UNC Request Workgroup Report	At what stage is this document in the process?

UNC 0754R:

Investigate Advanced Analytic Options to improve NDM Demand Modelling

01 Request
02 Workgroup Report
03 Final Modification Report

Purpose of Request:
To request a UNC Workgroup be established to investigate alternative 'advanced analytics' options in order to further improve the accuracy of the End User Category (EUC) Demand Models which are used to derive the Gas Demand Profiles which are key parameters in the calculation of Non-Daily Metered (NDM) Allocation and Capacity Invoicing.

	The Workgroup recommends to the Panel that this Request be closed. The Panel will consider this Workgroup Report on 20 October 2022. The Panel will consider the recommendations and determine the appropriate next steps.
	High Impact:
	Medium Impact: CDSP, Shippers and Transporters
	Low Impact: End Consumers

Contents

About this document:

This report will be presented to the panel on 20 October 2022.

The panel will consider whether the Request should be closed or returned to the workgroup for further assessment.

Any questions?

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1 Request

This Request is being proposed to investigate how the industry (via Demand Estimation Sub Committee - DESC) could improve the accuracy of the NDM demand modelling process further by utilising more advanced analytical approaches e.g. Machine Learning.

This follows on from findings presented by the Unidentified Gas (UIG) Task Force which identified that the NDM Modelling error, which is a significant contributor to the both the levels and volatility of Unidentified Gas, could be materially reduced further using such techniques.

Demand Estimation Sub Committee (DESC)

Each year DESC are responsible for confirming the End User Category (EUCs) Definitions, Gas Demand Profiles - Annual Load Profiles (ALPs), Daily Adjustment Factors (DAFs) and Peak Load Factors (PLFs). DESC also have the responsibility for reviewing the effectiveness of the NDM Algorithm every 3 years, which is now due. The timetable that DESC follows for it's annual 'Business as Usual (BAU) activities', particularly from March to August, does not contain a significant amount of available time for exploring alternative demand modelling options. The review of the performance of EUC demand models and any ad-hoc analysis is usually performed each Autumn/Winter period. In recent years this has included changing the EUC definitions within Bands 1 and 2 (Annual Quantity (AQ) range 0-293MWh pa) and the formula for deriving the Composite Weather Variable (CWV) (now includes a Solar Radiation term), both of which have contributed to improved EUC demand models and subsequently lower UIG.

Unidentified Gas (UIG) Task Force

The UIG Task Force was established to investigate all the possible causes of UIG and provide recommendations for resolving them. The daily estimate of NDM demand inevitably contains error, however the Task Force recommendation suggested the current approach to demand modelling could be improved with the use of Machine Learning* techniques.
*This is explained further within the "Machine Learning Options Paper" link provided in the "Additional Information" section below.

NDM Algorithm Consultation

In Q4 of 2020, an industry consultation was carried out to explore just how much change in the NDM Algorithm it was prepared to accept ahead of performing any investigative analysis. The results provided clear 'red-lines' in terms of the ALPs and DAFs. These parameters are used extensively across the industry and in many other processes and so any demand modelling approach changes should ensure these parameters are retained and therefore limit any updates to systems for most industry participants.

The establishment of a UNC Workgroup will allow any investigative work to proceed at a reasonable pace, given the already busy DESC schedule, and increase visibility of progress across the industry.

The ultimate impact of changes brought about by this Workgroup should be a better alignment of energy first time around between NDM Allocation and UIG i.e. less modelling error. This would also subsequently result in lower reconciliation/UIG volumes.

Scope

The proposed scope of this review is to consider different options of advanced analytic techniques to produce the underlying EUC Demand Models that are required to create the key parameters of ALP, DAF, and PLF. The Workgroup may investigate and recommend changes to the components and calculation of parameters associated to the CWV. Currently out of scope are any options which remove the following parameters: ALP, DAF, PLF, CWV and Seasonal Normal CWV (SNCWV).

The Workgroup could refer to the work done by the UIG Task Force as a starting point and/or consider any alternatives from interested industry participants.

For the Workgroup to maintain good progress and meet its timescales it will be necessary for industry participants to participate in the review and where relevant provide options and resource as it may not be possible for the CDSP to:

a) perform all the analysis of various options (given its commitments to DESC); and

b) have the necessary knowledge/experience in advanced analytic techniques such as Machine Learning.

On this basis it may require specialist advice which may not be available within the Workgroup. Should this be the case any third-party support requirements would need to be approved accordingly via DSC processes.

Impacts & Costs

The CDSP is most likely to be impacted, if any recommendations contained within the Workgroup Report are then taken forward, via Modifications etc., and ultimately implemented, given it is currently responsible for the production of the annual Gas Demand Profiles.

Any diversion from the current modelling approach will need to be reflected in updates to both its own and Shippers Demand Estimation modelling systems, policies and procedures.

In addition to publishing the headline parameters of ALPs, DAFs and PLFs, a number of supporting files are produced for the industry which include the underlying demand model calculations. The format of these and the ability to replicate the analysis is likely to change in the event the process/approach to producing the demand models is significantly different.

The values of the ALPs, DAFs and PLFs themselves could be markedly different to the current view, this may lead to a ‘step change’ in some of the downstream calculations such as NDM AQs and System Offtake Quantities (SOQs), however any change in the approach to the demand modelling should have proved itself to be a ‘better’ answer than the current calculation and so any movement in these values should be welcomed but also trialled well in advance of being used.

Recommendations

It is recommended that this topic is referred to a separate UNC Workgroup, to allow proper discussion of the topic and development of options.

Additional Information

Suggested Background/ References reading below:

- UNC Related Document: Demand Estimation Methodology
- Current approach to EUC demand modelling: Modelling Approach 2020
- UIG Task Force Findings: 13.2.5 – Accuracy of NDM Algorithm – Basic Machine Learning and 13.2.6 – Accuracy of NDM Algorithm – Advanced Machine Learning
- Possible uses of Machine Learning in Demand Modelling: Machine Learning Options Paper
- NDM Algorithm Consultation - Conclusions Document and Summary Presentation

2 Proposer's Initial assessment of Impact and Costs

Consideration of Wider Industry Impacts

None Identified

Impacts

Impact on Central Systems and Process	
Central System/Process	Potential impact
UK Link	• None, industry consultation has made it clear that current parameters used in NDM Allocation, AQ calculation etc should not be impacted
Operational Processes	• CDSP's Demand Estimation 'off-line' modelling processes and systems will be impacted by any change of approach

Impact on Users	
Area of Users' business	Potential impact
Administrative and operational	• Potential changes required if demand modelling files at the 'layer' below ALPs, DAFs and PLFs are used in any processes
Development, capital and operating costs	• None
Contractual risks	• None
Legislative, regulatory and contractual obligations and relationships	• Possible changes to UNC Related Document

Impact on Transporters

Impact on Transporters	
Area of Transporters' business	Potential impact
System operation	• None
Development, capital and operating costs	• None
Recovery of costs	• Any changes in the underlying demand models could have the effect of impacting downstream calculations of AQs/SOQs
Price regulation	• None
Contractual risks	• None
Legislative, regulatory and contractual obligations and relationships	• Possible changes to UNC Related Document
Standards of service	• None

Impact on Code Administration	
Area of Code Administration	Potential impact
Modification Rules	• None
UNC Committees	• None
General administration	• None
DSC Committees	• None

Impact on Code	
Code section	Potential impact
	• Section H

Impact on UNC Related Documents and Other Referenced Documents	
Related Document	Potential impact
Network Entry Agreement (TPD I1.3)	• None

Impact on UNC Related Documents and Other Referenced Documents	
General	Potential Impact
Legal Text Guidance Document	• None
UNC Modification Proposals – Guidance for Proposers	• None
Self Governance Guidance	• None
TPD	Potential Impact
Network Code Operations Reporting Manual (TPD V12)	• None
UNC Data Dictionary	• None
AQ Validation Rules (TPD V12)	• None
AUGE Framework Document	• None
Customer Settlement Error Claims Process	• None
Demand Estimation Methodology	• Very likely to be impacted depending on outcome of analysis e.g. formulae and/or wording to describe modelling approach
Energy Balancing Credit Rules (TPD X2.1)	• None
Energy Settlement Performance Assurance Regime	• None
Guidelines to optimise the use of AQ amendment system capacity	• None
Guidelines for Sub-Deduct Arrangements (Prime and Sub-deduct Meter Points)	• None
LDZ Shrinkage Adjustment Methodology	• None
Performance Assurance Report Register	• None
Shares Supply Meter Points Guide and Procedures	• None
Shipper Communications in Incidents of CO Poisoning, Gas Fire/Explosions and Local Gas Supply Emergency	• None
Standards of Service Query Management	• None

Impact on UNC Related Documents and Other Referenced Documents	
Operational Guidelines	
Network Code Validation Rules	• None
OAD	Potential Impact
Measurement Error Notification Guidelines (TPD V12)	• None
EID	Potential Impact
Moffat Designated Arrangements	• None
IGTAD	Potential Impact
DSC / CDSP	Potential Impact
Change Management Procedures	• None
Contract Management Procedures	• None
Credit Policy	• None
Credit Rules	• None
UK Link Manual	• None

Impact on Core Industry Documents and other documents	
Document	Potential impact
Safety Case or other document under Gas Safety (Management) Regulations	• None
Gas Transporter Licence	• None

Other Impacts	
Item impacted	Potential impact
Security of Supply	• None
Operation of the Total System	• None

Industry fragmentation	• None
Terminal operators, consumers, connected system operators, suppliers, producers and other non code parties	• None

3 Terms of Reference

Background

The Xoserve UIG Task Force reported that NDM modelling error is a significant factor in UIG volatility and that the use of advanced analytics such as Machine Learning, can contribute to reducing this error. The results of the Xoserve led industry consultation on the future of the NDM Algorithm concluded there was strong support for investigating advanced analytic options within certain boundaries (e.g. retain ALPs and DAFs). Improved NDM Allocation will result in a reduction in UIG volatility and subsequent Meter Point reconciliation/UIG volumes.

Topics for Discussion

- Understanding the objective
- Review UIG Task Force outcomes/analysis
- Confirm scope (consultation conclusions)
- Identify resources / expertise needed
- Agree Timescales
- Determine Data Requirements, Measures and Success Criteria
- Determine options for analysis
- Impact Assess the options
- Shortlist options before analysis
- Perform analysis
- Asses results against Success Criteria
- Development of Solution (including business rules if appropriate)
- Assessment of potential impacts of the Request

  include any potential Cross Code impacts

  Consider any potential impacts of the Significant Code Review and associated Code Freeze window.

- Assessment of implementation costs of any solution identified during the Request
- Assessment of changes to UNC Related Documents and any legal text.

Outputs

Produce a Workgroup Report for submission to the Modification Panel, containing the assessment and recommendations of the Workgroup including a draft Modification where appropriate.

Composition of Workgroup

The Workgroup is open to any party that wishes to attend or participate.

A Workgroup meeting will be quorate provided at least two Transporter and two User representatives are present.

Meeting Arrangements

Meetings will be administered by the Joint Office and conducted in accordance with the Code Administration Code of Practice.

4 Workgroup assessment of Impacts and Costs

Consumer Impacts

Workgroup agreed with the Proposer in section 2 that there were no consumer impacts though any consequential improvements to Demand Modelling accuracy will have longer term positive impacts on UIG which should benefit consumers overall.

Cross-Code Impacts

Workgroup concluded that implementing the changes outlined in Area 2 and 3 via the DESC Ad-Hoc Workplan would not result in any cross code changes.

Central Systems Impacts

Area 1: Impact to central systems and CDSP systems

Area 2: Minimal change to CDSP system only

Area 3: Potential impact to central systems and CDSP systems.

Detail of central systems changes will be addressed in Change Proposal documentation which will be raised if appropriate.

Panel Questions

There were 4 Panel Questions raised when Panel considered the new Modification 0754R on 18 February 2021.

Workgroup Questions:

1. The Workgroup to provide an interim report assessing the reporting schedule.

   Workgroup reported back to Panel on 21 October 2021 and requested an extension to the reporting date out to November 2022, which was approved.

2. Consider UNC IGT cross code impacts.

Workgroup concluded that implementing the changes outlined in Area 2 and 3 via the DESC Ad-Hoc Workplan would not result in any cross code changes.

3. Consider consumer implications and provide an update.

   Workgroup agreed with the Proposer in section 2 that there were no consumer impacts though any consequential improvements to Demand Modelling accuracy will have longer term positive impacts on UIG which should benefit consumers overall."

4. Confirm that potential changes won't have undue impacts on other processes.

   Workgroup concluded that no undue impacts on other processes had been identified.

Workgroup Impact Assessment

Workgroup met to discuss this review on the following dates:

- Workgroup 0754R 29 September 2022
- Workgroup 0754R 07 July 2022
- Workgroup 0754R 22 March 2022
- Workgroup 0754R 30 November 2021
- Workgroup 0754R 05 October 2021
- Workgroup 0754R 07 July 2021
- Workgroup 0754R 12 May 2021
- Workgroup 0754R 23 March 2021

At its first meeting in March 2021, Workgroup initially reviewed the NDM Supply Meter Point Demand Formula (also known as the NDM Algorithm) (see Figure 1).

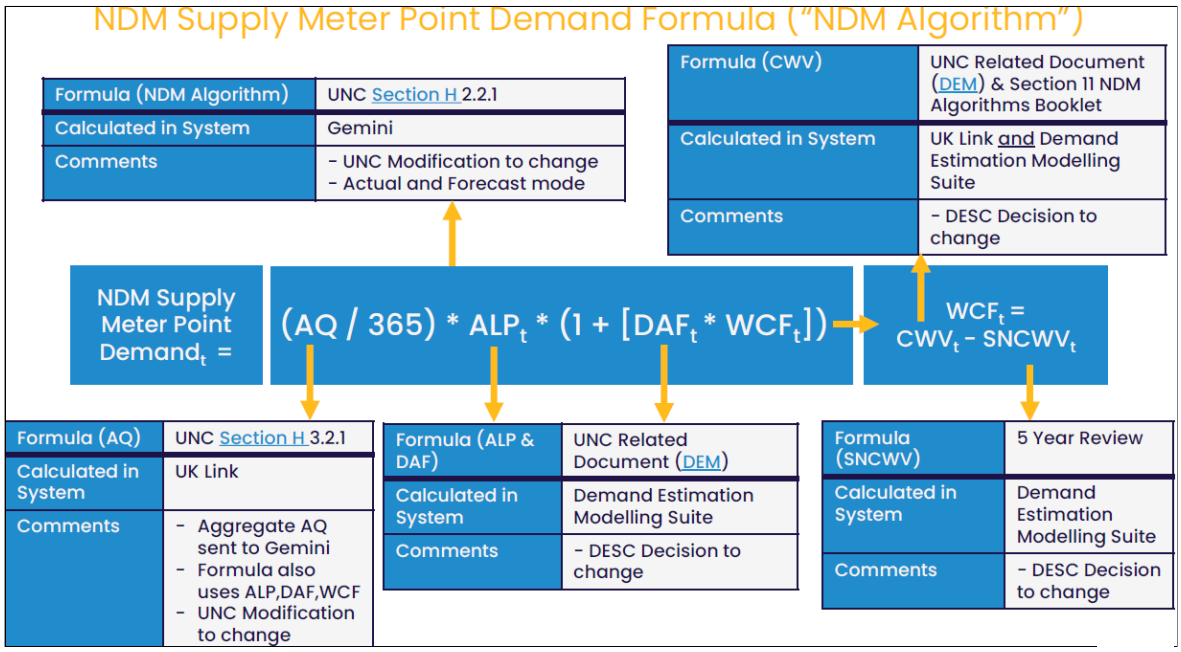
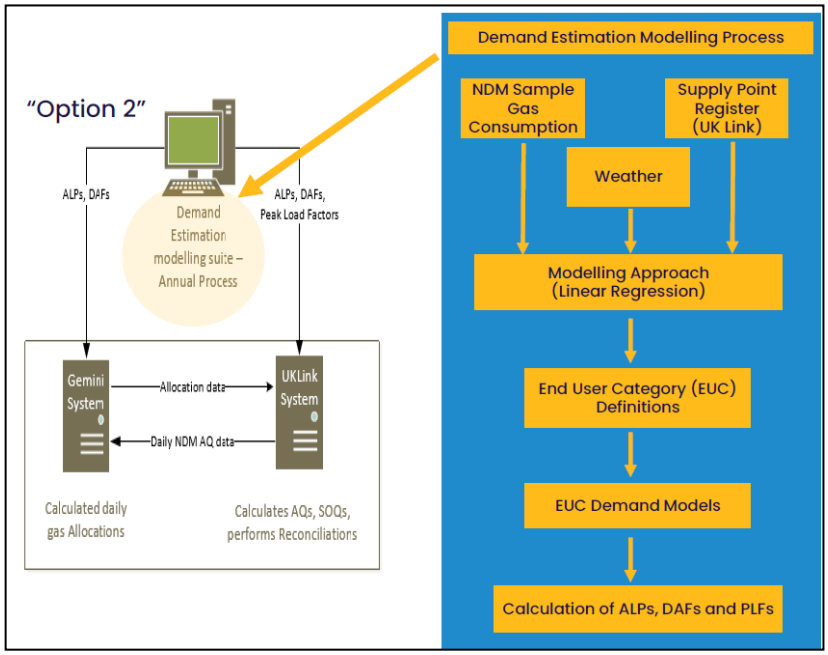


Figure 1: NDM Supply Meter Point Demand Formula ("NDM Algorithm")

Figure 2: Option 2



Key points noted:

- Whilst the calculations for the NDM algorithm are done within Gemini, it uses input from the UK Link system, such as Annual Quantity (AQ) and Composite Weather Variable (CWV) to make its calculations.
- CDSP representative, M Perry noted that the responses to the NDM algorithm consultation[1] carried out prior to the Workgroup commencing, evaluated three possible options for the Request and there was a preference for Option 2 and noted that this Option retained ALPs, DAFs and Peak Load Factors (PLFs) (see Figure 2):

Workgroup had a strong view that a black box solution would not be suitable and that whatever the outcome of the process was, that industry should still be able to calculate the ALPs and DAFs independently.

The current process of producing ALP or DAF depends on a linear regression, but if alternative ways of producing them exist, this process can be refined to form a more sensitive and adaptable parameter.

[1] https://www.gasgovernance.co.uk/sites/default/files/ggf/book/2020-12/NDM%20Algorithm%20Consultation%20Conclusions%20%2801%20December%202020%29.pdf

Workgroup reviewed the calculation for Unidentified Gas (see Figure 3):

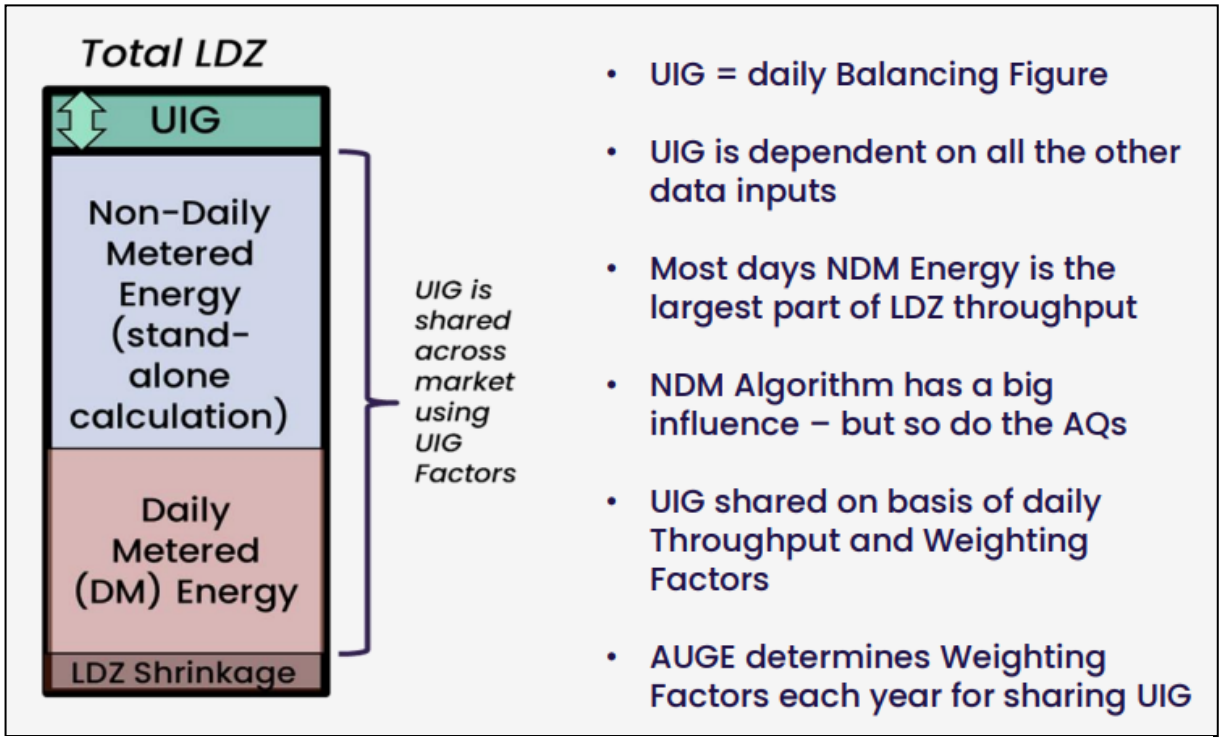


Figure 3: UIG composition

Workgroup briefly reviewed the recommendations produced by the UIG Task Force (these can be viewed here. Those specific to Machine Learning and the NDM Algorithm are 13.2.5, 13.2.6, 13.2.7 and 13.2.8.

Outcome of Workgroup meeting 1:

Areas to investigate

1. Investigate use of advanced analytics to:
    a. Improve the validation processes of NDM sample gas consumption to identify erroneous supply meter points
    b. Improve the 'infilling' of missing data
2. Investigate use of advanced analytics to review the appropriateness of the existing EUC definitions
3. Investigate use of additional data items on Supply Point Register for use in derivation of EUC definitions and production of Demand Models
4. Investigate use of advanced analytics to enhance further the weather vs demand relationship
5. Investigate use of advanced analytics to trial alternative approaches for producing more accurate EUC demand models.

Resourcing/Assistance from Workgroup

Workgroup Participants volunteered their expertise but noted they were all limited by operational constraints and were unable to provide any further 'manpower' resource towards carrying out the analysis required. This meant that all of the analysis for the Request would be provided by CDSP and the timescales and scope were likely to be based upon this, noting existing commitments of the Demand Estimation team on BAU activities to support DESC.

Workgroup Participants confirmed results are more likely to be accepted if they are carried out by an impartial industry participant (CDSP).

Approach

The Workgroup should proceed with analysis as an "academic exercise" and not be distracted at this stage with potential implementation issues, unless identified as obvious 'non-starters' by the Workgroup

More focus should be directed on the Winter period when volumes are at their highest.

Larger Data sets

Workgroup were keen to make use of data from Smart Meters and AMR, aiming to improve the level of granularity.

Data from the Data Communications Company (DCC) could be obtained in an anonymised form but to use this data, the CDSP would need specific data for each meter point such as its geographical area, meter type etc. This may mean it is difficult to anonymise.

Access to the relevant DCC volume data is restricted, as currently Smart Energy Code Section E states CDSP is entitled to see registration details only (see 2nd March 2022 DESC minutes)

Scope

Workgroup confirmed the Request objective would not include advocating transfer of sites with Smart and AMR meters to Product Class 2. This may be pursued by another means.

Workgroup amended the overall objective from "To investigate use of advanced analytics to improve the NDM Demand Modelling" to the new objective as follows:

- To investigate improvements to NDM Demand Modelling.

Outcome of Workgroup meeting 2 (May 2021):

CDSP reported on their background assessment of the potential areas of investigation and suggested a focus on 3 areas

- Area 1: Trial alternative approaches to deriving SND_t
- Area 2: Improve Validation Processes
- Area 3: Review End User Category definitions

For each area, where appropriate, the stated approach was to utilise advanced analytic investigations focusing on 1 or 2 LDZs with a report back to the Workgroup before deciding on wider coverage (i.e. more LDZs)

The success criteria will be primarily based on

1. Reducing modelling error
2. Subsequent reduction in UIG (temporary) and
3. Minimal impacts to simulated peak demand – statistical measures to be confirmed with Workgroup

Area 1: Trial alternative approaches to deriving SND_t

Objective:

- Explore alternative advanced analytic modelling approaches to identify whether a more accurate view of deriving SND_t can be produced and with it the subsequent ALPs, DAFs and PLFs.
- Identify any weaknesses, improvements and make recommendations which link to evidence of a reduction in NDM modelling error

Two potential routes for this approach were identified:

- Time Forecasting (e.g. ARIMA) Neural Network (this relates to UIG Task Force 13.2.6 and 13.2.7[2])
- Amendments to existing approach e.g. dummy variables for month, Individual day of the week

Area 2: Improve Validation Processes

The current validation process was reviewed in some detail to determine the Objective which was defined as follows:

- Explore use of advanced analytic techniques to improve validation routines prior to modelling
- Identify any weaknesses, improvements and make recommendations which link to evidence of a reduction in NDM modelling error

Three potential routes for this approach were identified:

1. Investigate latest data cleansing techniques/scripts
2. 'Uncertainty Estimation' (this relates to UIG Task Force 13.2.8[3])
3. Compare current post validation results to revised methods - both 'infill' approach and ability to identify suspicious demand patterns

Area 3: Review End User Category (EUC) definitions

EUCs and the breakdown of throughput for the period Gas Year 2019/20 was examined; Band 01 appeared to offer the area where the biggest potential for improvement could be seen with a focus on 01BND and 01BPD. The objective in Area 3 was defined as:

[2] UIG Task Force 13.2.6 https://www.xoserve.com/media/4096/1326-accuracy-of-ndm-algorithm-advanced-machine-learning.pdf
UIG Task Force 13.2.7 https://www.xoserve.com/media/41848/1327-accuracy-of-ndm-algorithm-advanced-machine-learning-options.pdf
[3] UIG Task Force 13.2.6 https://www.xoserve.com/media/4096/1326-accuracy-of-ndm-algorithm-advanced-machine-learning.pdf
UIG Task Force 13.2.8 https://www.xoserve.com/media/41849/1328-accuracy-of-ndm-algorithm-estimation-uncertainty-and-sample-set-validation.pdf

- Review the current line up of 39 End User Categories (EUCs) per LDZ and explore whether a more appropriate set of definitions and models exist.
- Identify any weaknesses, improvements and make recommendations which link to evidence of a reduction in NDM modelling error.

Three potential routes for this approach identified:

1. Cluster Analysis to identify 'more suitable' profiles
2. Review reconciliation data for EUCs as a method for assessing error ? e.g. how does reconciliation % compare across EUC Bands
3. Re-run Demand Attribution assuming Higher EUC Bands (e.g. 7,8) were Daily Metered.

At Workgroup in May 2021, CDSP reviewed the data sets available with Workgroup, explaining what was felt to be useful. The Workgroup discussed the availability of data, the age of the data, access to meter point and pre-payment data from Shippers and how this cannot be obtained directly through DCC. The systems setup and approach was also discussed in some detail with Workgroup Participants agreeing with the proposed approach to use SAS Enterprise Miner and SAS for Demand Estimation Modelling.

Outcome of Workgroup meeting 3 (July 2021):

Workgroup discussed the success criteria, agreeing this should be primarily based on reducing modelling errors.

Area 1

Workgroup agreed to focus on End User Categories (EUC):

- 01BND - Domestic model, representing nearly 90% of NDM supply points
- 02BNI – I&C Model, representing the second largest I&C consumer group within the Small NDM AQ range (0 to 2,196 MWh pa)
- 05B – I&C Model, representing the largest I&C consumer group within the Large NDM AQ range (2,196 to 58,600 MWh pa)

Workgroup agreed to focus on the following trial LDZs as these were felt to represent the total population well for the initial trial runs:

- North West (NW) and
- South East (SE).

Data availability was felt to be enough for the tasks envisaged at this stage.

Workgroup agreed with the following Success Criteria:

- Reduce Demand Modelling Error, particular during the higher volume periods in October to March. It was recognised there needed to be a consideration of the tradeoff between model accuracy and volatility;
- Reduction in temporary Unidentified Gas volumes, to reduce errors; and
- To minimise impacts to simulated peak demand, maintaining Peak Load Factors and Peak Day Demand (SOQ) levels.

Outcome of Workgroup meeting 4 (Oct 2021):

Workgroup agreed to request an extension to the reporting timeline so that the Workgroup could report to Panel in November 2022 or earlier if possible. This would allow the resource for Demand Estimation to do both the BAU work supporting DESC and the work required for this Request Workgroup 0754R.

The CDSP presented the initial findings noting the following assumptions:

- COVID years have been excluded from input as they made the models worse
- The data period used in the analysis is from April 17 to March 20
- The data used in the analysis is the sample data collected for modelling
- A method for standardising Sample data was required to allow training over multiple years
- A 3-year history was used as an alternative to model smoothing

Area 1 initial results

Machine Learning was used as well as tweaking parameters in the current modelling system, to understand the significance of different factors. The following approaches were investigated (see Figure **4**).

Approaches Tried	Description
Existing Model, Holidays included (all EUCs)	Opposite of current model (hols excluded). Examine significance of holidays on ALP
Existing Model, Summer Warm weather exclusion	To examine the significance of the warm weather exclusion i.e. allowing more warmer days into the models.
Machine Learning Regression	Both logistical and linear regression
Machine Learning Neural Networks	This is a Machine Learning method using a series of algorithms that work to understand the relationships between the data inputs (to emulate the way a brain operates)
Machine Learning Gradient Boosting	A Machine Learning method which produces a prediction model based from an "ensemble" of models
Additional Parameters	Adding data not currently used such as calendar month and additional weather information

Figure 4: Area 1 initial approaches tried

Area 1 Modelling Progression

The following methods were tried: Logical regression, machine learning linear regression, gradient boosted with various improvements.

Gradient boosted was found to give the closest forecast to actuals (based on MAPE – Mean Absolute Percentage Error). Gas year 2018-2019 was used for scoring the models as this had no COVID impact skewing the results.

Initial results using data from 01/04/2017 and 31/03/2020 suggested Neural Networks had the poorest performance in the training of the data (although fine tuning parameters may bring improvements). The gradient boosting method generally showed the best MAPE values from all the runs (MAPE values 0.9% - 2.2%. For all results presented please see slides presented at Workgroup: https://www.gasgovernance.co.uk/0754/051021).

ALPs were calculated for all 5 methods (see Figure 5), DAFs were calculated for some.

Area 1 Deliverables Methods Tried	ALP	DAF	Indicative Peak Load Factor
Existing Model Holidays included (all EUCs)	✔	✔	To be looked at later in process
Existing Model, Summer Warm weather exclusion	✔	✔	To be looked at later in process
Machine Learning Regression	✔	**Method unknown at present**	To be looked at later in process
ML Neural Networks	✔	**Method unknown at present**	To be looked at later in process
Machine Learning Gradient Boosting	✔	**Method unknown at present**	To be looked at later in process

Figure 5: Modelling Methods Tried

Indicative Peak Load Factor was not yet calculated and it was decided this would be looked at later in the process.

A number of areas were found where the newly calculated ALP differed from the published ALP:

- Bigger peaks and troughs with the calculated ALP
- Actual consumption does experience peaks and troughs, the challenge is separating 'normal' from the idiosyncrasies of the input data
- The calculated ALP has not reduced consumption in the May holiday period
- The calculated ALP has put a reduction in late June.

The results of Gradient Boosted ALP as compared with Neural Network model ALP for NW01BND and NW05B showed some unexplained areas, which Workgroup agreed should be investigated further.

Area 1 Challenges from the Model Development phase

These are summarised in Figure 6.

Challenges	Comment
Machine Learning methods produce a target value (in this case energy)	The ML techniques produce an "energy" figure which can be used to calculate an ALP. The is no obvious way of producing a weather correction and therefore a DAF or ILF value (still being investigated)
Current Modelling output i.e. Day of week, holiday factors, ILFs, Modelling Parameters	No obvious way of providing these outputs from Machine Learning (still being investigated)
Describing the outcome (metrics) of the models runs.	Some of the Machine Learning result metrics don't give a view of whether the ALP is reflective.
Understanding days with coexisting Holiday and weekend effects.	The Machine Learning models are overlapping weekend and holiday effects where they occur together. (Current modelling system gives preference to holiday factors)
Machine Learning is a 'Black Box' process	Unless we can get a clear ALP and DAF from the process there is difficulty applying the results to the population

Figure 6: Model development challenges

Further work in preparation for Workgroup meeting 5 was discussed and agreed with Workgroup, to cover:

- To investigate / develop a weather correction (DAF) methodology for the models.
- To further refine the models, including whether different methods will suit different EUCs.
- To understand how to describe to the group the model principles and the metrics for assessing them (assuming they will require different explanation / support information to the current method (for example alternatives to R^2 and ILF values).

Outcome of Workgroup meeting 5 (Nov 2021):

Workgroup discussed the two areas of focus (which were interim rather than final results):

- Improvement to models (including further investigation into previously visited methodology such as Neural Networks)
- Delivering DAFs and Load Factors (these are fundamental as they present a risk to not being able to deliver a Machine Learning solution).

Introduction to Gradient Boosting

The CDSP explained that boosting is an ensemble learning method that combines a set of weak learners into a strong learner to minimize training errors. In boosting, a random sample of data is selected, fitted with a model and then trained sequentially — that is, each model tries to compensate for the weaknesses of its predecessor. With each iteration, the weak rules from each individual classifier are combined to form one, strong prediction rule. Gradient boosting trains on the residual errors of the previous predictor. The name, gradient boosting, is used since it combines the gradient descent algorithm and boosting method.

Introduction to Neural Networks

The CDSP explained that neural networks, also known as Artificial Neural Networks (ANNs) or Simulated Neural Networks (SNNs), are a subset of machine learning and are at the heart of deep learning algorithms. Their name and structure are inspired by the human brain, mimicking the way that biological neurons signal to one another. Artificial Neural Networks (ANNs) are comprised of node layers, containing an input layer, one or more hidden layers, and an output layer. Each node, or artificial neuron, connects to another and has an associated weight and threshold. If the output of any individual node is above the specified threshold value, that node is activated, sending data to the next layer of the network. Otherwise, no data is passed along to the next layer of the network.

Workgroup heard that little success had been found with the full Neural Network approach, however combining a Neural Network with Generalised Linear Modelling had produced relatively good results.

Four Neural Network approaches were chosen for model verification:

- Multilayer - default
- Generalised Linear Model (GLM)
- Ordinary Radial (Equal width)
- Ordinary Radial (unequal width).

Both looking at the shape of the forecast and comparing the value of the residuals gave a good indication of which models were worth moving forward with.

The Neural Network method produced a much smoother ALP than the Gradient Boosting method with fewer unusual spikes (see slides presented to Workgroup 5 here: https://www.gasgovernance.co.uk/0754/301121).

Various incremental changes in the DAF calculation using Machine Learning and comparisons were shown and discussed at Workgroup, with more to investigate before Workgroup 6.

Assessing model error was done by assessing sample data against the following profiles:

- Current Approach ALPDAF
- Neural Network ALPDAF (GLM model)
- Gradient Boosting ALPDAF.

Workgroup agreed good progress had been made with calculating ALPs and DAFs and the results are fair compared to the live model. With good results from Neural Networks, the next stage was to look at adding in additional factors and tweaking the modelling methodology to see if results could be improved so activity could move into the Test Cycle.

Outcome of Workgroup meeting 6 (March 2022):

Area 1

Workgroup discussed the progress since the previous meeting on the following areas:

- Overview of Indicative Load Factor (ILF) calculations for the two Advanced Analytics approaches being trialled
    - NNGLM – Neural Network Generalised Linear Model (best result)
    - GBASE – Gradient Boosted model.
- Comparison with Live Models for the two approaches above with a focus on assessing trends by
    - Day of the Week (DOW)
    - Month
    - Holidays.

As before, the data was 01BND, 02BNI and 05B with both NW and SE LDZs.

The results from the Gradient Boosting method required further investigation, with a focus on the Peak Demand calculation.

As result of work to further understand the models and their characteristics, the comparison with live models led to more investigation being required into Day of the Week trends for 02BNI and 05B datasets.

Area 2

For Area 2 the Workgroup heard an introduction and confirmation that the focus would be on using Advanced Analytics to ensure the validation of the Sample data to produce quality inputs for the models. An initial area was utilisation of Machine Learning (M/L) to enhance the existing validation routines to help identify suspicious demand patterns in assessing sample MPRs. Uncertainty Estimation, as suggested by the UIG Task Force (https://www.xoserve.com/media/41849/1328-accuracy-of-ndm-algorithm-estimation-uncertainty-and-sample-set-validation.pdf) was agreed to be used.

Outcome of Workgroup meeting 7 (July 2022):

Area 2

Workgroup began by discussing the Current Validation Process. The current validation process attempts to filters out all errors in data that has been submitted. This happens whilst also ensuring that sufficient sample numbers are maintained for modelling. The current validation rules were originally designed when there were smaller datasets and technology / computers were less capable than they are now. The situation has moved from having two or three suppliers of data to over 20, which, on the positive side, has provided extra data to sample from but the challenge is with data quality and inconsistency between providers.

As an example, Workgroup heard that for the (current) Spring 2022 modelling validation outcomes, an initial sample of over 58,000 MPRs was decreased via validation to the final sample size of 3,000 (after stratification).

The following approaches were identified:

- Uncertainty Estimator: UIG Task Force validation suggestions (UIG Task Force 1328)
- Individual MPR Regression: Use of computer processing capability to target individual MPRs patterns – regression test Monday to Thursday for each MPR for high level pattern

- Winter Zero Consumption: Analysis of the number of zero consumption in the winter period, December to March) (i.e. targeting questionable patterns).

Uncertainty Estimator

This involved looking at assessing how an individual meter point demand pattern compares with a pattern of the wider EUC. Workgroup heard that, after some investigation, it appeared to be a useful technique which could be employed in validation to identify unusual demand patterns and or issues with data held on the Supply Point Register. The process still needs some refinement to produce similar output to that obtained by the UIG Task Force e.g. the distribution is not correct yet and needs some additional work. Other EUCs were to be tested to see if this technique could be used for them too.

Individual MPR Regression

Advanced Analytics applications and processing power capability has allowed the investigation of the underlying patterns for individual MPRs in large volumes. Taking the core Monday to Thursday data points, these can be used to look at the underlying demand vs weather pattern for each MPR. EUC 01BND has been assessed with the principal assumption that the data points should show an inverse relationship between weather and demand. This was questioned, was this true in the case of cooking only loads etc.? For all EUCs, as knowledge and analysis is built up, traits for specific EUCs could become evident. This could also help in identifying potential new EUC groupings (based on these traits).

The approach / hypothesis was that for 01BND models, they will generally have a strong relationship to weather, based on R^2 values; there were a reassuring number of sites which showed a strong demand to weather relationship. The second check looked at the CWV intercepts with a reassuring number of sites which showed a positive CWV intercept. Several of the sites with the suspicious (and negative CWV intercepts) were investigated and found to also have very low R^2 (suggesting the two methods complement each other).

In summary, Workgroup heard and agreed that the MPR regression test highlighted instances of MPRs which, although passing initial validation, required some further investigation. These checks were conducted soon after this years' sample data had been validated. Of the sites that had a negative CWV intercept, 17 that were investigated remained in the modelling datasets. These were removed prior to running the modelling. It appeared that this test could also be used to highlight where a different EUC sub-band profile may exist, or incorrect records were held on the Supply Point Register. The test may be improved to focus on other areas, e.g. weekend effects.

Winter Zero Consumption

While investigating techniques supporting validation, several of the MPRs identified in the previous two tests had a high amount of zero consumptions. It was felt that these might provide additional insight into unrepresentative demand patterns and highlight MPRs for further investigation.

The analysis shared should help gain insight in future on which MPRs seem unrepresentative of their EUC and so improve the EUC demand model performance. In addition, the checks could also potentially reveal different 'EUC groupings' outside of the current definitions used by the industry.

Each Summer, DESC confirms its 'Adhoc Workplan' which is effectively a list of items it would like to investigate further ahead of the next year's modelling cycle. One of the proposed items for the forthcoming year is to look at the current validation rules and techniques. Pending the results of the DESC discussion of their 'Adhoc Workplan' later in the month, the CDSP explained that they would expect to use the techniques discussed at Workgroup 6 in future validation runs and also in any

analysis investigating the appropriateness of EUC groupings. The proposal would be included as a new agenda item for consideration at the 19 July 2022 DESC meeting.

Workgroup briefly discussed whether any insight from the Workgroup on validation / cleansing routines used within Shipper organisations would benefit / be suitable to the Demand Estimation modelling process and a couple of Parties offered to liaise offline to do share findings.

Area 1: Trial Alternative approaches to deriving SND_t

Workgroups heard a summary of key takeaways from Area 1 analysis to date. Industry consultation carried out prior to Workgroup being established confirmed that access to demand models and parameters (i.e., ALPs and DAFs) ahead of the Gas Year was still a key requirement. The CDSP – Demand Estimation team's understanding of alternative Advanced Analytic options available for Demand Modelling has been enhanced e.g., the shortlisted approaches of 'Neural Network' and 'Gradient Boosting' have been used for analysis presented to the Workgroup. The results from these alternative approaches have revealed areas where the current modelling approach could be improved e.g., treatment of days of the week. One of the key tests is 'Has the modelling error reduced'? and although in some categories, improvements have been observed, overall, there has been no 'breakthrough' when compared with the current approach.

Workgroup Conclusion

DESC's 'Adhoc Workplan' has now been agreed to pick up 'Areas 2 and 3' within its annual cycle and this year the CDSP will be proposing a review of current validation rules and how techniques shared as part of this Workgroup to improve EUC demand modelling can be used. In addition, the CDSP will also be proposing a review of EUC definitions which again can be achieved using some of the Advanced Analytic techniques learned as part of this Workgroup.

Area 1 analysis (machine learning etc.), although providing useful insight, has not revealed a clear alternative approach to the existing demand modelling process, given the requirement to maintain ALPs, DAFs and PLFs.

- Workgroup was pleased that the work undertaken as part of 0754R will be used to enhance the BAU validation process via DESC.
- Workgroup looked forward to CDSP proposals to review EUC definitions. This topic has been added to DESC's Adhoc Workplan in late July 2022 with analysis due to be discussed at October, December 2022, and March 2023 DESC meetings.
- Workgroup finalised the Workgroup Report at its last meeting in September 2022 and will submit the Workgroup Report to Panel in October, recommending the Workgroup be closed.

At its next meeting (05 October), DESC will discuss the current performance of the demand models in the current unprecedented climate of very high energy prices and what has been termed "demand destruction" and recent high (negative) UIG values. This discussion may lead to consideration of further options to address the reactivity of the combined workings of the demand model.

Workgroup Participants noted that the CDSP has provided the analytical resource for the work done, whilst the range of Workgroup Participants over the duration of the Workgroup has been perhaps limited by operational constraints. This has meant that the timescales and scope have been set

accordingly. This may be related to a general resourcing issue which perhaps points to a need for a step change in the way industry handles such changes in future.

Workgroup Participants noted that the DESC team has made significant advances in its understanding of the range of techniques available and the potential for their utilisation in relation to demand modelling. There could have been more challenge and review of alternative ideas and routes to solve the problem but unless this is offered by many Parties, the pragmatic solution has been to have the in-house CDSP team provide the majority of the resource and grow a more exploratory and wider mindset.

The Proposer noted that the role of Code Manager would cover this type of work, funded by the whole industry and providing an independent pool of resource. Workgroup Participants noted that there is less familiarity with the concept and the scope of a Code Manager.

Workgroup noted that in future the space to explore these alternatives would need to be provided through DESC, including a workplan that has longer term areas of investigation, utilising more of a strategic capability.

5 Modification(s)

None required. The cooperative nature of the Workgroup has meant that the Areas 2 and 3 can be translated straight away into DESC's workplan for the coming Gas Year.

Workgroup noted that in future the space to explore these types of alternatives would need to be provided through CDSP and/or DESC, including a workplan that has longer term areas of investigation, utilising more of a strategic capability.

6 Recommendations

Workgroup's Recommendation to Panel

The Workgroup asks Panel to agree that this Request should be Closed.