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SGN PCD BIOMETHANE BLENDING STUDY: REDACTED EXAMPLE

EXECUTIVE SUMMARY

BACKGROUND

SGN have commissioned Dave Lander Consulting Limited to perform a blending study for x existing biomethane injection points on their gas distribution networks. The project is part of an SGN Price Control Deliverable (PCD) project “Biomethane Improved Access Rollout”, which is aimed at reducing the quantity of propane employed in enriching biomethane to meet the calorific value requirements of the Gas (Calculation of Thermal Energy) Regulations. A reduction in propane enrichment can be achieved by blending biomethane with higher CV natural gas flowing past the injection point and the PCD biomethane blending studies are to provide an estimate of the potential reduction for ten existing biomethane injection projects.

This blending study is for the site A biomethane injection site, at which Site A inject biomethane into SGN’s medium pressure gas distribution system at a site located near A Town.

CONCLUSIONS

a) Under the SNT LDZ demand scenario, annual propane consumption with blending could fall from around 998 tonne/y to around 579 tonne/y, a saving of around 420 tonne/y (42.0 %). Under the Cold and Warm LDZ demand scenarios, savings of around 551 tonne/y (55.2 %) and 272 tonne/y (27.2 %), respectively, could be achieved

b) Reducing propane enrichment has the added benefit of permitting a larger quantity of (unenriched) biomethane to be injected and under the SNT LDZ demand scenario annual biomethane injection increased from 14.366 million m^3 to 14.587 million m^3 – an increase of 0.221 million m^3 (1.5 %). Under the Cold and Warm LDZ demand scenarios an additional 0.290 million m^3 and 0.143 million m^3, respectively, of biomethane could be injected.

SGN PCD BIOMETHANE BLENDING STUDY: SITE A

1 INTRODUCTION

SGN have commissioned Dave Lander Consulting Limited to perform a blending study for x existing biomethane injection points on their gas distribution networks. The project is part of an SGN Price Control Deliverable (PCD) project “Biomethane Improved Access Rollout”, which is aimed at reducing the quantity of propane employed in enriching biomethane to meet the calorific value requirements of the Gas (Calculation of Thermal Energy) Regulations. A reduction in propane enrichment can be achieved by blending biomethane with higher CV natural gas flowing past the injection point and the PCD biomethane blending studies are to provide an estimate of the potential reduction for x existing biomethane injection projects.

This blending study is for the Site A biomethane injection site, at which Site A inject biomethane into SGN’s medium pressure gas distribution system at a site located near A Town. The biomethane is produced by upgrading biogas derived from anaerobic digestion of a mixture of cereal grain (maize and wheat) grass and sugar beet. The plant is designed to produce 1700 m^3/h of biomethane for injection into SGN’s distribution system. Injection is into a 7 barg local gas Intermediate Pressure (IP) distribution system.

2 AIMS AND OBJECTIVES OF THE BLENDING STUDY

The aim of the blending study is to assess options for blending of biomethane with natural gas and estimate the minimum quantity of propane needed to ensure CV requirements are maintained. The objectives are as follows:

a) To establish the demand and gas composition of natural gas available for blending.
b) To establish for the relevant LDZ the maximum lowering of natural gas calorific value that can be achieved without introducing capping of the daily Flow Weighted Average CV for that LDZ.
c) To establish the flowrates of biomethane that can be injected consistent with avoidance of capping.
d) To estimate the propane requirement to ensure biomethane injection at the agreed injection rate throughout the gas year by utilising the maximum blending potential, and hence the reduction in propane requirement that could be achieved.

3 REGULATORY BASIS OF BLENDING OF UNENRICHED BIOMETHANE

The regulatory basis of blending rather than enrichment of biomethane is paragraph (b) of Regulation 4A(1) of the Gas (Calculation of Thermal Energy) Regulations (the GCOTE Regulations, as amended 1997). Under normal circumstances the daily charging area CV (calculated as the flow weighted average of the daily CVs of each input to Scotland LDZ) is capped to no more than 1 MJ/m^3 greater than the lowest daily average CV of the inputs. However, 4A(1) paragraph (b) permits application of the cap to the daily average CV of a co-mingled point, provided it can be shown that no gas is conveyed to consumers before co-mingling.

In essence, therefore, although the daily energy and daily volume of biomethane flowing into SGN’s system is included in the calculation of the daily FWACV for the LDZ, the daily average CV of biomethane would not be the reference point for capping of the FWACV and instead the reference point would be the CV at the co-mingled point. The constraint on SGN is therefore the CV at the co-mingled point, and this will be dictated by the CVs of the biomethane and blending gas, as well as the proportion of biomethane at the co-mingled point.

It is likely that Ofgem will require demonstration that the CV at the co-mingled point is sufficiently high enough to avoid CV capping and essentially this will dictate that CV is measured at a suitable co-mingling point and telemetered to a central location[1].

4 INJECTION LOCATION

For this study a biomethane flowrate of 1700 m^3/h into SGN’s MP system was assumed. Bi-directional flow is not considered likely with the network configuration. The relevant LDZ is the LDZ.

[1] Currently, calculation of FWACV and management of capping is carried out by National Grid Gas, but this duty will be transferred to Xoserve at some point in the future.

5 METHODOLOGY

The study employed an Excel spreadsheet that models the blending/enrichment process in order to estimate the propane enrichment required in order to meet two key constraints:

a) The maximum biomethane injection flowrate
b) The CV of the biomethane – natural gas – propane mixture at the comingled point must not be less than a target CV set by SGN. The degree of blending (and hence the reduction of propane enrichment) is dependent upon flowrate of natural gas past the injection point and hence on the energy demand downstream of the injection point.

The model calculates propane requirement at hourly intervals over a 365 day period. For all of the PCD blending studies the period was agreed to be 01/01/1900 to 31/12/1900. Hourly propane requirements can be summed to provide daily or annual propane consumption either with blending or in the absence of blending (i.e., propane enrichment so as to ensure the biomethane – propane mixture meets the target CV.

A detailed description of the blending/enrichment model is provided in Appendix A.

6 RESULTS AND DISCUSSION

6.1 ANNUAL CONSUMPTION OF PROPANE

Estimated annual consumption of propane with and without blending is shown in Table 1 for the three LDZ demand scenarios.

Table 1: Annual consumption of propane with and without blending for three LDZ demand scenarios

LDZ demand scenario	Without blending, tonne/y	With blending, tonne/y	Saving, tonne/y	%
Cold	998.47	447.38	551.09	55.2 %
SNT	998.47	578.74	419.74	42.0 %
Warm	998.47	726.63	271.85	27.2 %

Propane consumption without blending is independent of the chosen LDZ demand scenario because it is dependent only by the (fixed) contracted biomethane flowrate and the target CV, which are independent of LDZ demand scenario.

The results in Table 1 assume that the contracted biomethane flowrate is for the enriched biomethane and hence includes propane (should any enrichment be required).

Also shown in Table 1 is the expected saving in propane use. As might be expected, greatest saving occurs for the Cold scenario, when demand and hence availability of blend gas is greatest. SGN have averaged recent historical demand and in general, recent overall demand tends to approximate the SNT scenario, so the propane savings are likely to be around 420 ±130 tonne/y, i.e., the SNT scenario, with uncertainty indicated by the Warm and Cold scenarios.

6.2 WITHIN-YEAR PROPANE USE

Figure 1 plots daily propane use with and without blending for the SNT LDZ demand scenario and Figure 2 plots daily propane use with blending, together with injection point daily demand, for the SNT LDZ demand scenario.

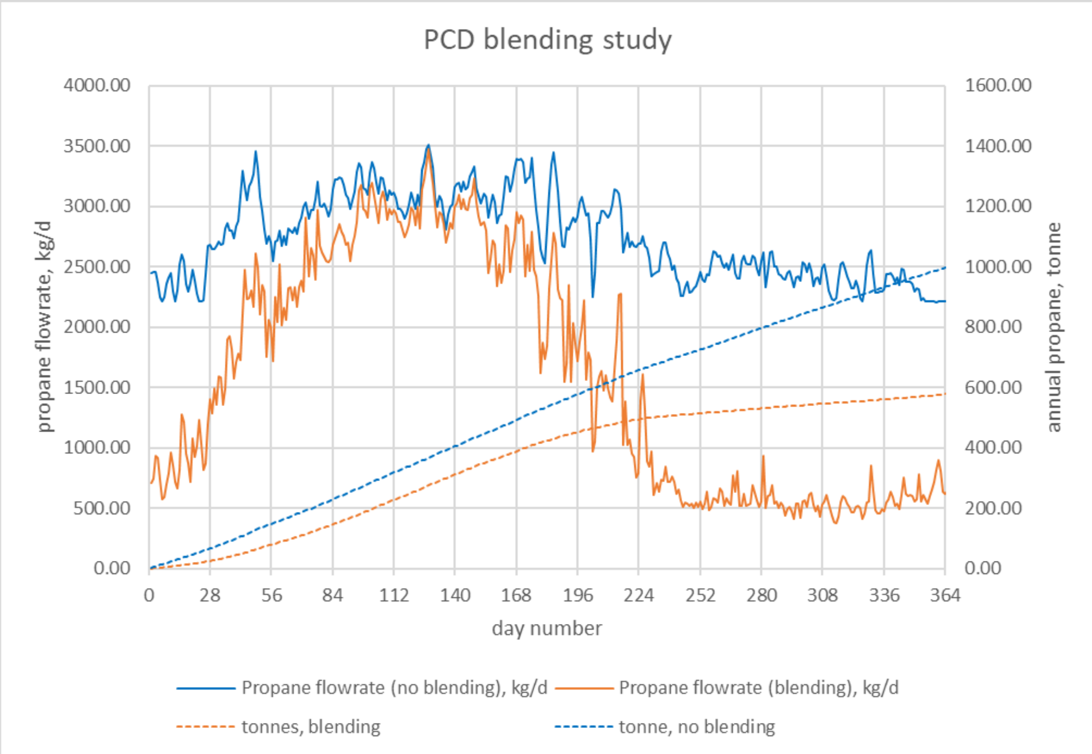

Figure 1: Plot of daily propane use with and without blending for the SNT LDZ demand scenario. The dotted lines show cumulative use.

As expected, propane use is greatest in the summer months, when demand is lowest and propane use is close to that without blending. For reference, day 56 in Figure 1 corresponds to 26/05/1900.

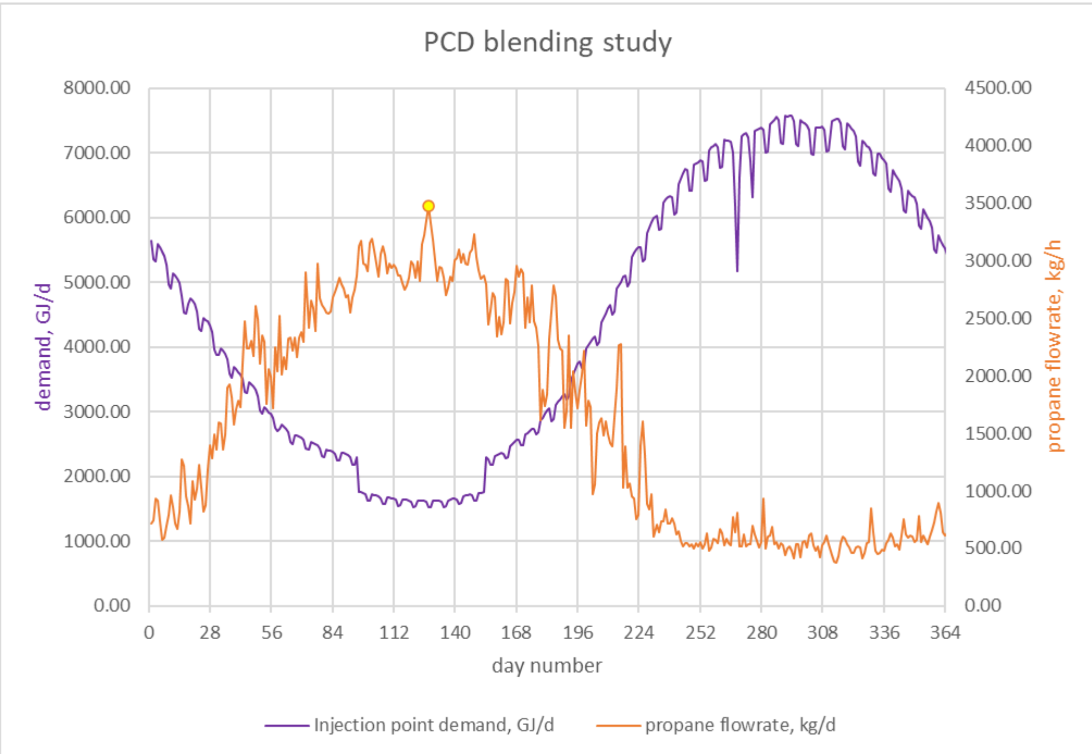

Figure 2: Plot of daily propane use with blending and daily injection point demand for the SNT LDZ demand scenario

6.3 ANNUAL BIOMETHANE INJECTION

Reducing propane enrichment has the added benefit of permitting a larger quantity of (unenriched) biomethane to be injected, Table 2 shows the annual volume of biomethane injected under the three LDZ demand scenarios.

Table 2: Annual volume of biomethane injected with and without blending for three LDZ demand scenarios

LDZ demand scenario	Without blending, million m^3/y	With blending, million m^3/y	Increase, million m^3/y	%
Cold	14.366	14.656	0.290	2.0 %
SNT	14.366	14.587	0.221	1.5 %
Warm	14.366	14.509	0.143	1.0 %

6.4 BLENDING GAS CV

Daily propane use can vary significantly from day to day and in general this variation is because of the variation in the difference between the CV of the blend gas and the target CV. When this difference is low, blending is less effective, and more propane enrichment is required. For Site A, blending gas CV was almost always (99.9% of the time) higher than the target CV for the chosen period for the study. Note that the study makes no allowance for transit time for blend gas exiting the NTS and arriving at the biomethane site. If this were significant it is possible that high CV gas exiting the NTS could influence the FWACV (and hence increase SGN's target CV) when blending gas at the biomethane site is low. This is shown in Figure 3 below. A delay of ca. four days would result in blend gas CV at the injection site being lower than the target CV.

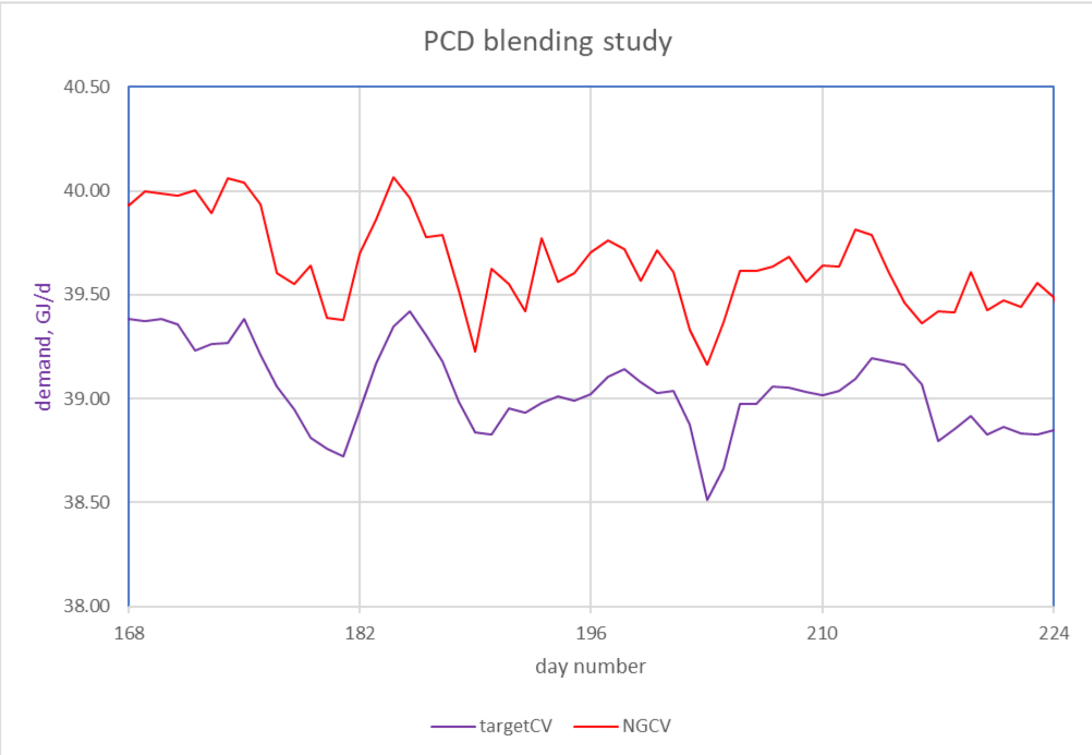

Figure 3: Plots of daily average CV of blend gas and target CV.

Blending gas for almost all of the period of assessment is assumed to be supplied from Z NTS offtake and changes in the CV of gas fed through this offtake tends to coincide with changes in the flow-weighted average CV (FWACV) and the target CV.

No correction for time of flight between Z NTS offtake and Site A was carried out for the blending studies because the time of flight correction is most likely to be demand dependent, and also, periods when blending gas CV is close to the FWACV (and hence target CV) are likely to matched by periods where blending gas CV is much higher than FWACV (and hence target CV). On average, therefore, blending gas CV will be close to the FWACV and the main driver for propane consumption and savings is the difference between Target CV and FWACV. SGN policy is for this difference to be around 0.6 MJ/m^3, and whilst increasing this difference would increase propane savings, it would be at increased risk of triggering a cap in billing CV.

6.5 OPERATION MODE

Figure 4 shows the operating modes expected for Site A, indicating the number of hours in each operation mode for each day of the 365-day period.

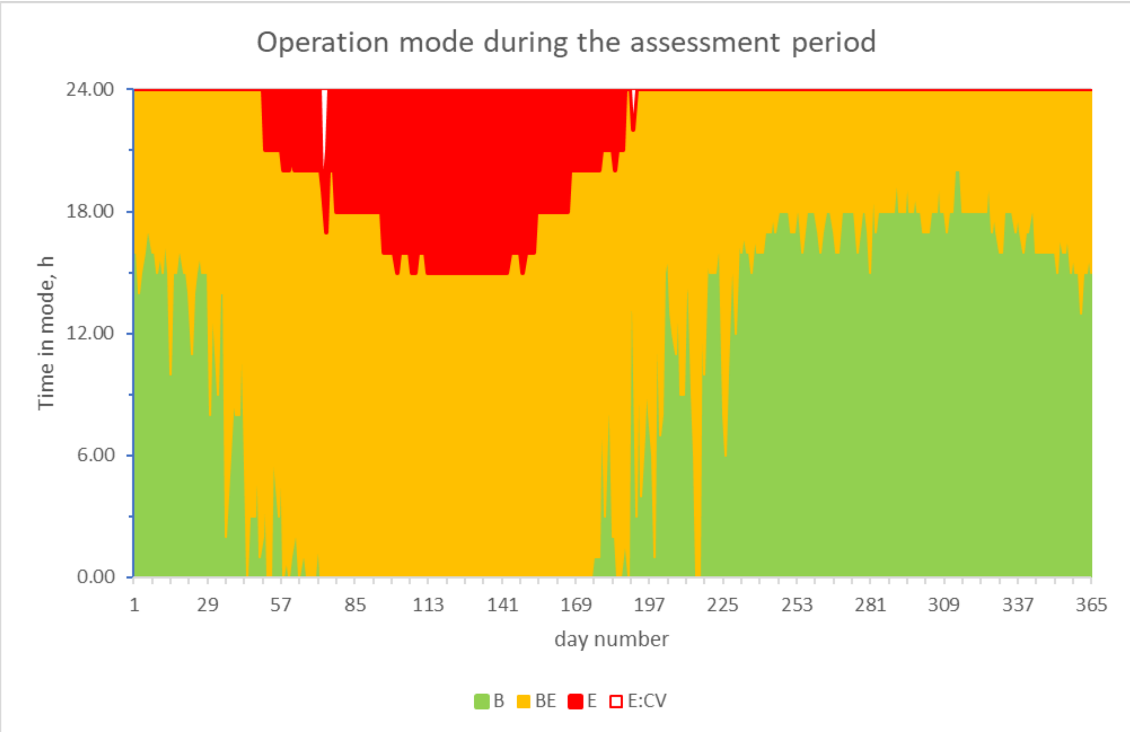

Figure 4: Stacked area chart showing the number of hours in each operation mode for the 365-day period studied.

Blending without propane enrichment ("B") was possible for 25.3 % of the 365-day period studied. The most frequent operating mode (59.5% of the 365-day period) was "BE", i.e., mixed blending and enrichment. Full enrichment only with no blending occurred for 15.0% of the period. Full enrichment was predominantly because of low demand; full enrichment because blending gas CV lower than target CV contributed just 0.1% of the period studied.

6.6 INFRASTRUCTURE CHANGES TO PERMIT BLENDING

Two principal changes would be required to accommodate blending at biomethane sites.

Firstly, a suitable Remote Monitoring Point (RMP) would have to be selected and a gas analysis probe inserted, at which the calorific value of the comingled natural gas/biomethane/propane mixture is determined. This point would be the co-mingled point according to paragraph 4A(1) of the GCOTE Regulations.

Secondly, the enrichment control system would have to be modified so as to permit control of calorific value at the RMP after injection, rather than control of the enriched biomethane prior to injection. The degree of sophistication of control may need to be improved, e.g., incorporation of feed-forward elements such as changes in blend gas CV, target CV. In addition, should the CV of the blending gas be lower than the target CV, control of calorific value prior to injection would be required, rather than at the RMP, so as to ensure unnecessary enrichment of blending gas is avoided.

7 CONCLUSIONS

a) A study of blending of biomethane injected at Site A has been carried out for the period 01/01/1900 to 31/12/1900 to estimate the reduction in propane enrichment that might be achievable

b) Under the SNT LDZ demand scenario, annual propane consumption with blending could fall from around 998 tonne/y to around 579 tonne/y, a saving of around 420 tonne/y (42.0 %). Under the Cold and Warm LDZ demand scenarios, savings of around 551 tonne/y (55.2 %) and 272 tonne/y (27.2 %), respectively, could be achieved.

c) Reducing propane enrichment has the added benefit of permitting a larger quantity of (unenriched) biomethane to be injected and under the SNT LDZ demand scenario annual biomethane injection increased from 14.366 million m^3 to 14.587 million m^3 – an increase of 0.221 million m^3 (1.5 %). Under the Cold and Warm LDZ demand scenarios an additional 0.290 million m^3 and 0.143 million m^3, respectively, of biomethane could be injected.

ANNEX A: DETAILED EXPLANATION OF THE BLENDING/ENRICHMENT MODEL

BLENDING/ENRICHMENT MODEL

The study employs an excel spreadsheet that models the blending/enrichment process in order to estimate the propane enrichment required to meet a number of constraints:

a) The maximum biomethane injection flowrate, which for this study is taken to be 1700 m^3/h. The contracted maximum biomethane flowrate agreed between SGN and the biomethane Delivery Facility Operator (DFO) is 1700 m^3/h and includes any propane required for enrichment. Note that this is the maximum flowrate at any time and not an average flowrate; the Network Entry Agreement does not permit higher flowrates at some time of the day to compensate for lower flowrates at other times. Unless otherwise stated, all volumes and volume flowrates are for the real gas at reference conditions of 15°C and 101.325 kPa.

b) The CV of the biomethane – natural gas – propane mixture at the comingled point must be no less than a target CV set by SGN. The comingled point is a point downstream of the injection point at which the CV is determined. The comingled point CV provides a reference point for application of daily charging area CV. SGN set the target CV to below the forecast daily Flow Weighted Average CV with a suitable margin to reduce the likelihood of capping. Typically, this may be Forecast FWACV minus 0.6 MJ/^{3}. Capping occurs at FWACV minus 1.0 MJ/m^3, so the margin is ca. 0.4 MJ/m^3.

c) It is assumed that the SGN will always accept the contracted maximum flowrate of biomethane for the purpose of the model. However, in reality this is dependent on prevailing demand on the network at suitable levels. In periods of low demand, this may mean that line packing operates, i.e., system pressure is allowed to increase to accommodate biomethane injection greater than demand or where SGN agree to network pressure setting changes, the accommodation of greater volumes of biomethane into the network by increasing the zone of influence of the biomethane injection point.

The degree of blending (and hence the reduction propane enrichment) is dependent upon flowrate of natural gas past the injection point and hence on the energy demand downstream of the injection point.

The model calculates propane requirement at hourly intervals over a 365 period. For all of the PCD blending studies the period was agreed to be 01/01/1900 to 31/12/1900. Hourly propane requirements can be summed to provide daily or annual propane consumption either with blending or in the absence of blending (i.e., propane enrichment so as to ensure the biomethane – propane mixture meets the target CV.

CALCULATION OF PROPANE REQUIREMENT

In the blending/enrichment model, propane requirement is calculated from the energy balance for the section of pipeline between the injection point and the comingled point.

Energy flowrate entering the section of pipeline is the combined energy flowrates of natural gas, biomethane and propane, which is equal to the demand downstream of the injection point

$$V_g CV_g + V_b CV_b + V_p CV_p = V_m CV_m = V_m CV_t = d \qquad \text{Equation 1}$$

Where V refers to volume flowrate, CV refers to calorific value and subscripts g, b, p and m refer to natural gas, biomethane, propane and the mixture, respectively. The downstream demand is given by *d*.

The CV of the mixture CV_m is given by:

$$CV_m = (1 - x - y)CV_g + xCV_b + yCV_p \qquad \text{Equation 2}$$

Where x and y are the mole fractions of biomethane and propane in the mixture.

Without blending, the objective is simply to enrich the biomethane to the target CV. Flowrate of natural gas can be ignored and we can simplify Equation 2 to

$$CV_m = (1 - y)CV_b + yCV_p \text{, from which} \qquad \text{Equation 3}$$

$$y = (CV_t - CV_b)/(CV_p - CV_b) \quad \text{Equation 4}$$

In order to estimate propane saving, the model calculates the propane requirement in the absence of blending, i.e., enrichment of biomethane to meet the target CV, which is derived from Equation 4 above.

For the case of blending, however, the objective is to estimate the minimum value of y in Equation 2, i.e., in order to ensure the mixture CV meets the target CV. By setting $CV_m = CV_t$, Equation 2 can be rearranged to

$$CV_t = (1 - x - y)CV_g + xCV_b + yCV_p \text{ , from which} \quad \text{Equation 5}$$

$$x = \frac{[CV_t - CV_g - y(CV_p - CV_g)]}{(CV_b - CV_g)} \quad \text{Equation 6}$$

The procedure adopted is as follows:

a) Establish whether propane enrichment is required by setting *y*= 0 and calculating *x* from Equation 6 and V_b from $V_b = xV_t$(see Equation 1). If V_b is less than the required biomethane flowrate, then enrichment is required.
b) If propane enrichment is required adjust y and re-calculate *x* and V_p, and again check whether V_b equals the required biomethane flowrate. Continue adjusting y until V_b equals the required biomethane flowrate. Adjustment of y was carried out using a simple interval-halving routine.

The propane calculation was implemented in Excel in the form of a User Defined Function. The UDF can be configured to provide propane requirement as volume (of the vapour) or as mass.

Note that in Step b):

- On some (relatively rare) occasions, the CV of the natural gas used for blending was less than the target CV and the above procedure will over-estimate propane requirement because – under this situation – the propane requirement is that required to enrich both the biomethane <u>and</u> the blending gas to the target CV. The UDF therefore checks whether blending gas CV is less than the target CV, and if so, calculates propane requirement under "enrichment" mode, i.e., that given by equation 4.
- If there is very low demand, x and y are such that the natural gas volume flowrate becomes zero (or less) and so the UDF calculates propane requirement under "enrichment" mode.

DATA SOURCES - DEMAND

Hourly demand at the injection point was provided for the 365 day period by SGN and is based on a peak hourly flowrate past the injection point that was predicted for the peak daily LDZ demand under a 1 in 20 LDZ demand scenario. The injection point is the point at which the pipe from the biomethane site connects to the SGN network. Peak hourly flow at the injection point is assumed to occur at 07:00 on each day and at other times is given by 24 hourly factors (F_h):

Table 1: Hourly factors F_h employed by SGN to scale peak hourly demand at the injection point

Time	06:00	07:00	08:00	09:00	10:00	11:00
F_h	0.87	1.00	0.80	0.70	0.65	0.65
Time	12:00	13:00	14:00	15:00	16:00	17:00
F_h	0.65	0.65	0.65	0.82	0.90	0.95
Time	18:00	19:00	20:00	21:00	22:00	23:00
F_h	0.80	0.75	0.70	0.50	0.40	0.30
Time	00:00	01:00	02:00	03:00	04:00	05:00
F_h	0.30	0.20	0.20	0.20	0.23	0.39

The hourly factors in Table 1 are those employed by SGN when performing capacity studies and are assumed not to vary with demand type and hence are conservative (in that they probably under-estimate demand).

Daily peak injection point demand d(peak day, daily, 1in20) under the 1 in 20 LDZ demand scenario was estimated from SGN's supplied figure for peak hourly injection point demand under the 1 in 20 LDZ demand scenario by multiplying by 14.26 (the sum of the individual hourly factors). From this a daily factor (Fd) was estimated to convert from LDZ daily demand to injection point daily demand. This results in the following

$$d(peak\ day, daily, 1in20) = d(peak\ day, hourly, 1in20) \times 14.26$$ Equation 7

$$F_d = \frac{d(peak\ day, daily, 1in20)}{D(peak\ day, daily, 1in20)}$$ Equation 8

Where d relates to injection point demand and D relates to LDZ demand.

The value of d(peak day, hourly, 1in20) supplied by SGN for Site A is 25484.79 m3/h = 1004.59 GJ/h, which gives a value for d(peak day, daily, 1in20) of 14325.44 GJ/d. SGN supplied a value for the LDZ for D(peak day, daily, 1in20) of 1276392.08 GJ/d, which results in a value of the daily factor Fd of 0.011223 (Site A/the LDZ).

Finally, SGN supplied LDZ daily demand data for each day of the year under Cold, SNT and Warm LDZ demand scenarios. These were converted to percentages of D(peak day, daily, 1in20).

Hourly injection point demand on a given day under a given LDZ demand scenario is estimated by:

a) Calculating D(day#, daily, LDZ scenario) from D(peak day, daily, 1in20) and the percentage of D(peak day, daily, 1in20) for the chosen day and LDZ demand scenario
b) Calculating d(day#, daily, LDZ scenario) by multiplying D(day#, daily, LDZ scenario) by Fd
c) Calculating d(day#, hourly, LDZ scenario) by dividing d(day#, daily, LDZ scenario) by 14.26 and multiplying by the appropriate hourly factor for each hour in Table 1 above.

Note that assumption of a constant value for Fd makes the implicit assumption that the biomethane injection location follows the same weather conditions as that for the LDZ as a whole. This may not be appropriate on a particular hour or day, but it is assumed to hold on average over the year. Annual propane usage for enrichment for a given LDZ demand scenario is therefore expected to be more accurate than individual daily or within-day values.

DATA SOURCES - BLENDING GAS CALORIFIC VALUE

Calorific value of the blending gas was taken from calorific value data supplied by SGN for selected NTS offtakes. These data were supplied as 365 daily "Z03" files, which are created daily by the DANINT software on site. Each Z03 file contains a calorific value calculated every 4 minutes or so throughout the gas day and was processed automatically using an Excel macro to calculate hourly averages for each hour of each gas day.

It was assumed that Site A is supplied with gas from Z offtake. Occasionally, gas may not be flowing through Z NTS offtake and in such situations the relevant CV was taken from a single alternative NTS offtake: Y.

Note that no allowance was made for time for blending gas to travel from the NTS offtake to the biomethane injection site.

DATA SOURCES - TARGET CV

SGN provided hourly values of target CV set for the biomethane injection site for the assessment period.

OTHER DATA ASSUMPTIONS

Calorific value of the biomethane produced is assumed to be 36.8 MJ/m^3 – from 01/01/1900 to 31/12/.1900, the average composition with hydrocarbons of carbon number greater than 1 indicates a CV of 36.83 MJ/m^3.

The calorific value of (Commercial) propane is taken to be 95.76 MJ/m^3.

Volumetric demands supplied by SGN were converted to energy demands assuming a CV for natural gas of 39.4192 MJ/m^3.

Density of propane vapour at reference conditions is taken to be 1.899 kg/m^3.

Contracted flowrate of biomethane was taken to be 1700 m^3/h.

OPERATION MODE

The User Defined Function also indicates the mode of operation and within the spreadsheet model this is indicated by a text flag. The key modes are:

Mode	Flag	Description
Blending	B	Blending only with no propane enrichment.
Blending/enrichment	BE	Blending and propane enrichment.
Enrichment only	E	Propane enrichment only.
Enrichment: low CV	E:CV	CV of the blending gas is less than the target CV.