Development of National Grid Gas' NTS Licence obligations under Special Condition C28

Summary of the Scheme of Work

Contents

1 Executive Summary

This summary of the Scheme of Work is based on the best information currently available to National Grid. It seeks to set out the expected timeline and associated cost of works that National Grid NTS (National Grid) plans to undertake for the purposes of developing a long term incentive for the reduction of National Grid's Greenhouse Gas Emissions commencing 1 April 2013.

Two projects were initially identified to improve the quantification of National Grid's greenhouse gas emissions. It was estimated that these projects would increase the accuracy of emissions calculations for natural gas that is vented from a number of vent types, which include compressor station vents, pipeline depressurisation during maintenance, PIG trap maintenance, filter maintenance and scrubber maintenance.

The Scheme of Work was reviewed by an external consultant and Ofgem to ensure that the works identified within this document are appropriate for the development of a long term Greenhouse Gas Emissions incentive. The review identified additional information which suggested emissions from compressor seal leakage and valve leakage might be more significant than was expected at the time of the development of the two proposed projects. As a result, the Scheme of Work has been updated to reflect the additional findings and to provide a focus on the largest potential sources of venting. The Scheme of Work has been updated to now include 4 projects to provide this focus:

- Project 1: Improve current venting calculations for pipeline depressurisation and station vents
- Project 2: Enable compressor vent mass calculations to be split between automatic vents and other vents
- Project 3: Improve current calculations of compressor seal leakage venting
- Project 4: Introduce valve leakage venting calculations for compressor isolation valves and unit vent valves

Two additional projects were included in the Scheme of Work, which relate to the reduction of greenhouse gas emissions via the development of alternatives to venting natural gas. These projects identified the potential to reduce some emissions from assets, such as compressors and chromatographs. Development would be focused on factors such as adsorption, re-compression or flaring to reduce vented emissions. These costs are expected to be largely funded under the Innovation Funding Incentive (IFI)[1] and are explained in more detail in Section 5.

The external review supported the recommendations for the development of new techniques via the IFI funding mechanism. Results from the Scheme of Work and the IFI projects are expected to enable National Grid to measure these emissions more effectively. They are also expected to enable the construction of incentives that are based around the reduction of vented emissions.

Costs of the Non-IFI funded elements are expected to remain within the £500k limit set out in Special Condition C28 of the gas National Transmission System (NTS) licence.

Subsequent analysis by National Grid has also suggested that the actuation of valves during compressor state changes and the actuation of valves during valve maintenance might also vent significantly more gas than initially believed (possibly approximately 950 tonnes per annum). At this stage, information is not robust and further analysis is required to provide better calculations. As

[1] The Innovation Funding Incentive is a mechanism introduced by OFGEM to encourage the networks to invest in appropriate research and development (R&D) activities that focus on the technical aspects of network design, operation and maintenance. The principal objective is to deliver benefits to consumers, taking a longer term view, by enhancing efficiency in network operating costs and capital expenditure.

National Grid has a very limited ability to affect these emissions, any further work needs to make a balance between data quality and the ability to reduce emissions via this activity. As a result, a draft appendix to the Scheme of Work will be submitted to Ofgem by 1 September 2011 to set out a relevant programme of work to improve the accuracy of the calculation of the emissions arising from gas actuated valves.

The draft appendix will then be subject to a review process, which will take into account expected costs, calculation accuracy requirements and the ability to influence these vented emissions. National Grid will then, subject to approval by the Authority and funding proposals, take forward the proposals to enable the development of a long term incentive for the reduction of National Grid's greenhouse gas emissions commencing 1 April 2013.

2 Introduction

In March 2011, Ofgem published its Final Proposals Consultation on the National Grid Gas System Operator Incentives; these incentives became effective from 1st April 2011.

Within the Final Proposals Consultation, Ofgem introduced a new NTS Licence Special Condition C28 ('C28') that obligated National Grid to develop a Scheme of Work, co-operate with the Authority and any consultants in a review of the Scheme of Work. National Grid would then undertake the agreed activities set out in the Scheme of Work. This document is a summary of the agreed Scheme of Work as directed on 30th June 2011.

Following the external review, National Grid identified that the actuation of valves during compressor operation and maintenance / the actuation of valves for valve maintenance is likely to vent more gas than initially expected. Ofgem requested that National Grid further investigate these elements in a draft appendix to the Scheme of Work by 1st September 2011. The draft appendix will set out programme of work to improve the accuracy of the calculation of the emissions arising from gas actuated valves installed on the National Transmission System (NTS) and owned and operated by National Grid.

3 Background

3.1 Why does National Grid vent natural gas?

Currently, there are activities associated with the commissioning, operation, maintenance and de-commissioning of assets on the NTS which result in the release of natural gas into the atmosphere. This release of natural gas from NTS assets into the atmosphere is known as 'venting'.

In summary, natural gas is vented to varying degrees from eight NTS separate asset types:

- Compressors
- Pipeline maintenance
- PIG Traps
- Filters
- Scrubbers
- Measurement, including gas chromatographs
- Valves and valve actuators
- Compressor Stations

3.2 What is the current level of natural gas venting and what is the impact of venting on Greenhouse Gas Emissions

The amount of natural gas vented from the compressors in 2010 was 3556 tonnes, which makes up around three quarters of vented NTS emissions currently estimated. In terms of greenhouse gas emissions, the equivalent CO_2 emissions to venting of natural gas from NTS compressors is approximately 74,000 tonnes of CO_2e.

Figure 1 below illustrates how the asset types listed in section 3.1 above contribute to the total venting of natural gas and the equivalent CO_2 greenhouse gas emissions.

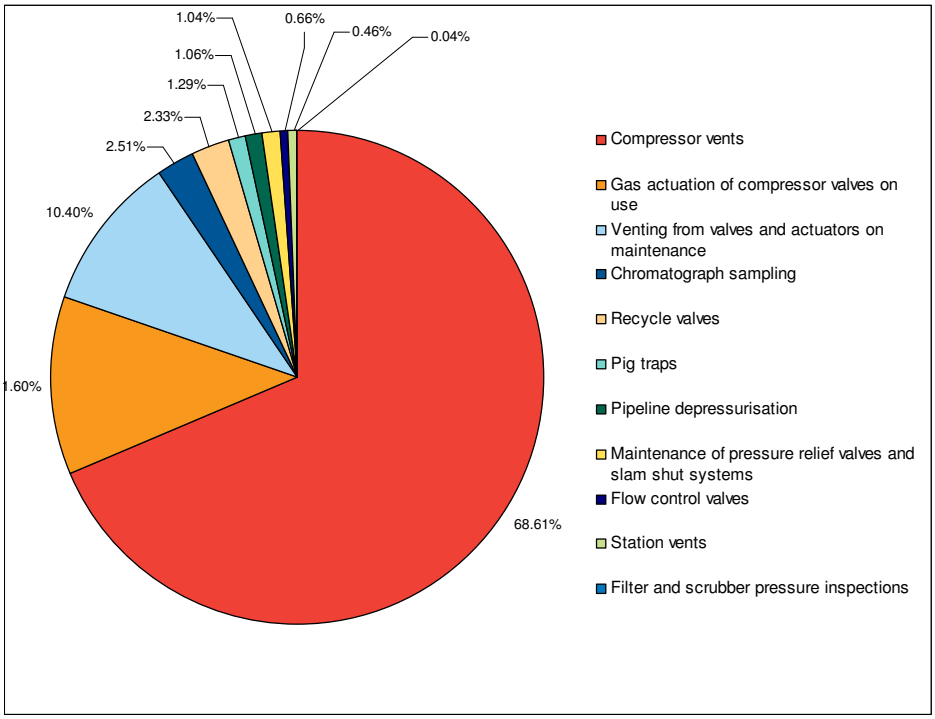

Figure 1: Estimated venting by emission type

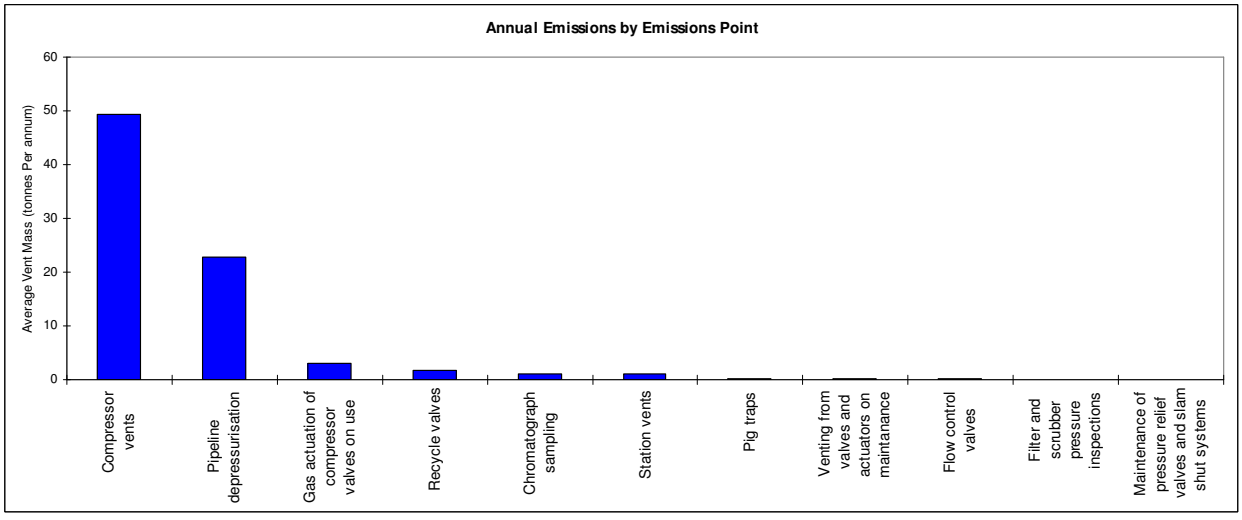

Figure 2: Estimated annual vents, in tonnes per annum, by emission point. Calculations are based on total emissions by emission point divided by the total number of assets that are expected to vent in an average year.

National Grid has estimated that compressor vent actions are responsible for around 70% of total annual vents that are currently quantified. The independent review has suggested that the vent mass from the compressor seal leakage component of compressor venting might be higher than the level currently estimated for this vent type by National Grid.

Although other vented emissions are potentially less significant than compressor venting, they collectively represent around 30% of total vented emissions (based on National Grid's estimates). Chromatographs are responsible for approximately 2.5% of the total vent mass and this gas is vented on a continuous basis while the equipment is operational. Other emissions points, such as pipeline depressurisations, are relatively high volume, low frequency events. For example, National Grid estimates show that on average, approximately 23 tonnes of natural gas is vented each time a pipeline section is depressurised.

A description of the vent types referenced within the above graphs can be found within Section 3 and Appendix 6 of National Grid's Gas System Operator Incentives Initial Proposals Consultation 2011/12[2].

3.3 Current measures to minimise Greenhouse Gas Emissions

Efficient operation of the NTS to deliver secure supplies at a reasonable cost has always been a key driver in the development of the system. Over time, environmental performance has become a higher priority and the current commercial arrangements and operational systems are being reviewed in the light of this drive to reduce the environmental impact of our activities.

In general, measurements from around the system are used to enable the monitoring of safe operation of the system and to inform commercial processes such as billing. In addition, there are some areas where National Grid's environmental performance is specifically measured, such as in calculating the emissions from the use of compressors, but equivalent calculation methodologies are not yet in place for all potential emissions from the NTS.

The current Greenhouse Gas Emissions from Compressors System Operator Incentive Scheme is designed to provide an incentive for National Grid to make the trade-off between choosing to depressurise compressor units (venting the gas within them) or to keep units on standby - which incurs costs associated with ancillary electrical equipment (vent fans, oil pumps etc) and leakage (venting) through the shaft seal.

Reductions in the level of natural gas vented to atmosphere from the target are linked to incentive revenue, which is based on the value of the environmental cost of the natural gas emissions saved. If this revenue is greater than any incremental costs incurred in realising this reduction, it would lead to a profit. If the level of natural gas vented is greater than the target, National Grid faces a loss equivalent to the environmental cost of the natural gas emissions above this level. The incentive applies to both gas and electrically driven compressors and currently expires in March 2013.

Under the incentive, the amount of gas vented at compressor stations is compared against a target. The incentive target for the formula years 2011/12 and 2012/13 is 3007 tonnes, with a deadband from 2,857 tonnes to 3,157 tonnes of natural gas. For every tonne vented above or below the deadband,

[2] National Grid's Gas System Operator Incentives Initial Proposal Consultation for 2011/12 was published in November 2010 and the Initial Consultation for July 2012/13 was published in July 2011. These documents are available at http://www.nationalgrid.com/uk/Gas/soincentives/docs/ and http://www.nationalgrid.com/uk/Gas/soincentives/archive/2010_11/index.htm

National Grid is subject to a penalty or payment of approximately £1,145. This is equivalent to £100,000 for every 87 tonnes vented above or below the target. The incentive is summarised in the graph below.

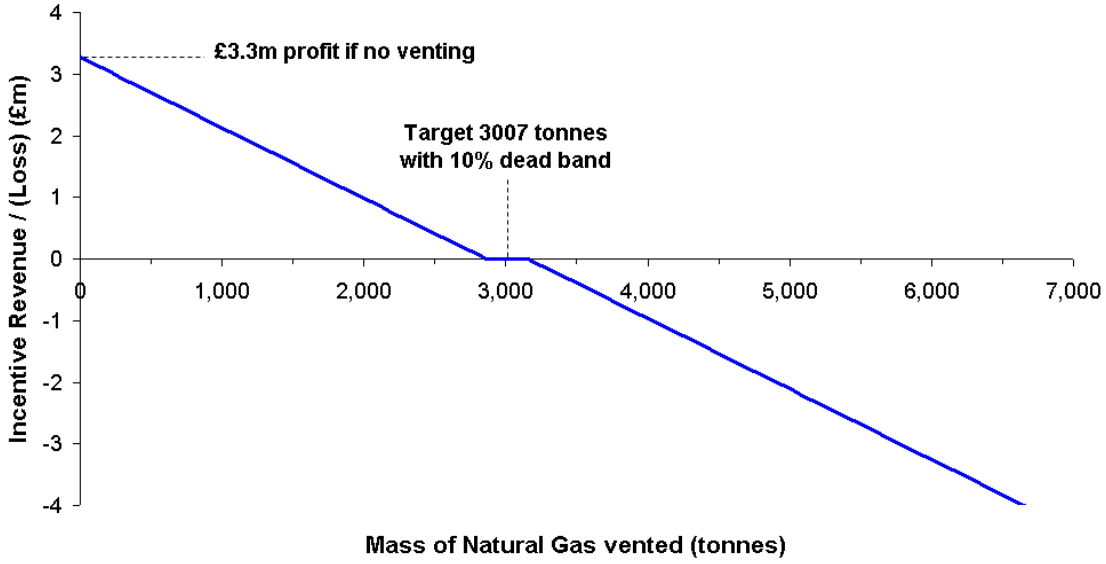

Figure 3: 2011/12 Greenhouse Gas Incentive

To further reduce the environmental impact of the NTS, further work and investment is required to understand the drivers of venting. This includes the collection of relevant data to more accurately calculate the emissions and explore alternatives to venting natural gas. The Scheme of Work seeks to provide an agreed approach, timetable and estimated costs for this further work for the purposes of developing a long term Greenhouse Gas Emissions Incentive.

3.4 Consultant Review of the draft Scheme of Work

The draft Scheme of Work was reviewed by a consultant and Ofgem. Following this process, the Scheme of Work was brought together and it included amendments to reflect the outcome of the review.

At the first consultant review meeting, the consultant suggested that measurement is an enabling step towards emissions reductions and may lead to some reductions due to the focus brought by measurement.

In the Consultant's report and at the following review meeting, the consultant proposed that further work should be considered regarding seal leakage from compressors and valve leakage from compressor unit isolation and vent valves. The consultant expressed a view that this could be more important than increasing the scope of emission points where venting is quantified. The consultant also supported the project that aims to enable compressor process vents following a trip to be distinguished from other vents (project 2). Additionally, the consultant supported the proposed research and development. There was some discussion about whether the size of individual venting events or number of assets should be considered in addition to the estimated level of venting and level of influence.

Following this meeting, National Grid has provided analysis of the level of venting relative to the number of vent events and assets (see Table 2) to aid discussions about which projects to improve measurement of venting are appropriate. Also, quotations were requested for work to understand the

seal leakage from compressors and valve leakage from compressor unit isolation and vent valves and to implement a measurement methodology for these vents.

A further review meeting was held where a number of issues were addressed:

- A number of areas in Project 1 appear to have a marginal benefit with respect to costs incurred. Therefore, only pipeline depressurisation and station vents should be progressed.

- National Grid also provided new analysis of venting from gas actuators for compressor operation and venting from gas actuators for valve maintenance. The analysis was based on best available information and estimated that approximately 950 tonnes of natural gas might be emitted by these sources per annum. Although the estimate was not believed to be robust, the vent mass was significantly larger than expected. Discussions took place with respect to the provision of a more robust process to quantify these emissions. This will be subject to an appendix to this document, as outlined in section 2 of this document.

This Scheme of Work has been updated to incorporate the above details.

4 Proposed approach to quantify venting of natural gas from the NTS

As described briefly in Section 3.1 above, there are eight main areas that contribute to the overall Greenhouse Gas Emissions of the NTS through the venting of natural gas. To further develop a robust methodology to quantify the Greenhouse Gas Emissions arising from the venting of natural gas from the pipeline system, National Grid has identified a number of projects, summarised in the following table.

	Proposal	***Deliverable***
1	Improve the current venting calculations including compilation of asset data	• Set up process to enable calculation of vented emissions from pipeline depressurisation • System modification to enable centralised reporting of station vents • Track vented emissions for the calendar year 2012 • The vent flow rate for each chromatograph type on the NTS (part of an IFI R&D project)
2	Enable compressor vent mass calculation to be split into those following an automatic venting trip and others	• Deliver capability to calculate the compressor vent mass at all compressor sites, following an automatic venting trip
3	Improve the current venting calculations of compressor seal leakage venting	• Identify & assess key leakage factors • Review of findings from leakage factor assessment • Record leakage rates from gas compressor seals by type according to method of rationalisation • Develop method(s) to quantify seal leakage rates • Implement methodology to enable revised seal leakage venting calculation
4	Introduce venting calculations for compressor unit isolation valves and unit vent valves	• Identify & assess key leakage factors • Review of findings from leakage factor assessment • Record leakage rates from valve by type according to method of rationalisation • Develop method(s) to quantify valve leakage rates • Implement methodology to enable valve leakage to be included within venting calculation

Table 1: Revised summary of proposed venting quantification projects following consultant review

National Grid considers that in order to fully support the development of a long term Gas System Operator incentive to reduce targeted greenhouse gases a level of 'base data' using an improved methodology for the quantification of vented natural gas will be required. To enable the development of this approach, National Grid considers that base data for the calendar year January 2012 to December 2012 would be useful, where possible, when developing the Gas System Operator incentives for April 2013 onwards. National Grid has therefore assumed that, where feasible and economically efficient, activities identified within the Scheme of Work should seek to develop a methodology for the quantification of vented natural gas by December 2011, to enable venting to be quantified from January 2012.

National Grid considers that the activities listed in the above table are the most appropriate to undertake in so far that they seek to introduce a methodology to efficiently quantify vented emissions with respect to the size and complexity of each asset type.

Each activity listed within the table above is explained in further detail in the following sub-sections.

4.1 Project 1: Improve current venting calculations for pipeline depressurisation and Station Vents

Current Measurement Approach and Potential Improvements:

National Grid has, as a minimum, aimed to align these proposals to Defra's guidance in 'Guidance on how to measure and report your greenhouse gas emissions'. The most common approach used to calculate Greenhouse Gas (GHG) emissions is to apply documented emissions factors to a known activity data from defined emissions sources:

Estimated Activity Data x Emission Factor = GHG emissions

where:

Estimated Activity Data is the mass of gas vented in tonnes; and
Emissions Factor is Global Warming Potential for natural gas venting.

Estimated Activity Data is calculated using a consistent methodology which can include factors that have a variable nature such as gas pressure, asset dimensions, calorific value (CV) and vent trigger information. This methodology can be used to calculate activity data for individual emissions sources or groups of emissions sources where inputs can be based on live and / or nominal values.

- Nominal values can be derived from historic information to provide an average, which could be from design specifications or equipment data sheets (shown in blue).
- Live values are actual readings from monitoring systems and are specific to emission point source (shown in red).

Figure 4 shows a conceptual design of a method that could be used to determine GHG emissions from vented emission sources on the NTS. It considers the emissions sources by type, grouping together like sources and emissions estimation methodologies.

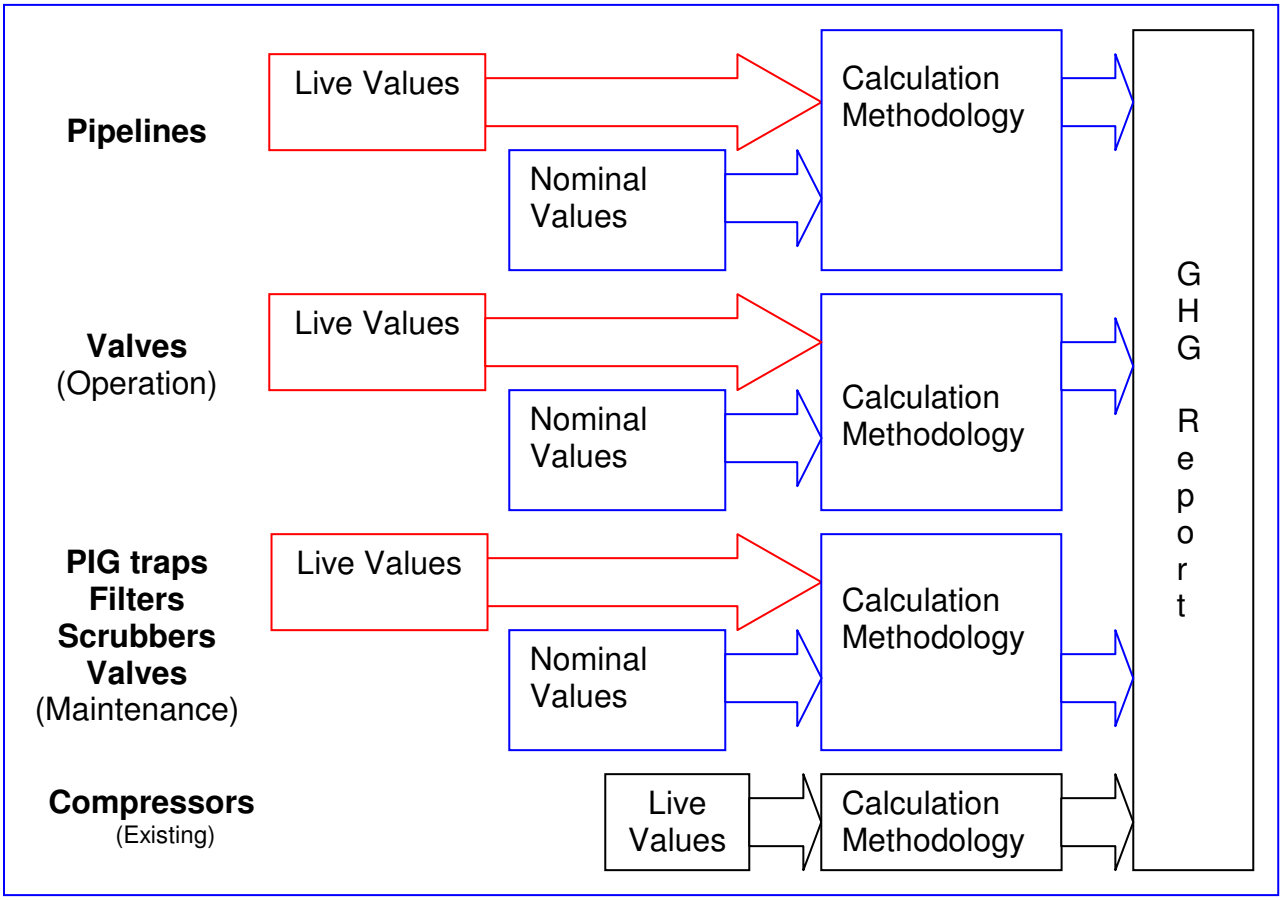

Figure 4: Potential conceptual design for a quantification methodology for vented emissions on the NTS with 'live' values where feasible

As the uncertainty of calculations are dependant on the accuracy of the inputs, the use of live data provides a higher degree of confidence in any estimate of activity data. However, this has to be considered against the cost of providing this data through investment in systems and / or additional resource requirements. For example, the manual collation of pressure and gas quality data for pipeline depressurisations would require the development of on-going manual processes and would need to be developed to ensure that all activities are captured consistently. However, the automation of this process (i.e. using live data) would incur a sizeable cost to link systems and could create issues around linking in to a Critical National Infrastructure (CNI) system. Therefore, it is important to maintain a balance between the sensitivity of inputs with respect to the output, the magnitude of the relevant emissions and the quality of the data that is required.

Proposed Approach:

Natural gas emission calculations for compressor stations have been developed using a methodology which has been embedded into an existing system. This existing system, which is used for compressor environmental reporting and condition monitoring, had many of the attributes required to provide environmental emissions data (including live values). Further developments have been made to improve the quality of data and improving the methodology of the more complex emission points.

There is no suitable donor system available to extend this methodology to other types of natural gas emissions, such as pipeline depressurisations, pig traps, scrubbers and filters and there are often no sensors on these assets to record events. Therefore, significant additional costs would be incurred to build a process and / or system to collect and calculate these vented emissions.

At present, emissions from the maintenance of PIG traps, filters and scrubbers account for around 1% of total emissions (using current estimates). Therefore, consideration has been given to the balance between the relative amount of venting from these assets, data accuracy, information systems expenditure and operating expenditure. Following discussions between National Grid, the Authority and the consultant, these items have been excluded from Project 1.

However, whilst pipeline depressurisations and station vents are relatively low frequency occurrences, the vented volumes are relatively high for each event and, therefore, these aspects have been included in the scope of Project 1, using live values for aspects such as dimensions, frequency and pressure and nominal values for gas quality (which is not readily available and has a relatively low importance in the venting calculation).

Figure 5 shows the suggested approach by rationalising emission types by groups of like emissions and utilising existing systems, such that minimum development is required.

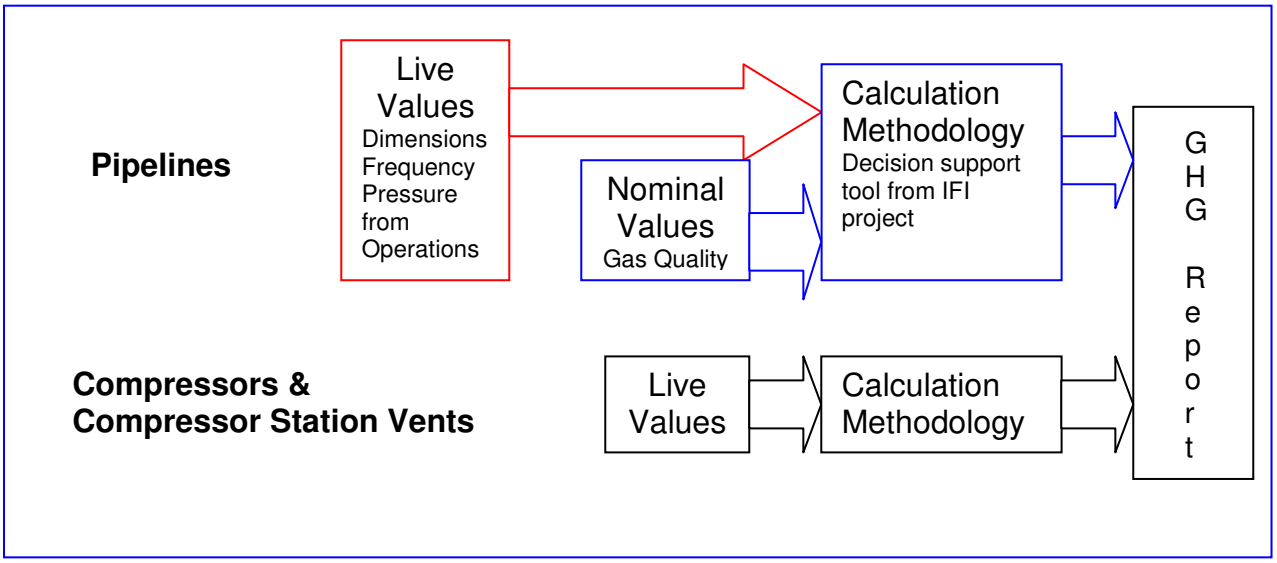

Figure 5: Proposed conceptual design for a quantification methodology for vented emissions on the NTS

The collection of actual frequency of venting events would require some procedural and reporting changes to the operational documentation and a data collection exercise. This would require initial set up costs and some ongoing costs to collect and calculate the vent mass. However, the benefits of this approach are as follows:

- A consistent approach to emissions calculation using 'live' input values where these inputs can be collated cost efficiently, with some nominal input values into the emissions calculation methodology;
- Relatively low set up costs with some ongoing operating costs, which will become clearer as the process is further developed. The set up costs include the development of processes to collect pressure data when maintenance occurs (on-site or at the nearest site) and a system modification to enable centralised reporting of station vents.
- An increase in the accuracy and information available for vented emissions to inform the development of a long term incentive for the reduction of National Grid's Greenhouse Gas Emissions.

As the final Scheme of Work is implemented, the operating cost implications should become clearer for the ongoing costs of reporting on a wider range of emissions, with its impact on reporting complexity.

Summary

The following table summarises the relevant changes proposed for each of vent type.

Vent Sources / Activities	Proposed Improvements	Assessment Factors			
		Magnitude of Emissions Per Event	Magnitude of Emissions Per Asset	Accuracy of Current Measurement	Degree of Influence to Reduce Impact of Venting
Compressor process vents	- Development of trip signal to enable compressor vent mass calculation to be split between automated vents (due to asset trips) and those taken by the operator for other purposes (project 2)	Medium	High	High Quality	Medium
		Use operating strategy to optimise venting, or find an alternative to venting to atmosphere.			
Other compressor vents (seal leakage and other)	- Research to quantify valve leakage vent emissions from compressor unit isolation valves and vent valves (project 3) - Research to quantify vent emissions from wet and dry compressor seals (project 4) - System development which depends on the outcome of research into valve leakage and seal leakage (project 3 & 4)	N/A	High	Rough estimate	Medium
		Consultant's estimate of seal leakage may be inaccurate. It might be possible to alter operating strategy to reduce seal leakage, or replace gas starter motors and wet seals with dry ones (capital project), where retro-fitting is possible and efficient.			
Gas actuation of compressor valves on use	- Development of a calculation methodology that can be used to provide a more robust estimation of these vented emissions than is currently available. This will be considered in the Appendix to the Scheme of Work	Very low	Medium	Rough estimate	Low
		Current estimates are based on initial calculations and are likely to be inaccurate. Although there are currently no alternative assets that have improved venting characteristics and maintenance schedules are linked to operational requirements, it is desirable to further understand the magnitude of these emissions.			
Gas actuation of valves on maintenance	- Development of a calculation methodology that can be used to provide a more robust estimation of these vented emissions than is currently available will be considered in the Appendix to the Scheme of Work	Very low	Very low	Rough estimate	Low
		Current estimates are based on initial calculations and are likely to be inaccurate. Although there are currently no alternative assets that have improved venting characteristics and maintenance schedules are linked to operational requirements, it is desirable to further understand the magnitude of these emissions.			
Vent of cavity in valve maintenance	- Not proritised	Low	Low	Rough estimate	Very low
		Valve maintenance must be carried out, but no alternatives to venting have yet been found.			
Chromatograph sampling	- Improved flow rate information (R&D project)	N/A	Medium	Good estimate	Medium
		There is a current project investigating alternatives to the existing venting practice.			
Recycle Valves	- Due to the nature of operation, a more complex methodology is required, with live inputs. These attributes are not readily available. Investment not appropriate to capture emissions from small emission point	N/A	Medium	Rough estimate	Unknown
		Little information is currently available with respect to recycle valves.			
Vent of PIG trap during runs & preceding maintenance	- Not prioritised	Very low	N/A	Rough estimate	Low
		Consider whether techniques that might be developed for other vent types could be transferred efficiently when they are understood.			
Pipeline depressurisation	- Improved frequency, asset volume data - Use Decision Support tool from IFI project to calculate volume vented using actual pressure during operation	Very High	N/A	Good estimate	High
		Alternatives to venting are being investigated.			
Slam shut systems on maintenance	- Not prioritised	Very low	Low	Rough estimate	Low
Flow control valves	- Due to the nature of operation, a more complex methodology is required, with live inputs. These attributes are not readily available. Investment not appropriate to capture emissions from small emission point	N/A	Very Low	Rough estimate	Very low
Station vent	- One site requires a survey as modification works have been completed - System modifications to enable centralised vent reporting	High	Medium	Good estimate (excl. 1 site)	High
		For planned station vents, the degree of influence is high (repressurisation units can be rearranged). But for emergency station vents, the degree of influence is low.			
Pressure relief valves on maintenance	- Not prioritised	Very low	Very low	Rough estimate	Low
PIG trap pressure inspections	- Not prioritised	Very low	Very low	Rough estimate	Low
Filter pressure inspections		Very low	Very low	Rough estimate	Low
Scrubber pressure inspection		Not known	Very low	Rough estimate	Low

Schedule of Proposed Deliverables

	Description of Deliverables	Estimated Dates in the C28 Scheme of Work
Stage 1	System modifications to enable centralised data collection for pipeline depressurisation	Dec 2011
	System modification to enable centralised reporting of station vents	Dec 2011
Stage 2	Collection and calculation of venting data for calendar year 2012 to inform incentive development	Jan 2013

4.2 Project 2: Enable compressor venting calculations to be split between automatic vents and other vents

Venting from a compressor as part of de-pressurising a compressor and associated pipework is triggered either when the compressor is no longer required for active duty, for safety reasons when maintenance needs to carried out or for safety reasons should the compressor trip, for example if the compressor control system detects a fire.

In order to improve performance of gas compressor units, it would beneficial to understand the proportionality of venting associated to the different scenarios which may cause the compressor to vent. Analysis of improved venting data could be used to identify issues where the root cause is:

- Behaviour of the System Operator; or
- Asset condition or suitability.

Development of solutions can be used to eliminate or minimise the effects of the above using the results from data analysis to support any improvement through asset investment or application of operating techniques.

Compressor venting is already calculated using existing data systems by vent type. To enable vents following an automatic venting trip to be separately identified and calculated, changes would need to be made to existing systems, which for most compressor stations could most likely be implemented by December 2011. Changes to the remaining 3 sites, which are currently in the process of being upgraded, would need to occur once their software upgrades have been completed.

In order to implement this split of compressor venting into vents resulting from a compressor trip and other vents, the findings of the survey would need to be implemented, and these requirements are not clear until the surveys have been completed. Implementation costs are dependent on the complexity of mapping between the systems.

Conclusions of surveys may indicate an impact on the existing Centralised Reporting Systems and require changes to this software. To ensure that systems continue to operate, without comprising the integrity of reporting, the software needs to be fully tested after modification. The extent of this activity is dependent on the magnitude and how intrusive any changes are. As this system has only recently moved into National Grid's internal information system support, there is limited information to base any costs which may arise from integration of any such findings.

Schedule of Proposed Deliverables

	Description of Deliverables	Estimated Dates in the C28 Scheme of Work
Stage 1	Survey all NTS compressor sites, except for St Fergus, Warrington and Hatton	Dec 2011
	Survey for 3 remaining compressor sites	Following site works
Stage 2	Implement split of compressor venting into trip and non-trip vents for all NTS compressor sites, except for St Fergus, Warrington and Hatton	Dec 2011
	Survey for 3 remaining compressor sites	Following site works
Stage 3	Centralised Reporting System changes if required	Dec 2011

4.3 Project 3: Improve current calculations of compressor seal leakage venting

As part of the normal operation and maintenance of compressors on the NTS, natural gas is vented as follows:

- To purge the compressor (and fuel lines on gas powered compressors) of air, prior to starting a compressor. This is necessary to remove the risk of air entering the pipeline system;
- On some compressors, where a gas starter motor is installed, natural gas is used to start the compressor;
- On most compressors, there is a small amount of leakage around a seal on the compressor shaft when the compressor is pressurised. This seal is used to separate combustion products from the areas where pipeline gas is actually being compressed; and
- Depressurising a compressor and associated pipework when the compressor is no longer required for active duty, for safety reasons when maintenance needs to carried out or for safety reasons should the compressor trip.

Depressurising a compressor is currently considered to be the largest source of venting from NTS compressors, however this depressurisation does allow auxiliary electrical equipment such as ventilation fans and oil heating/circulation pumps to be switched off saving on the electrical costs and reducing the environmental impact of consuming electricity and the seal leakage venting resulting from the compressor being in a pressurised state.

Gas at mains pressure in the compressor body is retained by the compressor shaft seal, which vents natural gas as part of normal operation (seal leakage). Some gas compressor seals used on the National Transmission System are wet seals with the dry gas seals accounting for the remaining gas seals. Over time dry seals are expected to dominate the NTS compressor fleet as this is the current preferred standard.

Wet Seals

The basic wet seal consists of two seals, which use oil that is circulated under high pressure to form a barrier against compressed gas leakage (figure 6). Very little gas escapes through the oil barrier, but considerably more gas is absorbed by the oil on the process gas side of the barrier, thus contaminating the seal oil. Seal oil is purged of the absorbed gas (using heaters, flash tanks and degassing techniques) and recirculated. The wet seal system is totally dependant upon the integrity of a seal oil system which is very complex and expensive containing reservoirs, pumps, coolers, filters, pipework and separators. Wet seals (as used on some NTS compressors) tend to leak at a higher rate than dry seals.

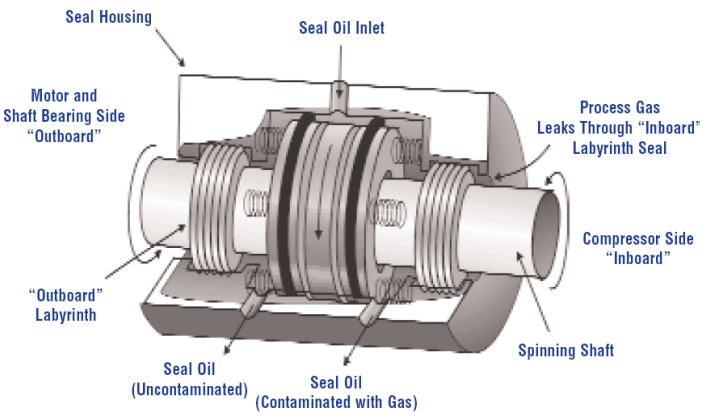

Figure 6: Wet gas seal

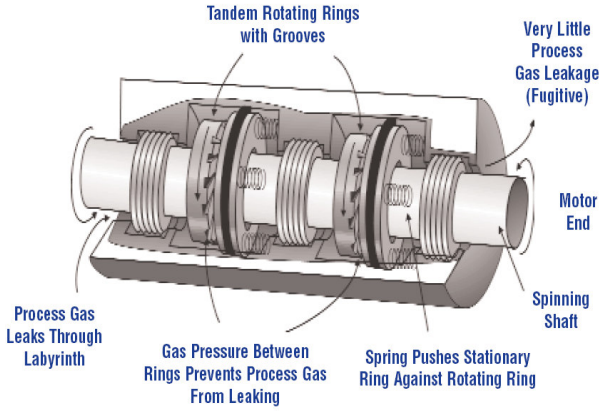

Figure 7: Dry gas seal

Dry Seals

Dry gas seals do not use oil as a barrier and instead rely on non-contacting gas seals. The seals are used at the interface of the gas compressor shaft and the casing to seal the pressurized process gas from the atmosphere. Dry gas seals operate mechanically using grooves, which are etched onto the surface of the rotating ring that is fixed to the compressor shaft (Figure 7). When the compressor shaft rotates at high speed, compressed gas has only one pathway to leak down the shaft.

In the consultant's opinion, the compressor vent measurement methodology should differentiate between wet and dry seals, and preferably use leakage rate estimates specific to each compressor seal. Given the potential magnitude of the difference between the various estimates (see Figure 8 below) for seal leakage, National Grid considers that this is an area that should be reviewed to ensure that the methodology in place is appropriate.

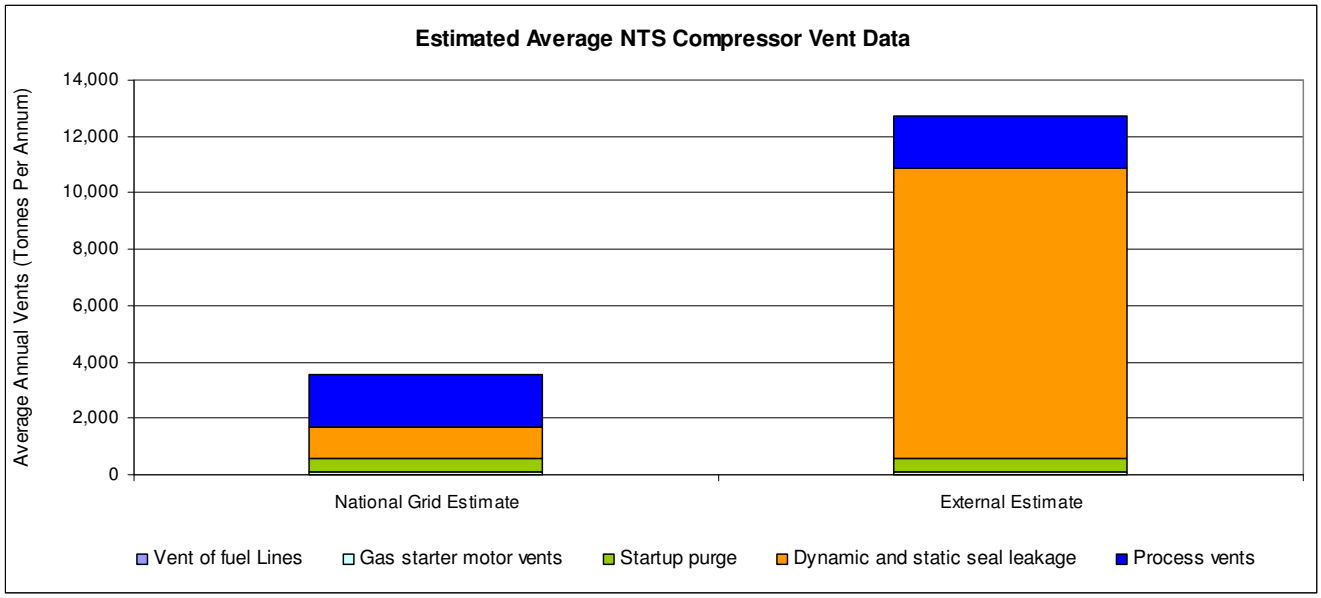

Figure 8: Differences between National Grid and external assumptions for compressor venting[3]

National Grid aims to run a tender to quantify the vented emissions from compressor seal leakage (project 3) and valve leakage from unit vent valves and unit isolation valves (project 4). The final methodology will be based on a competitive tender process.

Current Greenhouse Gas Emissions Incentive

In order that the incentive continues to drive the desired behaviours by National Grid, it is important that any incentive mechanism should use a consistent calculation methodology for the target and performance measure. This would ensure that any incentive payments or penalties reflect National Grid's actual operational performance rather than changes to the calculation methodology. Therefore, we consider that any potential misalignments, which are as a result of a change to only one part of the calculation process (either actuals or incentive target), need to be taken into account as part of this process. This would mean that National Grid would not profit or lose as a result of improvements to the calculation methodology.

[3] Compressor dynamic and static seal leakage calculations are based on the best data that is currently available to NGG. The Appendix to the Scheme of Work includes the development of improved calculations for this venting source

National Grid believes that there are two options that would effectively deal with the potential calculation disparity that could be created between reported actuals and the incentive target. The first option would be to report actuals based on the new methodology and to update the seal leakage component of the current incentive target, so that the actual performance and the target are calculated on the same basis. In the event that it is too complex to change the calculation basis for the current incentive scheme, the existing actuals methodology and the current incentive targets could be used for the existing reporting process, while the new methodology could be calculated and reported outside of this process and be used to guide the development of any longer-term incentives.

Schedule of Proposed Deliverables for projects 3 and 4

	Description of Deliverables	Estimated Dates in the C28 Scheme of Work *
Stage 1	External assessment to identify sources of leakage. Identify key leakage factors and assess leakage past isolation valves and unit vent valves and leakage through seals. Assessment of overall leak Review the process to date to consider whether to progress to stage 2	January 2013
Stage 2	External analysis of a small number of site types using outputs of stage 1 to produce a best practice method for measurement of leakage	
Stage 3	Extrapolate results from stage 2 to all sites to develop and implement algorithms and systems to quantify seal and valve leakage	

* Actual dates and timings will be depend on the results of a further competitive review process

4.4 Project 4: Introduce valve leakage venting calculations for compressor isolation valves and unit vent valves

The unit isolation valves on a compressor are used to isolate or enable flow from the pipeline to and from the compressor. The unit vent valve is open when the compressor is being brought to a de-pressurised state or is in a de-pressurised state.

When there is a pressure differential across a valve (when a valve is closed), there maybe some leakage across the valve seats that leads to a small quantity of gas being vented to atmosphere.

When a compressor is de-pressurised, the closed unit isolation valve would have the pressure of the NTS pipeline on one side of the valve and atmospheric pressure on the other side of the valve. This differential pressure (up to 90 bar) across the valve seats can lead to valve leakage.

When a compressor is pressurised, the closed unit vent valve would have the pressure of the NTS pipeline on one side of the valve and atmospheric pressure on the other side of the valve. This differential pressure (up to 90 bar) across the valve seats can lead to valve leakage. The amount of leakage across the unit vent valve would be expected to be smaller than that across the unit isolation valve because the valve is much smaller (typically 6 -12 inch diameter rather than 24 - 48 inch diameter).

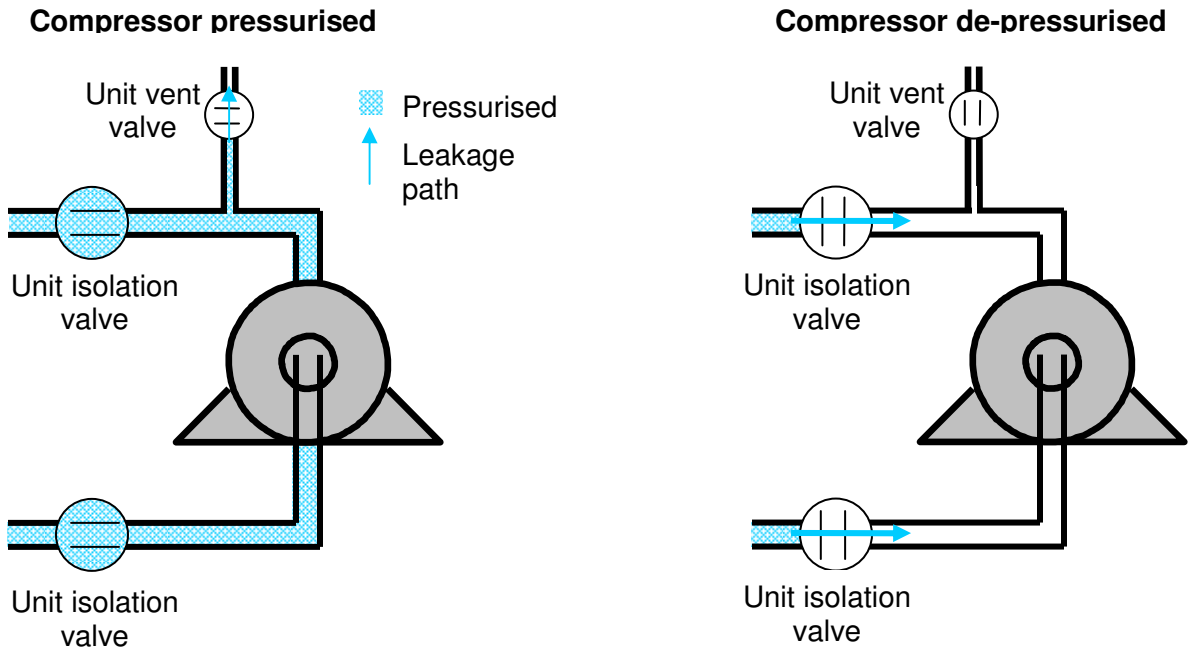

Figure 9: Diagram showing seal leakage across unit isolation valves and unit vent valves on a compressor

As part of the review of the Scheme of Work, the consultant suggested that compressor valves should be considered in order that any operational optimisation between de-pressurising a compressor or leaving a compressor in a pressurised state considers a more complete picture of the relevant emissions. National Grid is intending to run a tender for the work to quantify the leakage across these valves and put in place a measurement system.

For the detail of the work proposed and the Schedule of Proposed Deliverables, please see project 3.

5 Projects relating to alternatives to venting

5.1 Background: What are the alternatives?

Two specific projects have been identified to develop alternatives to the venting of natural gas. These projects, if successful, could identify approaches to reduce emissions from the NTS. Where these approaches are assessed to be efficient and economic, they could be progressed further which could lead to investment and / or changes in process on the NTS that could reduce National Grid's Greenhouse Gas Emissions. The projects identified have the potential to facilitate the reduction of some of the emissions from chromatographs (~100 tonnes of natural gas vented per annum) as well as other vent types such as compressor venting (3556 tonnes of natural gas vented in 2010) in the current operating environment.

An IFI (Innovation Funding Incentive) project Environmental Study for Future Above Ground Facility Developments (Phase 2) which completed in April 2011 identified four potential techniques and technologies that National Grid could potentially investigate further:

a) Venting and Leakage – Operational Considerations

There are a number of operational issues that relate to venting and leakage that may affect the overall energy use of a compressor:

- When units are stopped and left pressurised, the rotating pumping action of the dry gas seal cannot work and gas leaks across the seal faces.
- When units are de-pressurised, there may be a greater leakage of gas through the vent system than is lost through the dry or wet gas system when the units are pressurised. This is due to the unit process isolation valves experiencing a high differential pressure when de-pressurised.

b) Adsorbed Natural Gas Storage (ANG)

Adsorbed Natural Gas (ANG) technology, in which natural gas is adsorbed by an appropriate adsorbent material with high porosity is a promising method of capturing and storing natural gas (mainly methane) at low or intermediate pressure ranging from 5 to 50 bar.

Activated carbons usually have the most favourable characteristics for use as the adsorbent for ANG storage due to their large micropore volume, and they can be well compacted into a packed bed. It is low cost, widely available and developed for methane adsorption. An illustration of the how gas is adsorbed is shown in Figure 10.

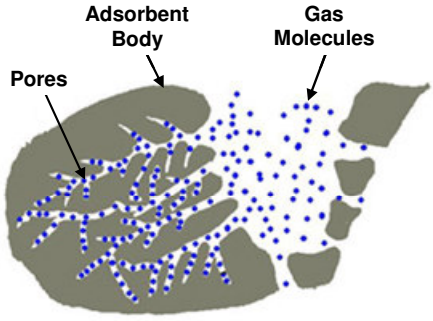

Figure 10: ANG - Principle of operation

By means of gas adsorption, ANG has potential to provide a promising storage solution as an alternative to venting.

c) Re-compression – Compressor stations

It may be possible to recover most of vent or leakage gas by use of a small recompression unit, gas storage or a combination of both. First, the compressor would be de-pressurised by recompressing the gas into storage or into the NTS pipework with the vent valve closed. If the isolation valves leaked when the unit was de-pressurised on standby, the control system would detect when the casing pressure rises above a minimum pressure, e.g. 1 bar. The small compressor would then be started to re-compress gas into storage or the NTS pipework. When the compressor casing pressure reached a lower pressure, e.g. 0.0bar, the compressor would be stopped and the cycle repeated.

d) Flaring

Flaring is an option that can be used to reduce the emissions of methane and natural gas to the atmosphere. Flaring is used to consume waste gases in a safe and reliable manner through combustion. It is routinely used to dispose of flammable gases that are either unusable or uneconomical to recover. Flaring can also be used to depressurize gas processing equipment during routine maintenance and emergencies. For National Grid, the task of reducing methane emissions to the atmosphere through several of its operations it is likely that any flare system will have to be enclosed and ground-based, possibly portable and clearly with high performance efficiency. This requirement tends to focus on more sophisticated flare systems.

5.2 Current Work

Alternatives to venting from the NTS: Benefits and Background

The project has been ongoing since March 2009 and has been amended in line with progress. The project initially had a delivery date of January 2011, which has subsequently been revised to December 2012.

The potential benefits from undertaking this work include:

- Development of new best practice for lowering methane emissions during de-pressurising activities prior to maintenance or de-commissioning
- Reduction in National Grid's natural gas emission inventory
- Improved energy management

The project to date has included:

- Tandem recompression and flaring for pipelines. During preparations for decommissioning work at a compressor site in 2010, a full-scale demonstration was conducted of doubled-up recompression (one of National Grid's rigs, plus a second hired rig) and a controlled flaring rig (normally used for safe incineration of hazardous chemicals). Addition of the second recompression rig accelerated depressurisation above 7barg and then took the pressure below 1barg without reaching its limit. The flaring rig was then used successfully for the remaining gas, taking the pressure below atmospheric pressure. A decision tool is being developed on the best technique to use in terms of recompression units and controlled flaring.
- ANG Storage for compressors. During the initial phase of the project, laboratory-scale tests on a small ANG storage system provided encouraging results. Analysis also showed that there was potential to install a larger ANG storage system on 5-10 compressor stations, where it would be used to provide the alternative to venting with the least carbon footprint. Work was therefore started on the design of a large-scale demonstration rig.

Based on these initial results, the project has been amended (see schedule of proposed deliverables below) to include the development of the scaled-up ANG storage demonstration through the expansion of the design to full operational standards. If successful, the output of this part of the project

will therefore provide the complete design package that can be tailored to the needs of particular compressor stations and the substantial potential to reduce methane emissions from compressors when they are shut down.

For compressor unit venting, the aim would be to capture the gas using an ANG storage vessel, with subsequent discharge / recompression of the gas into the lower pressure gas turbine fuel system.

Where these techniques are proved technically feasible, it may be appropriate to consider the potential for implementation across the NTS. In order to understand the potential for roll-out, the techniques would need to be considered for each potential implementation site to understand whether that site is technically suitable (e.g. has downstream donor system for lower pressure gas, flow rates of gas currently vented etc) and whether the technique is likely to be economic for the system usage and maintenance requirements at that site. The complexity of any feasibility survey is dependent on the outcome of the research and development. The feasibility survey is dependent on the outcome of the IFI project.

This proposal does not include the implementation of any techniques identified through Research and Development, such as through these IFI projects. Any investment that may be identified as part of this process would be speculative at this stage and cannot currently be well justified. Therefore investments relating to implementation have not been included within National Grid's Well Justified Business Plan for the RIIO-T1 period given the level of maturity of these techniques. National Grid would welcome the opportunity to consider the appropriate future steps following the outcome of this research and development.

Schedule of Proposed Deliverables

Number	Description of Deliverables	Estimated Dates at in the C28 Scheme of Work
Stage 1 1.1. 1.2. 1.3. 1.4.	Interim recommendations relating to options for methane reduction (Technical Note). Report on results and recommendations. Equipment procurement and evaluation activities (lab-based). Evaluation, analysis and reporting of 'improved recompression' and 'flaring' trials at Bathgate.	**Completed**
Stage 2 2.1. 2.2. 2.3.	Design, planning and procurement of equipment for large-scale evaluation trials Construction of ANG demonstration facility (storage and use of 'waste' gas). Evaluation, analysis and reporting of ANG trial.	Jun 2011 Mar 2012 Jun 2012
Stage 3	Report on best practice and operational procedures.	Jun 2011
Stage 4	Internal management and consultation related to the R&D.	Dec 2012
Stage 5	Implementation feasibility study if appropriate	March 2013

Bleed reduction on gas chromatographs

There are over 130 gas chromatographs at various points around the NTS that take samples of pipeline gas in order to provide information on gas quality.

Currently, gas chromatographs continuously bleed gas to speed up the transit of gas from the insertion probe to the gas chromatograph. A second, smaller bleed is then used to purge the gas chromatograph.

The aim of this IFI project (see schedule of proposed deliverables below) is to confirm the emission rates and evaluate options to reduce the emissions. This will include oxidation of the gas to carbon dioxide (e.g. small-scale catalytic combustors). The project will also review alternative methods to provide sufficient transit speed, as appropriate.

The potential benefit for this project could be to reduce the amount of natural gas vented to atmosphere, where investment is efficient, which can be valued at the environmental cost of natural gas venting. The estimated level of venting from chromatographs in 2010 was 100 tonnes of natural gas as at Autumn 2010. The outcome of the project may also facilitate further benefits from more responsive gas analysis.

Further work would need to be completed before any new types of chromatographs could be used, as the equipment would need to be compliant with ISO 10715:1997 (Natural Gas – Sampling Guidelines) before it could be used on the gas National Transmission System.

As in the alternatives to venting project, if the equipment considered under this project is considered technically feasible, it may be appropriate to consider the potential for implementation across the NTS through a feasibility survey. Again, the complexity of any feasibility survey is dependent on the outcome of the research and development. Following the outcome of the earlier project stages, the feasibility survey is dependent on the outcome of the IFI project.

This proposal does not include the implementation of any techniques identified through Research and Development, including those identified in these IFI projects. Any investment that may be identified as part of this process would be speculative at this stage and cannot currently be well justified. Therefore investments relating to implementation have not been included within National Grid's Well Justified Business Plan to be submitted in July 2011 for the RIIO-T1 period given the level of maturity of these techniques. National Grid would welcome the opportunity to consider the appropriate future steps following the outcome of this research and development.

Schedule of proposed deliverables

Number	Description of Deliverables	Estimated Dates in the C28 Scheme of Work
Stage 1	Options study report for the potential reduction of natural gas emissions from gas chromatograph systems on NTS above ground facilities	Aug 2011
	Internal management of IFI project.	Aug 2011
Stage 2	Implementation feasibility study if appropriate	Dec 2011

5.3 Future Work

Based on the progress of the current research and development, further IFI projects are being discussed by the Steering Group for Alternatives to Venting. A workshop was set up to develop the detailed scope for a project to look at recompression of gas commonly vented from NTS compressors, without using ANG storage . At the workshop, our strategy was re-evaluated and therefore a number of new projects are now being considered, which have not yet been fully developed. These projects include the following potential areas of work (as shown in Figure 11 below):

- evaluation of further emissions
- consideration of whether current policies are still fit for purpose when environmental impacts are considered
- management of venting where required.

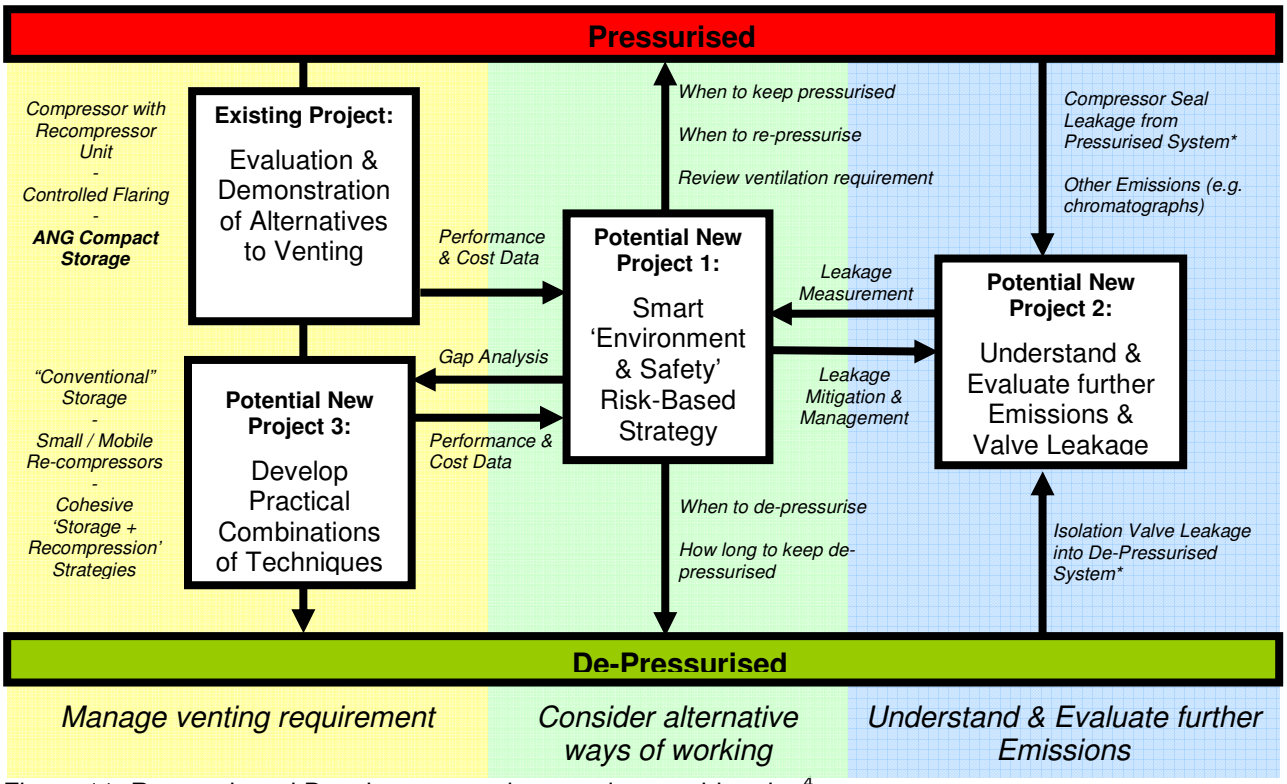

Figure 11: Research and Development projects under consideration[4]

[4] The projects marked with an * have been included within Projects 3 & 4 in the Scheme of Work

6 Next Steps

In line with the obligations stated within Special Condition C28 of the NTS licence and later directions, the Scheme of Work was submitted to the Authority.

National Grid shall undertake the activities set out within the Scheme of Work within the timescales outlined in the updated Scheme of Work or such other timescales as the Authority may reasonably direct. The timescales of projects 3 and 4 are subject to change following tender under the framework agreements in place.

Finally, National Grid will, whilst undertaking the activities included within the Scheme of Work, continue to assess how these activities can facilitate the establishment of a long term external gas system operator incentive to reduce the Greenhouse Gas Emissions arising from venting natural gas. A summary of the activities proposed in the Scheme of Work is provided below in Figures 12 and 13:

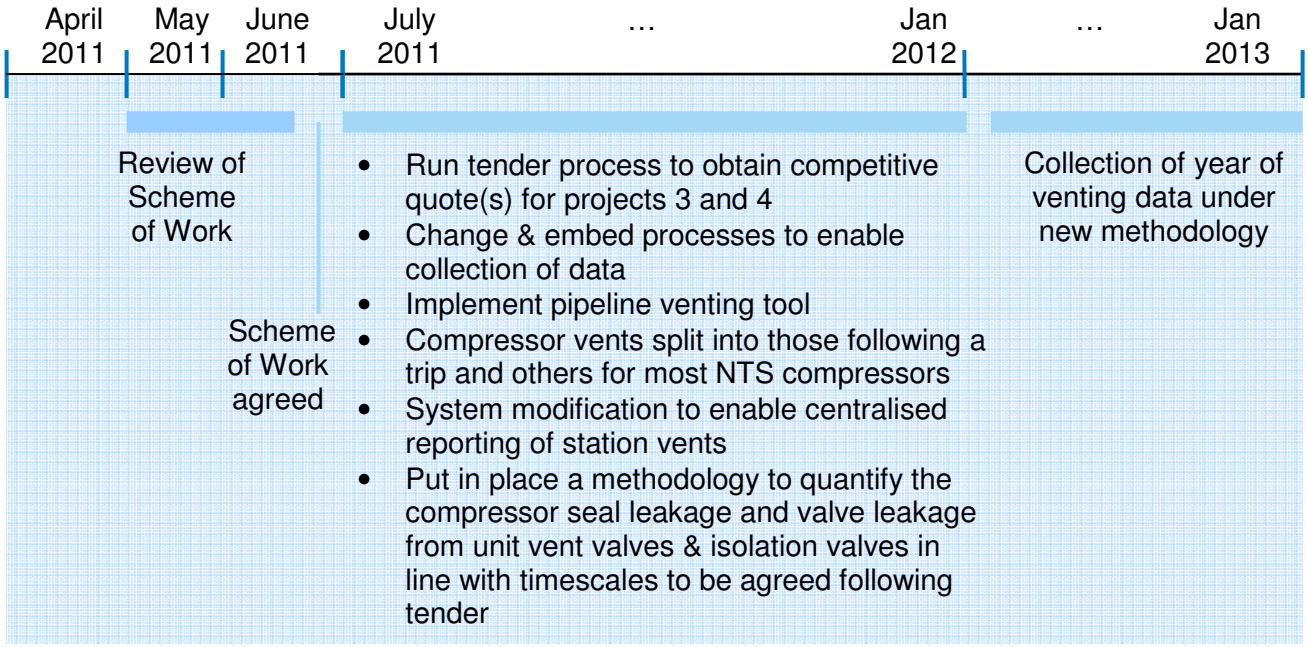

Figure 12: Overall timescales for venting quantification work proposed within the Scheme of Work

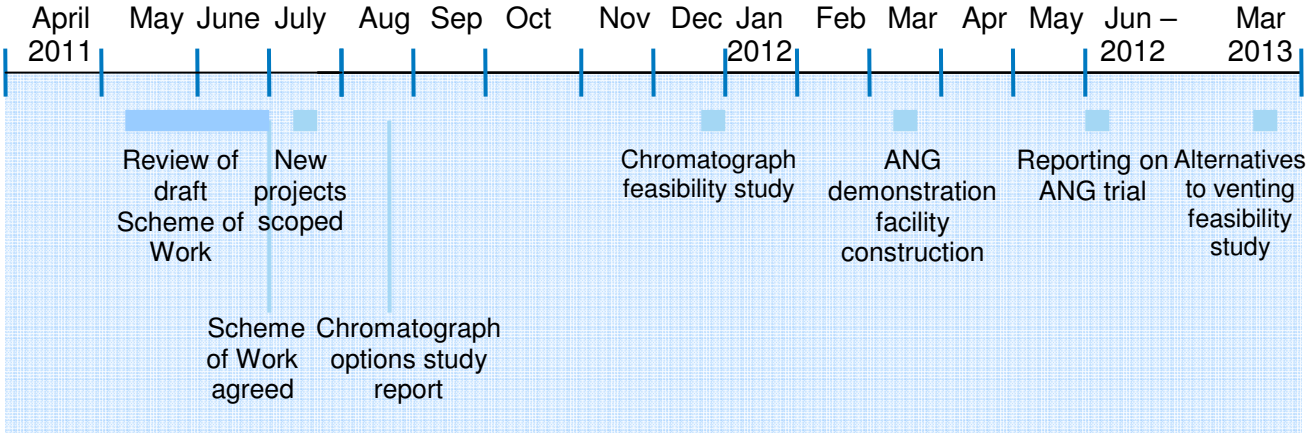

Figure 13: Overall timescales for Research and Development work proposed within the Scheme of Work