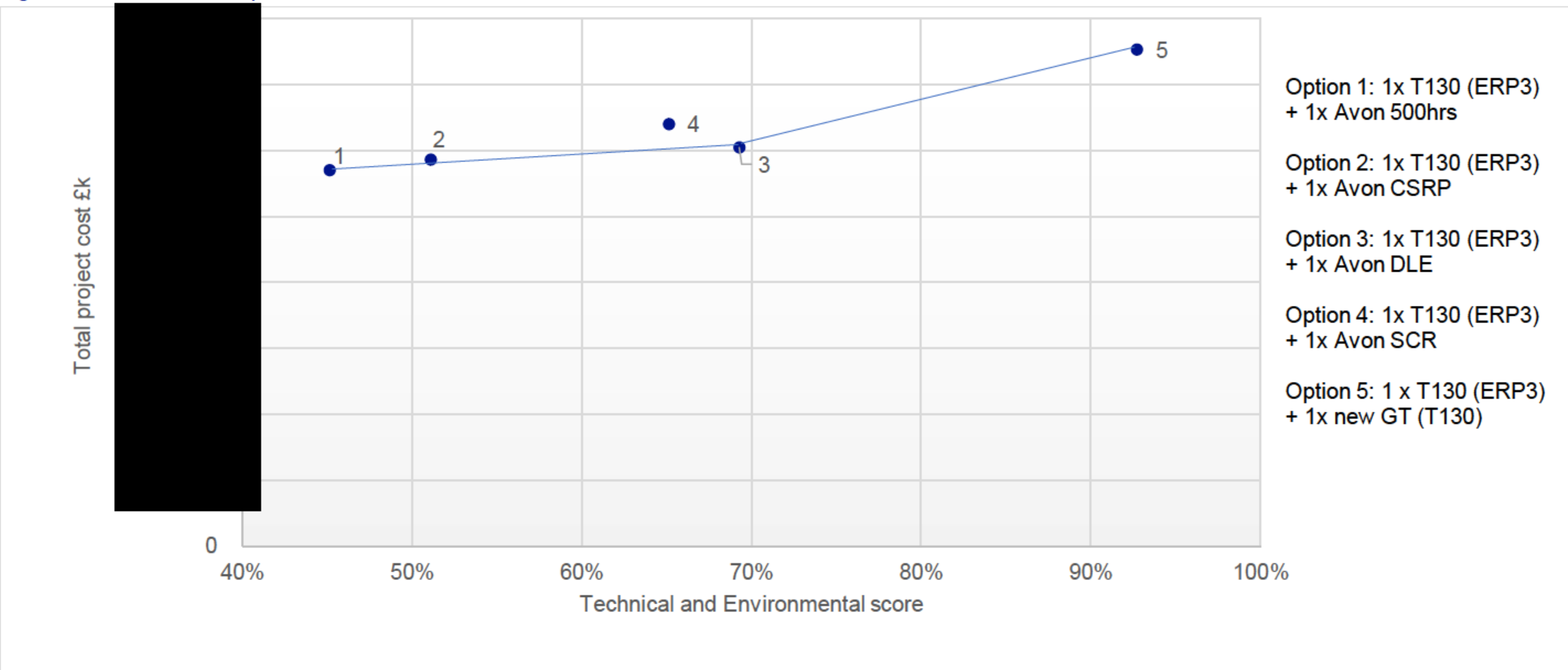
*Constraint testing*

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 Peterborough being a strategically critical site moving gas around the network (predominantly to support movement of gas into the south where the bulk of the demand exists) 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 5 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 1 (unmitigated Avon) has the highest associated constraint costs 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 option is very 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; lead unit unavailable; 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.

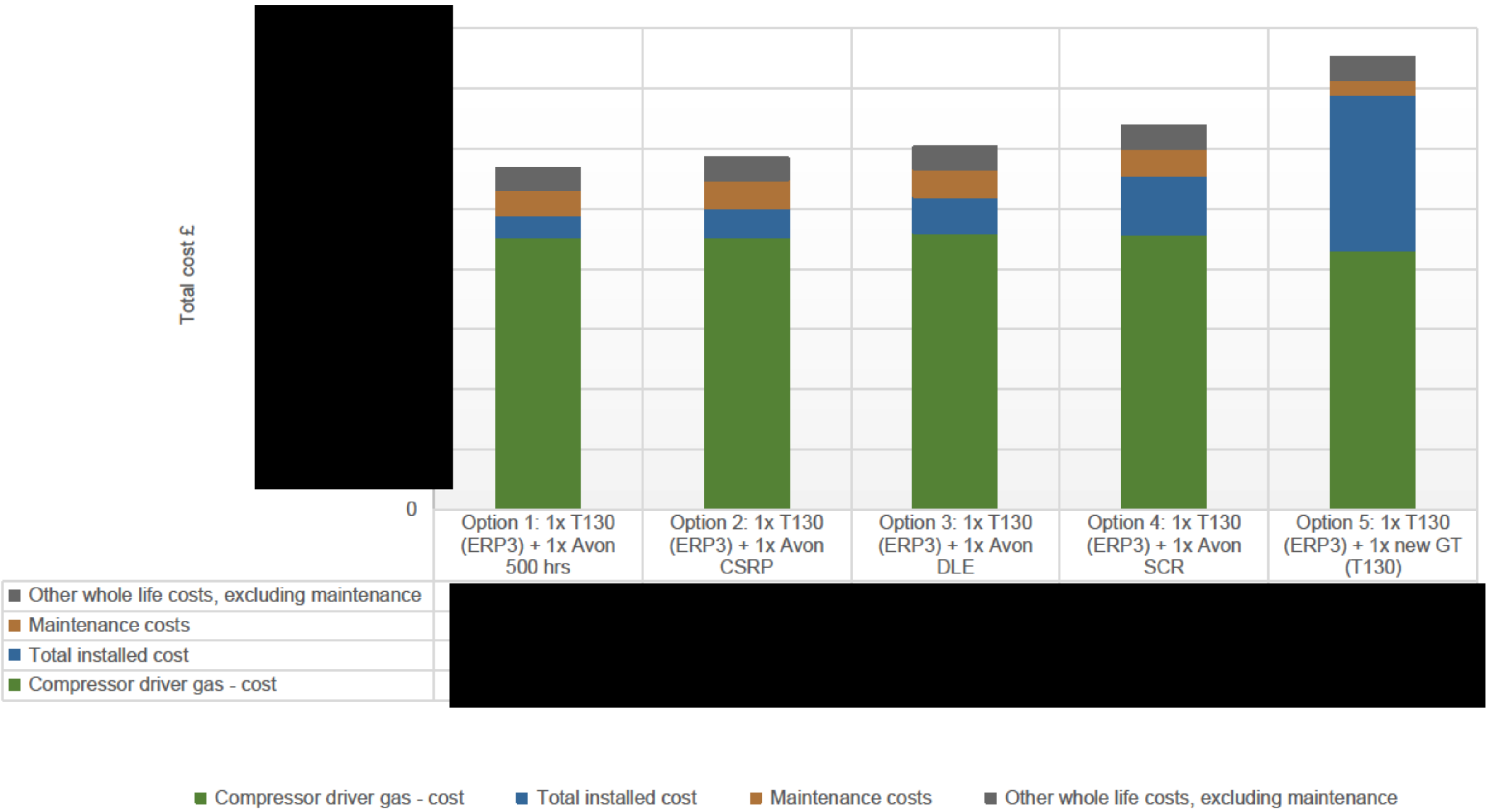
Key points to note when interpreting the chart are as follows:

- 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 and catalyst replacement are added for Option 4 SCR.

The chart illustrates that total energy costs are reasonably comparable across all options, with Option 5 (including a new GT) being slightly lower. For the new GT option, installed capex costs comprise approximately [redacted] 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*

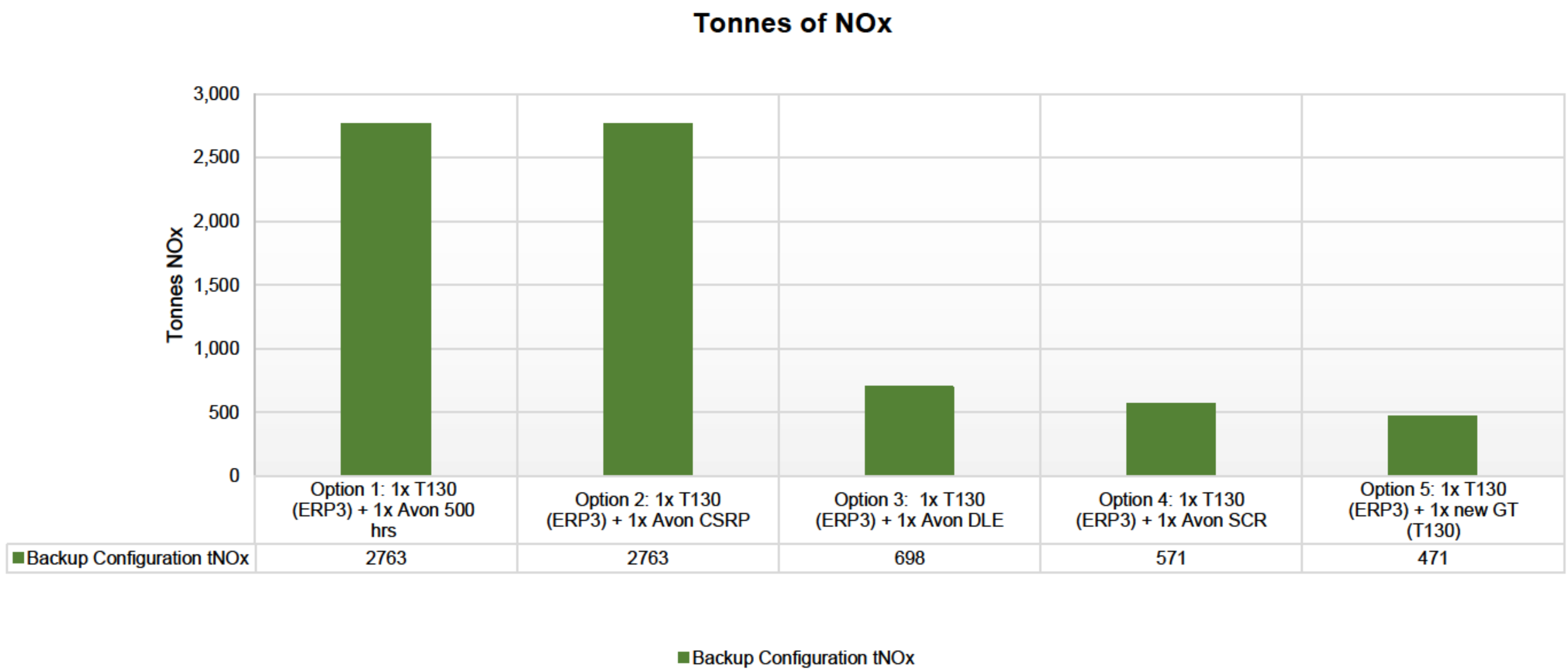


### *Mass emissions*

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.

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*



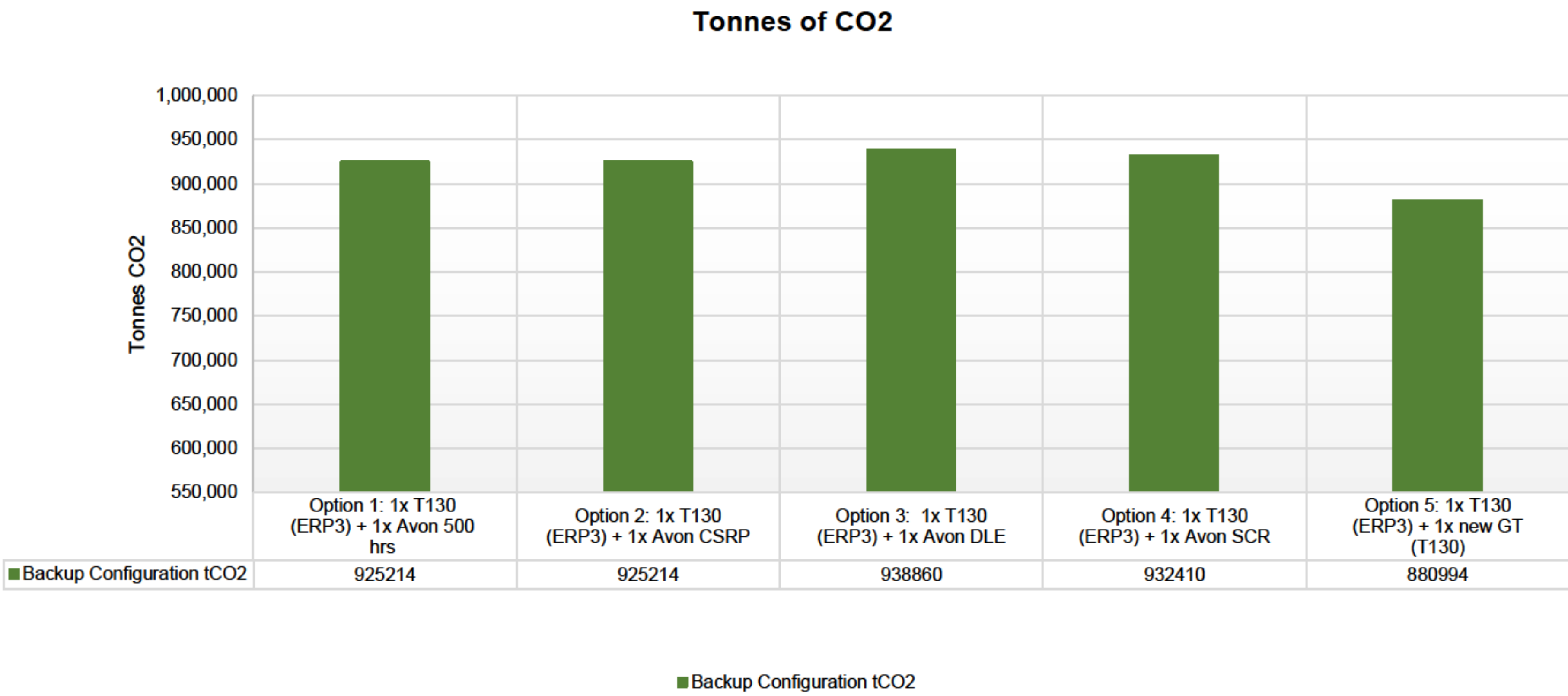
The chart illustrates that the options which retain an Avon on 500h and the Avon CSRP have the highest NOx levels as they have no abatement technique and perform poorly in terms of emissions.

The Avon SCR, Avon DLE and new GT options produce comparable NOx 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 (ERP3) T130 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.

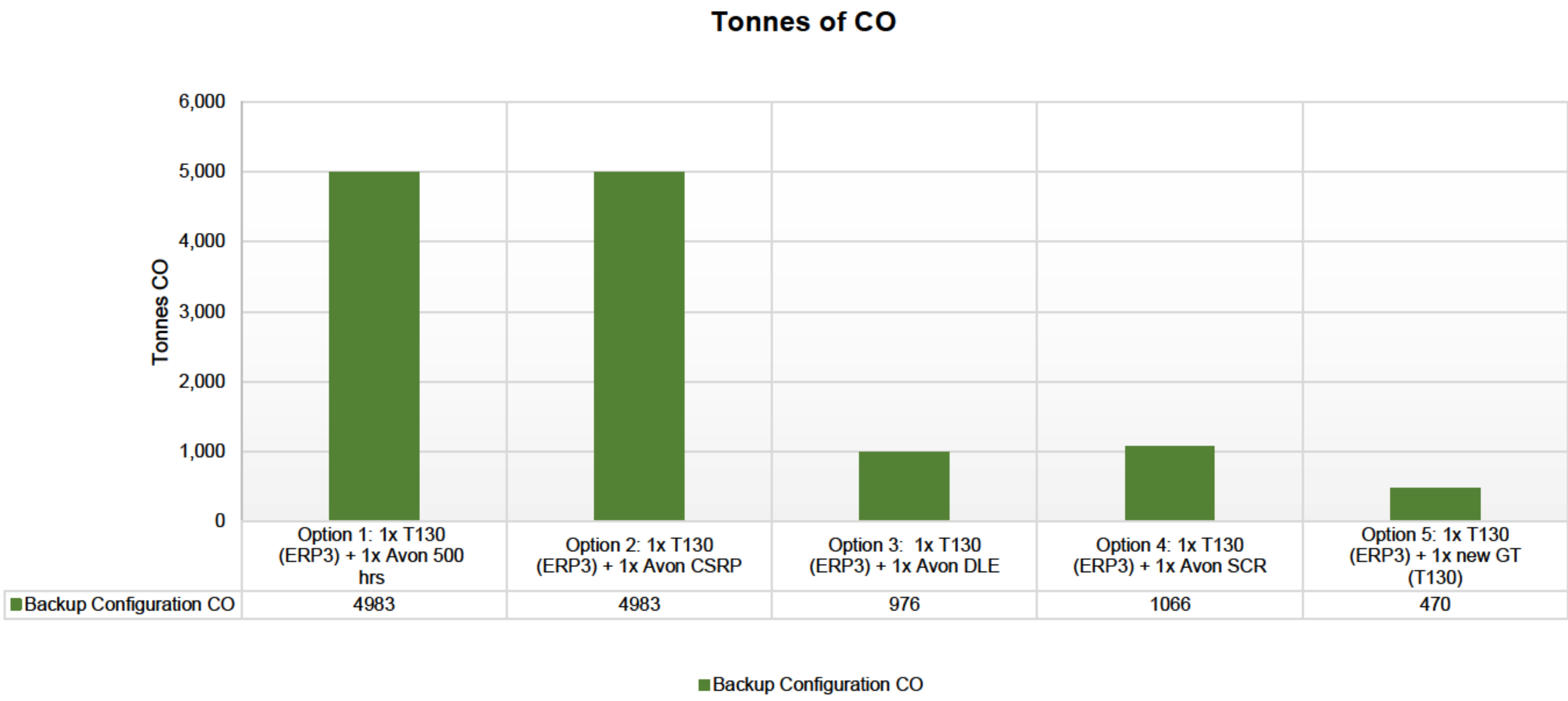
It should again be noted though that the site would not operate in the backup configuration for a 20 year period (the BAT model period). This is a necessary assumption made in conducting a BAT assessment of the backup scenario. The realised emissions will depend on the likely percentage availability of the lead units and the need to run the backup configuration. Given the high availability of the lead units the resulting NOx emissions from a backup unit are likely to be relatively low. However, given the relatively high parallel running hours required, backup arrangements could only run for about 6 weeks before the 500 hours derogation would be exceeded. Additionally at Peterborough it is expected that two units will be required to operate in parallel for approximately 60% of the year. If unavailability of a T130 coincided with a high number of parallel running hours, NOx emissions from the Avon CSRP unit would be materially higher compared with the Avon DLE/SCR and new GT backup arrangements. There is also current uncertainty regarding the EA regulatory position regarding applicability of CSRP as a BAT solution.

*Figure 8 $tCO_2$ emissions*




Option 5, running 2x T130s in a backup configuration produces marginally lower $CO_2$ emissions in this BAT assessment, compared to other options.

*Figure 9 tCO emissions*




The Avon 500h 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 T130s 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 hours 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 4 (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 alongside Unit A at Peterborough.
- In the backup configuration, Option 3 (DLE) could potentially represent a BAT solution since the performance is 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 T130s/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. Although it should be noted that the benefits of this option are dependent on how often the backup unit is required to operate.
- 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 very 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 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 starts 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.

- This BAT assessment considers the Peterborough station in isolation, it is recognised that the Huntingdon compressor station has significant interaction on the NTS gas network with Peterborough and the two stations can operate together (or independently) to meet supply and demand. As such further combined assessment may be required at a later stage.

[redacted]