# Safety & Firm Gas Monitor Methodology

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nationalgrid

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Front cover: The Rough offshore gas platform. Photograph courtesy of Centrica plc

**SAFETY & FIRM GAS MONITOR METHODOLOGY DISCLAIMER**

## Contents

# 1.0 Introduction & Background

This note explains and illustrates the methodology that has been used to establish the 2009/10 Gas Safety (Management) Regulations (GS(M)R) Safety Monitors ("safety monitors") and the 2009/10 Firm Gas Monitors ("firm gas monitors").

Prior to 1 November 2004, the Network Code required National Grid Gas to establish Top-up storage profiles (one per storage facility type) against which actual storage stocks could be monitored throughout the winter period. The purpose of the Top-up arrangements was to underpin security of supply to firm customers. However, following Ofgem's 2004 Top-up review, the Top-up arrangements were removed from the Network Code.

To ensure that sufficient gas is held in storage to preserve the ongoing safe operation of the gas transportation system, the concept of safety monitors has been introduced into the National Grid Gas GS(M)R Safety Case. The Uniform Network Code (UNC) (inter alia) requires us to publish the safety monitors and to provide regular reporting of actual storage stock levels for comparison with these monitors. As the name suggests, the focus of the safety monitors is public safety rather than security of supply. They provide a trigger mechanism for taking direct action to avoid a potential gas supply emergency (as defined in the Gas Safety (Management) Regulations).

In addition, the UNC requires us to calculate and publish firm gas monitors based upon the forecast demands of firm consumers. The firm gas monitors are published solely for the purpose of providing further information to the market.

# 2.0 Overview of Methodology

There are two main steps in the assessment of the respective storage monitors:

- The calculation of the storage requirement at the start of the winter for each type of storage
- The assessment of the way in which this initial requirement decays as the winter progresses, known as the winter profile

In the case of the safety monitors, each of these steps is more complicated than it is for the derivation of the firm gas monitors. The reason for this is explained in Section 3, which sets out the safety monitor calculation process in detail. Section 4 describes the firm gas monitor calculation and Section 5 describes the temperature adjusters.

## 2.1 Revisions to Safety Monitor methodology

Prior to winter 2009/10 we have made a number of changes to the safety monitor methodology, to improve security of supply whilst at the same time facilitating improved transparency and enhanced information provision to the market. **It is important to note that these changes have not affected the overall safety monitor space requirement.** The revisions to the safety monitor methodology sought to;

- Treat all storage types equitably, by grouping all storage types/facilities together such that there is only one aggregated monitor for space. Hence operational storage space is apportioned equitably across all storage sites, including those with high cycling rates, rather than apportioning over the historically determined three storage types, Long, Medium and Short range storage.

- Retain the prevailing determination of storage space requirements but make the deliverability requirement more visible. Hence there is one safety monitor for space and one for deliverability.

We believe that by having just one safety monitor for space and one for deliverability, there is greater clarity for market participants in terms of their operational decision making.

# 3.0 Safety Monitor Calculation Process

## 3.1 Stored Safety Gas Space and Deliverability Requirements

The concept behind the safety monitors is to ensure that sufficient gas is held in storage to support those gas consumers whose premises cannot be physically and verifiably isolated from the gas network within a reasonable time period. To achieve this all gas consumers are categorised into one of two groups:

- Protected by Monitor - Gas is held in storage to facilitate continuity of supply to these consumers even in a 1 in 50 winter
- Protected by Isolation – Network safety would be maintained if necessary by physically isolating these customers from the network

The storage deliverability safety monitor indicates the minimum level of deliverability required to both safely isolate loads that are “protected by isolation” and also support loads that are “protected by monitor”. The deliverability safety monitor is therefore providing operational cover should an emergency be called on any particular day, whilst the space safety monitor ensures that there is sufficient gas in store to support “protected by monitor” loads for the remainder of the winter.

The categorisation into these groups (accepted by the HS&E as part of the National Grid Gas Safety Case revision) is summarised in the table below:

**Table 1: End Consumer Categorisation for Safety Monitors**

| Sites which can be safely isolated from the network | Sites which require protection under the safety monitor |
|---|---|
| NTS Interruptibles | Priority Firm DM |
| LDZ Interruptibles | Ireland Firm |
| NTS Power Firm | >5860 MWh NDM |
| NTS Industrial Firm | 2196-5860 MWh NDM |
| DM (excluding priority customers) | 732-2196 MWh NDM |
| | 73-732 MWh NDM |
| | 0-73 MWh NDM |

The safety monitor storage requirements comprise two elements:

- **Supply-demand**: Storage required to support ‘protected by monitor’ loads, assessed using a severe winter load duration curve and assumed supply levels;

- **Non supply-demand**: Storage required during the process of demand reduction, effectively to support ‘protected by isolation’ loads in the period over which these loads would be isolated from the system.

These two components are considered separately in the next two sub-sections.

### 3.1.1 Stored Safety Gas Space Requirements – Supply-Demand for ‘Protected by Monitor’ Load

This element of the stored safety gas requirement is calculated using a traditional approach of matching supplies to demand. The severe (1 in 50 diversified) load duration curve only includes those demands identified in the right-hand column of Table 1. As shown below in Figure 1, assumed supplies are matched to demand using a “bottom-up” approach. The hierarchy of supply sources assumed is: firstly Non Storage Supplies, including UKCS and Norwegian supplies, LNG importation, Interconnector imports and finally storage.

For the 2009/10 calculation, the starting point for our supply assumptions was the base case outlined in our 2009/10 Winter Outlook Report[1]. This is detailed in Table 2 and represented a balanced view of the level of supply that may be expected on average over a prolonged cold spell. However, for the safety monitor calculations we have assumed IUK flows to be zero at all times. We believe this is prudent given the significant level of supply uncertainty associated with IUK flows and because the focus of the safety monitors is public safety rather than security of supply.

**Table 2: Supply Assumptions**

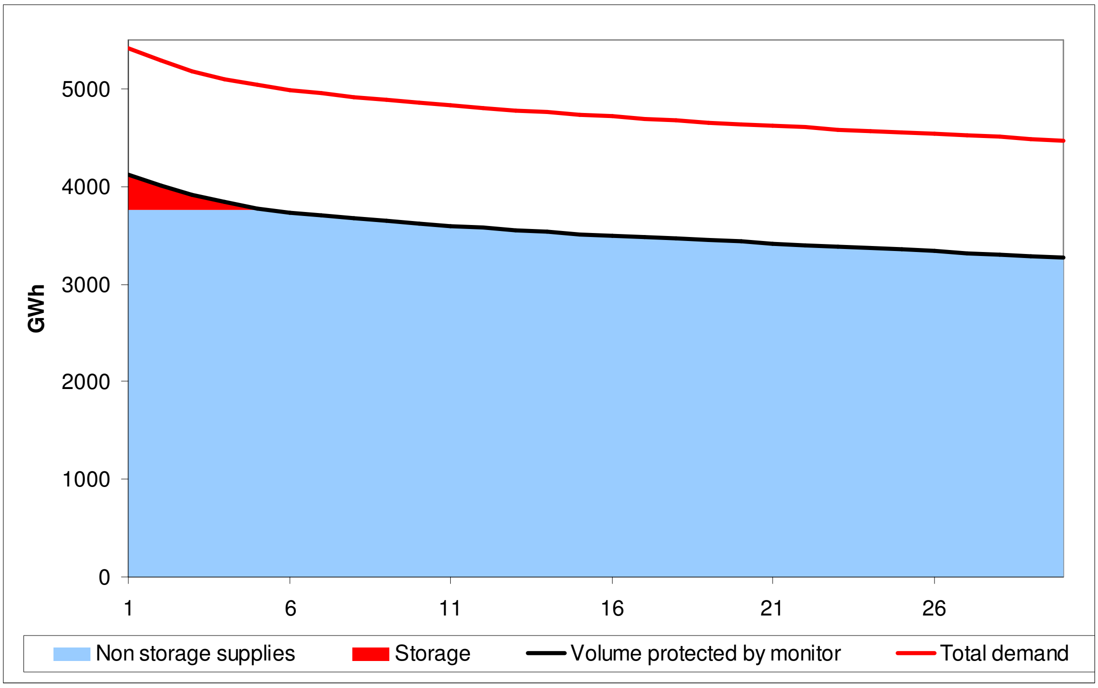
| Supply | Deliv. (GWh/d) |
|---|---|
| 90% max UKCS | 1995 |
| Norway | 1112 |
| LNG Imports | 438 |
| IUK Interconnector | 0 |
| BBL | 216 |
| Total non storage supply | 3761 |
| Storage[2] | 1360 |

Note that the storage requirement is no longer broken down into Long, Medium or Short, but is a single storage space requirement apportioned equitably across all storage sites.

[1] http://www.nationalgrid.com/NR/rdonlyres/C3A81245-D988-48A4-80F2-5082F601E06D/37301/Winter_Outlook_Report_200910_01102009.pdf

[2] Includes Rough, Hornsea, Holehouse Farm, Hatfield Moor, Humbly Grove, Aldbrough, Avonmouth, Glenmavis and Partington and reflects latest information available at time of Safety Monitor calculation

**Figure 1: Stored Safety Gas Space Requirements – Supply-Demand**




The resulting storage requirement is shown in Table 3. The right hand column in this table shows the number of days that storage would be required in a severe winter to support this demand base only (given the other supply-side assumptions).

**Table 3: Stored Safety Gas Requirements – Supply-Demand**

| Supply | Deliv. (GWh/d) | Space Available (GWh) | Space Required (GWh) | Space Required (%) | Maximum Days (Day No.) |
|---|---|---|---|---|---|
| Storage | 1360 | 49597 | 847 | 1.7% | 5 |

Table 3 shows a modest space requirement of just 847 GWh for up to 5 days. As shown in Figure 1, this is highly dependent on the assumption for non storage supply. Hence a lower level of non storage supply results in a higher space requirement for an increased duration.

### 3.1.2 Stored Safety Gas Space Requirements – Non Supply-Demand for Isolation Process

For those consumers that are protected through physical isolation from the network, there is an additional storage requirement to reflect the time that such a process could take, for example as a result of:

- Time taken for the request to reach a large number of end consumers
- Time taken for isolation to take place (to avoid damage to plant, bringing on of alternative fuels etc.)
- Refusal of GS(M)R direction to cease taking gas (in this event National Grid Gas might need to visit the site in order to effect isolation)

To determine the storage requirement for isolation, a number of assumptions need to be made, e.g. regarding the level of demand when isolation is called and the response rate of the consumer groups identified in the left hand column of Table 1.

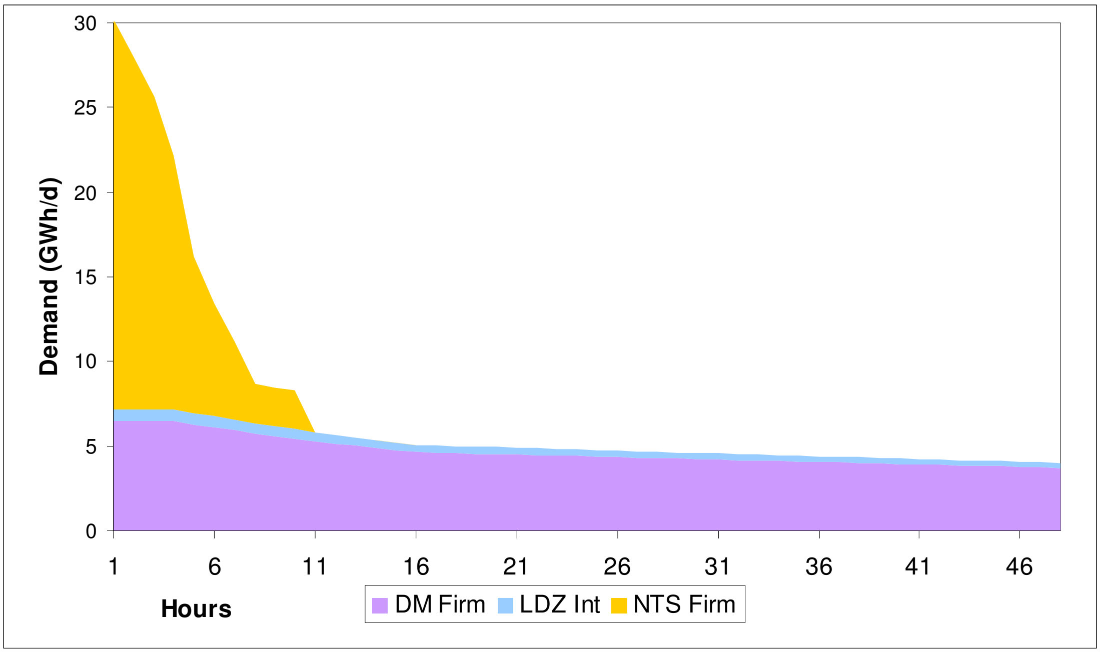
Our key assumptions in this area include:

- For interruptibles, based on operational practice, interruption would be called prior to the gas day in question
- NTS interruptibles are assumed to be fully off before the gas day in question
- 94% of LDZ interruptibles (based on operational exercises) are assumed to interrupt before the gas day, i.e. going into the relevant gas day only 6% of LDZ Interruptibles continue to take gas
- Demand reduction would take place over a 48 hour period, although heavily weighted to the start of this period
- For the load shedding profiles of NTS firm sites and DM sites, we have used results from operational exercises. This includes an assessment of those loads that would have to be physically isolated due to a refusal to cease taking gas

The assessment of this storage requirement requires an examination of all the demand days at the top end of the 1 in 50 load duration curve (in a demand range of approximately 5400 to 3600 GWh/d), to cater for all possible demand levels at which such an isolation process could occur.

Assuming that this isolation process took place at a demand level equivalent to Day 1 followed by Day 2 on the 1 in 50 load duration curve, the estimated demand profile for 'protected by isolation' loads over the 48-hour period is as shown in Figure 2.

**Figure 2: Demand Profile for Isolation (Day 1 then Day 2 demand levels)**




These hourly demands are summed and then added to the estimated demand of the 'protected by monitor' sector, to derive estimates of the total daily demand on the two days of the assumed isolation process. This allows the total storage requirement on those days to be assessed. This calculation is repeated for every day at the top end of the 1 in 50 load duration curve.

Figure 3 shows the estimated storage requirements for isolation purposes for the top 80 days on the 1 in 50 load duration curve. Note that the line represents a two day requirement, for example, the highest requirement of 883 GWh of gas is the summation of 569 and 314 GWh for days 1 and 2 respectively. It can be seen that the requirement drops rapidly, but is required to some extent over roughly 40 days.

**Figure 3: Storage Requirement for Isolation Profiling**

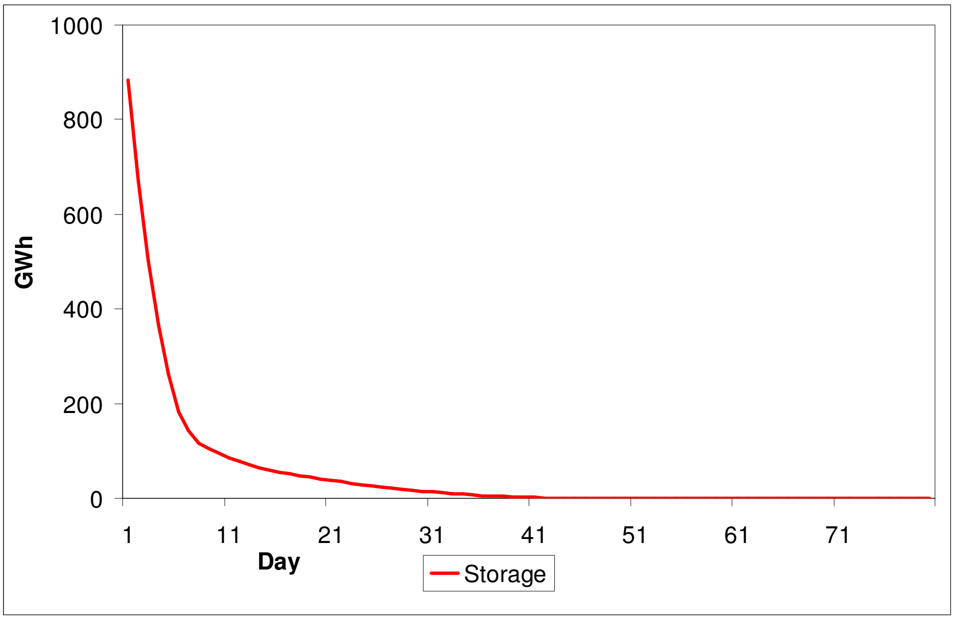



Table 4 summarises the maximum storage requirements for isolation profiling.

**Table 4: Stored Safety Gas Requirements – Isolation Profiling**

| | Space Available (GWh) | Space Required (GWh) | Space Required (%) | Maximum Days (Day No.) |
|---|---|---|---|---|
| Storage | 49597 | 883 | 1.8% | 42 |

These storage requirements reflect the total level of storage that may be required on the days in question, including that required to support 'protected by monitor' loads. There is therefore an element of double-counting with the supply-demand component described in Section 3.1.1 above. The following sub-section explains how the two components are combined in such a way as to avoid double-counting.

### 3.1.3 Stored Safety Gas Space Requirements – Total

The total safety monitor storage requirement combines that calculated for supply-demand purposes for 'protected by monitor' loads with that calculated to support the non supply-demand component for the isolation process. This is summarised in Table 5.

The total requirement is the supply-demand component plus an additional component for protection by isolation: this is less than the full protection by isolation requirement as described in section 3.1.2, due to double counting of high demand days. The additional component is calculated as follows:

- For each day at the top of the 1 in 50 load duration curve, the estimated storage requirement for isolation profiling (a 48-hour requirement as described in Section 3.1.2) is compared with the supply-demand requirement on that day and the subsequent day (as illustrated in Section 3.1.1).
- The difference between these two requirements is noted, and the maximum difference across each of these days in question represents the incremental requirement for isolation purposes for that storage type.

Table 5 presents the output of this analysis.

**Table 5: Stored Safety Gas Space Requirements – Total**

| | Space Available (GWh) | Supply-Demand (GWh) | Isolation (GWh) | Additional Isolation (GWh) | **Total Space Required (GWh)** | **Space Required (%)** |
|---|---|---|---|---|---|---|
| Storage | 49597 | 847 | 883 | 280 | **1127** | **2.3%** |

Table 5 shows that the total storage required is 1127 GWh, which is less than the sum of the supply-demand component (847 GWh) and the isolation component (883 GWh). The additional requirement for isolation purposes is therefore only 280 GWh.

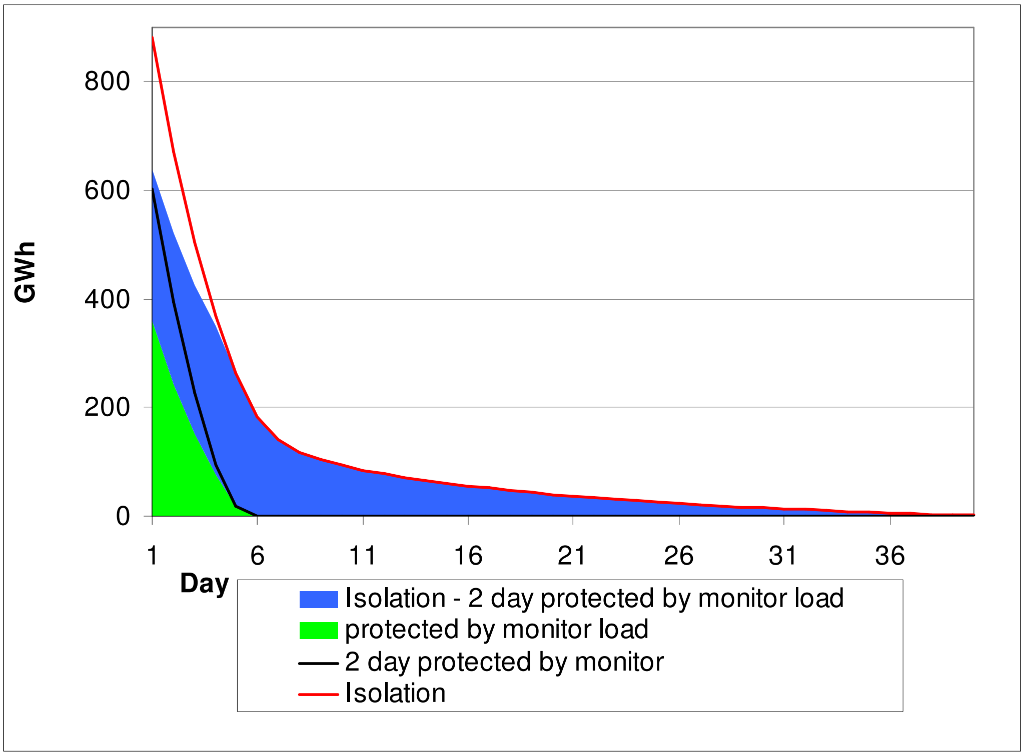
### 3.1.4 Stored Safety Gas Deliverability Requirement

The revisions made to the safety monitor methodology prior to winter 2009/10 do not change the overall safety monitor space requirement, but make the storage deliverability requirement more visible by setting a safety monitor deliverability requirement.

The deliverability requirement is that required to meet the supply demand requirement plus any additional for isolation for any day of the winter.

Figure 4 shows how the safety monitor deliverability requirement is calculated.

**Figure 4: Storage Requirement for Isolation and Supply/Demand**




The red line shows the isolation requirement (shown previously in Figure 3), which is a two day requirement. The green area shows the protected by monitor load requirement (that is for supply/demand purposes) for each day (shown previously in Figure 1). The black line shows the protected by monitor load for a 48 hour period, i.e. the same period as for the isolation requirement. The blue area shows the isolation requirement less the protected by monitor load for a 48 hour period. The combination of the blue and green areas gives the total deliverability requirement for any given day on the load duration curve. For winter 2009/10, the maximum safety monitor deliverability requirement is 639 GWh. Table 6 summarises the Safety Monitor Deliverability Requirement.

**Table 6: Stored Safety Gas Deliverability Requirement**

| | Maximum Deliverability (GWh/d) | **Safety Monitor Deliverability (GWh/d)** |
|---|---|---|
| Storage | 1360 | **639** |

## 3.2 Winter Monitor Profiles

Section 3.1 set out the calculation of the initial storage space requirements for the safety monitors. To reflect the use of storage under severe conditions, winter profiles (often referred to generically as storage monitors) have to be determined.

The key to developing the storage monitors is to establish a link between the demands associated with Day numbers on a load duration curve and the periods within a winter when such demands could be expected. This is achieved through two relationships:

- The relationship between Day number and temperature
- The latest possible occurrence of temperatures (hence Day number) within a winter

As with the initial storage requirements, the safety monitor space profile is constructed by considering separately the requirements for supply-demand for ‘protected by monitor’ load, and for demand profiling for ‘protected by isolation’ load. These components can then be combined to produce the final monitor.

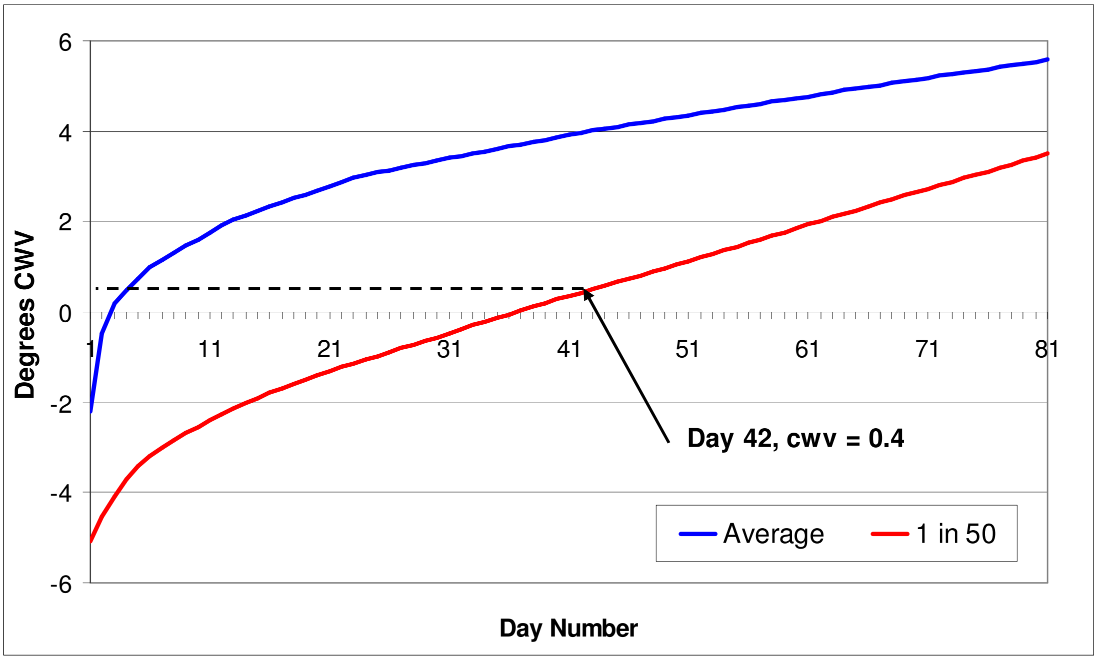
As the use of isolation can be considered a “one-off” and is simpler to assess, this is considered first.

### 3.2.1 Safety Monitor Space Requirement Winter Profile – Isolation Process

Sections 3.1.2 (Table 4) showed that to support the isolation process, storage is required at demand levels at or above Day 42. The associated maximum storage space requirement is 883 GWh . However, as mentioned in Section 3.1.3 (Table 5), the actual additional requirement for isolation, over and above that required for supply-demand purposes is 280 GWh.

As the use of these storage volumes is considered to be a “one-off” event, it is necessary to calculate the latest possible occurrence within the winter when these storage requirements may be utilised. These latest dates have been calculated from a relationship between temperature (composite weather variable, or CWV) and Day number. This is known as a weather duration curve (WDC) and is shown below in Figure 5 for the coldest days in a severe (1 in 50) and average winter.

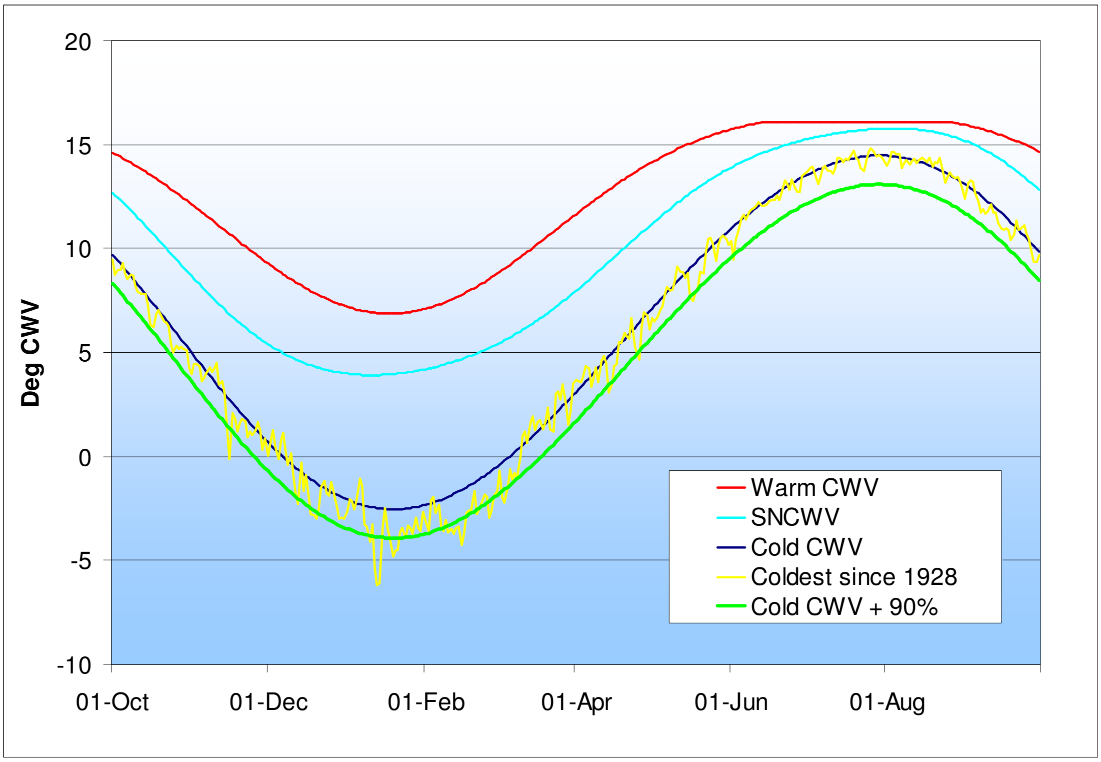
**Figure 5: Weather Duration Curve**




For each day of the WDC there is an associated temperature (CWV). For example, Day 42, the last use of storage for isolation has a CWV of 0.4℃.

Figure 6 shows a number of CWV profiles for the 2009/10 gas year.

**Figure 6: 2009/10 Composite Weather Variables**

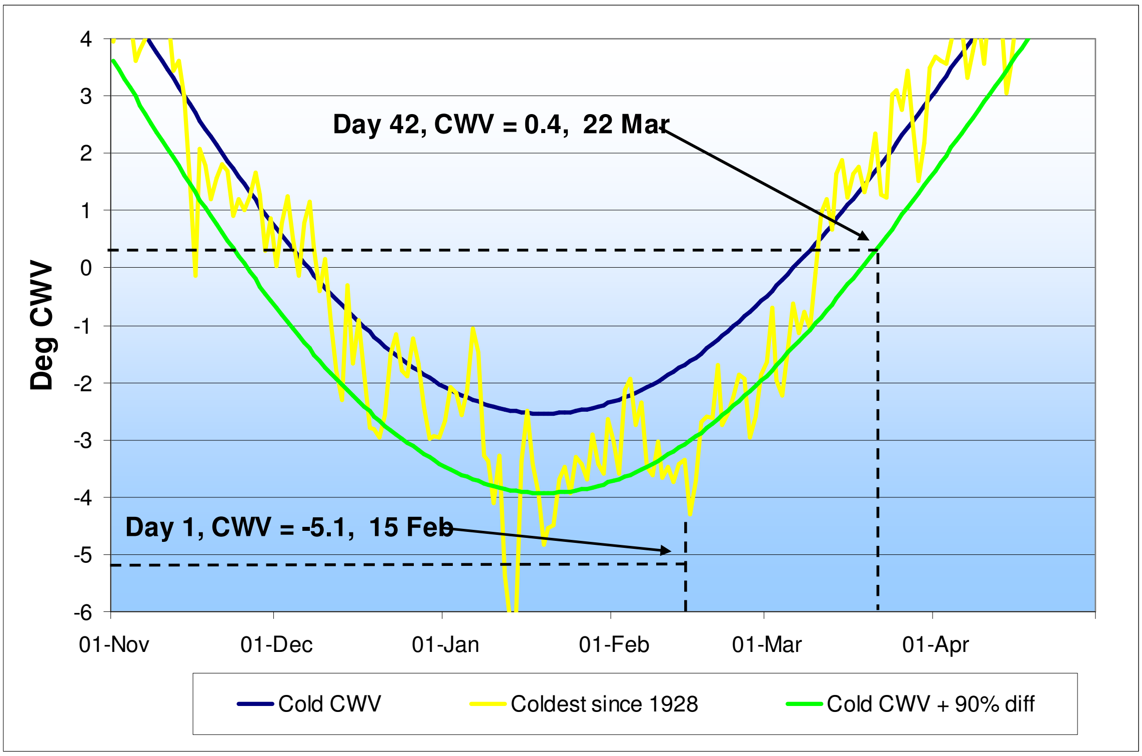



The smooth red, light blue and dark blue lines are CWV profiles for warm, seasonal normal and cold conditions respectively. The lowest CWV on the cold CWV profile is –2.54°C. Cold conditions represent a moving 7 day profile (smoothed) of 1 in 20 conditions. (The 1 in 20 peak day would be well below this curve as it represents a winter peak day rather than a weekly assessment.) The yellow line represents the coldest CWVs ever seen on any corresponding day since 1928. As one would expect, the coldest CWVs are often lower than the dark blue cold CWV profile. To ensure that an appropriately broad assessment is made of the latest potential occurrence within a winter of a particular CWV, we have developed a further line. This line shown in bright green represents the Cold CWV plus the 90$^{th}$ percentile of the difference between the Cold CWV and coldest since 1928. The bright green line is 1.39°C lower than the Cold CWV across the whole profile. The lowest CWV on the bright green line is therefore -3.93°C. Figure 7 shows the lowest portion of the CWV profile in more detail.

It should be noted that the bright green line (and the Cold CWV) represents, in aggregate, conditions that are much more severe than 1 in 50. However the purpose of this approach is to determine the possibility of when cold weather can occur within a winter rather than to assess total storage requirements.

Our starting point is to use the bright green line to establish the assumed latest dates at which individual temperatures (CWV) may occur.

**Figure 7: 2009/10 Composite Weather Variables – Coldest Section**



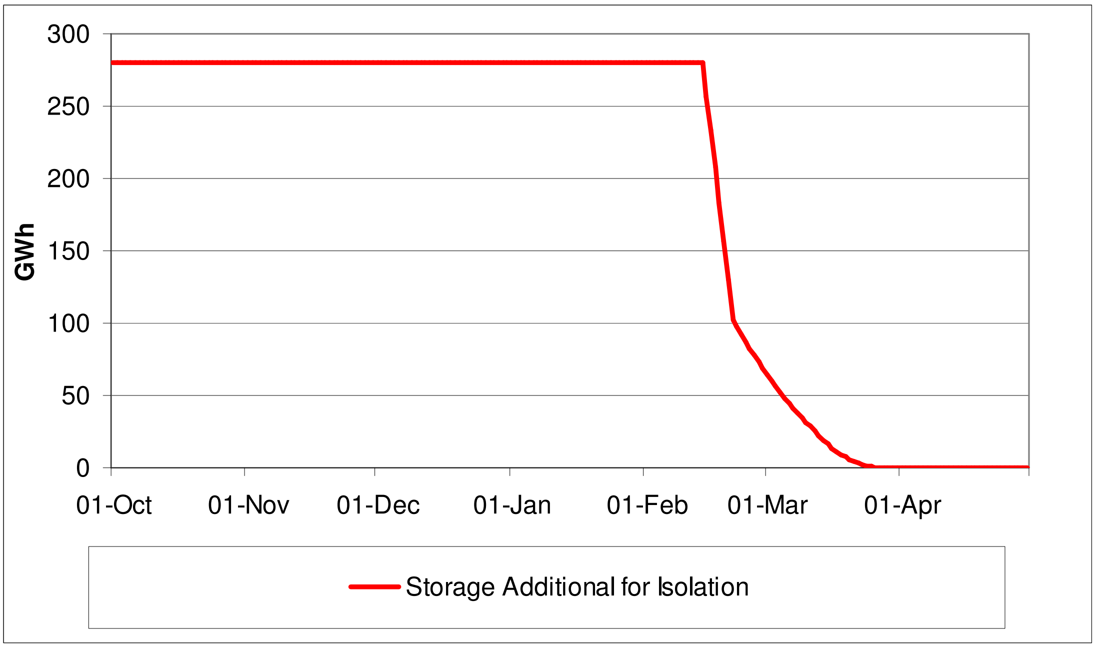

The CWV for Day 42 (last use of storage) on the 1 in 50 severe weather duration curve is 0.4°C. Using the bright green curve, this equates to 22 March.

It is important to calculate the latest potential occurrence within the winter of Day 1 on the 1 in 50 WDC, which has a CWV equal to -5.1°C. This date represents the latest possible requirement for all the 280 GWh. To determine the occurrence of Day 1 the coldest day curve (yellow line) is chosen. The date for this is 15 February. Though not the coldest day ever experienced, this date is considered as the latest date for the possible occurrence of a Day 1. This is because it represents the latest date when the actual CWV has approached the CWV for 1 in 50 conditions of -5.1°C.

In establishing the winter profiles for this component of the safety monitor, we therefore assume that the storage requirement will remain at 280 GWh up to 15 February, then decay to zero by the end of March.

By considering the storage requirement associated with each day on the severe load duration curve, and establishing the latest day at which each of these days could occur, the winter profile for this component of the space safety monitor can be constructed. This is shown in Figure 8.

**Figure 8: Safety Monitor Winter Profile – 'Protected by Isolation' Load**




Seven day smoothing is applied to this curve to avoid unnecessary lumpiness.

### 3.2.2 Safety Monitor Space Requirement Winter Profile – Supply-Demand for 'Protected by Monitor' Load

Section 3.1.1 (Figure 1 and Table 2) explained the calculation of the supply-demand component of the storage requirements for the safety monitors. For day numbers greater than 1, this component is assumed to decay across a specific portion of the winter, rather than after the latest occurrence of a specific day, as is the case with the isolation process component described in Section 3.2.1. This is because the supply-demand storage requirement reflects a winter-long need rather than a "one-off" event as would be the case to support an isolation process.

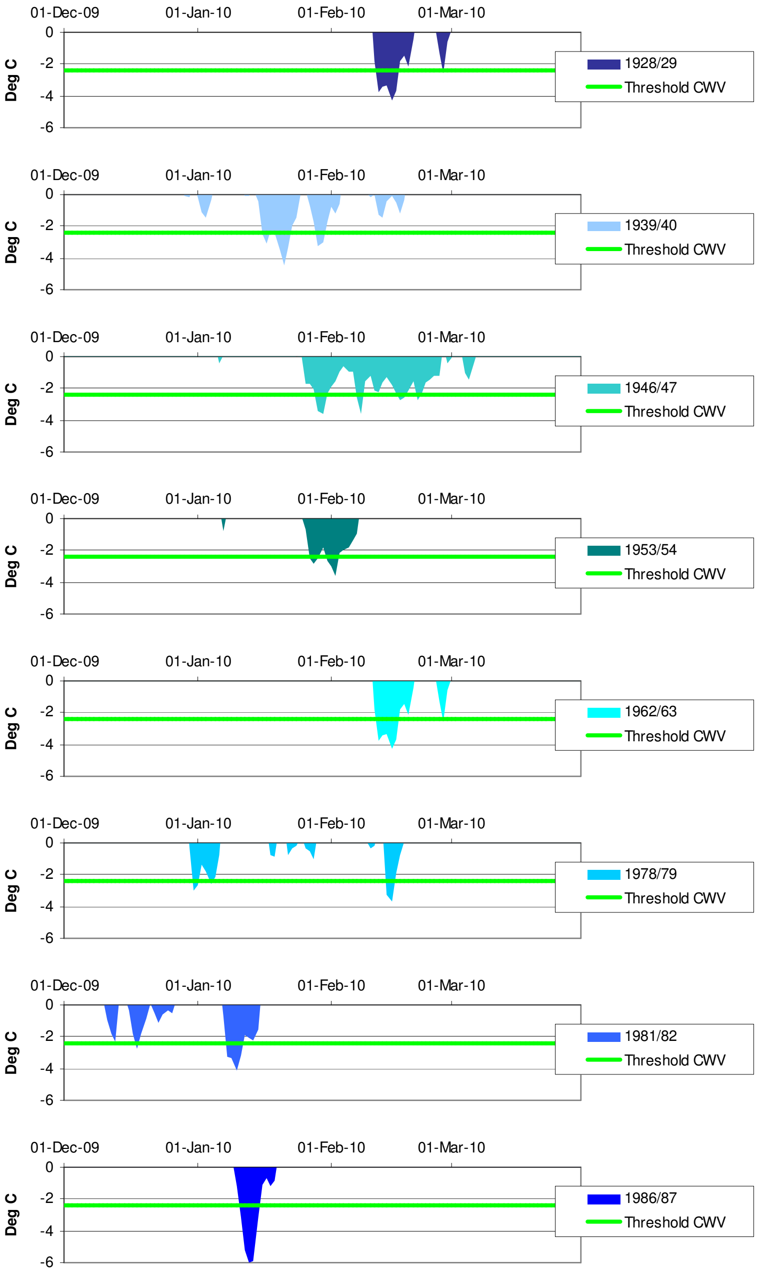
The threshold temperature and maximum number of days required is shown below in Table 7.

**Table 7: Threshold temperature and maximum number of days required for Supply-Demand for 'Protected by Monitor' load**

| Supply | Maximum Days (Day No.) | Threshold temperature (℃) |
|---|---|---|
| Storage | 5 | -3.4 |

To determine the winter profile, the latest possible occurrence of each day from the 1 in 50 severe load duration curve when storage is required needs to be calculated. Therefore it is necessary to calculate the latest possible occurrence of 5 days of temperatures lower than -3.4℃ (which is the CWV for day 5 on the severe WDC). In order to calculate this, historic temperatures for 81 years (1928/29 to 2008/09) were analysed. There is only one year on record where there were more than 5 days of national temperatures below the threshold temperature, this is 1962/63. The 5th-from-last day in 1962/63 where the national average temperature was below the threshold temperature was 20 January. However this methodology is not considered robust as this limited dataset will not capture the latest possible occurrence within a winter of 5 days of temperatures below -3.4℃. For the purpose of this analysis, we therefore added +1℃ to the threshold temperature. This increases the number of relevant winters to eight, and enables the analysis to be undertaken using a larger dataset. It should be noted that this does not have any effect on the initial safety monitor space requirement, but does provide adequate cover within the safety monitor space profile for the possibility of late cold weather. It is also worth noting that the temperature adjusters (see Section 5.0) enable the monitors to be adjusted downwards within-winter when cold conditions are encountered to ensure the monitors are not held too high for too long if cold weather was to occur. Figure 9, shows the eight years of historical temperatures where there were 5 or more days of temperatures below the revised threshold of –2.4℃.

**Figure 9: National Average temperatures for eight 'cold' years for December to March**

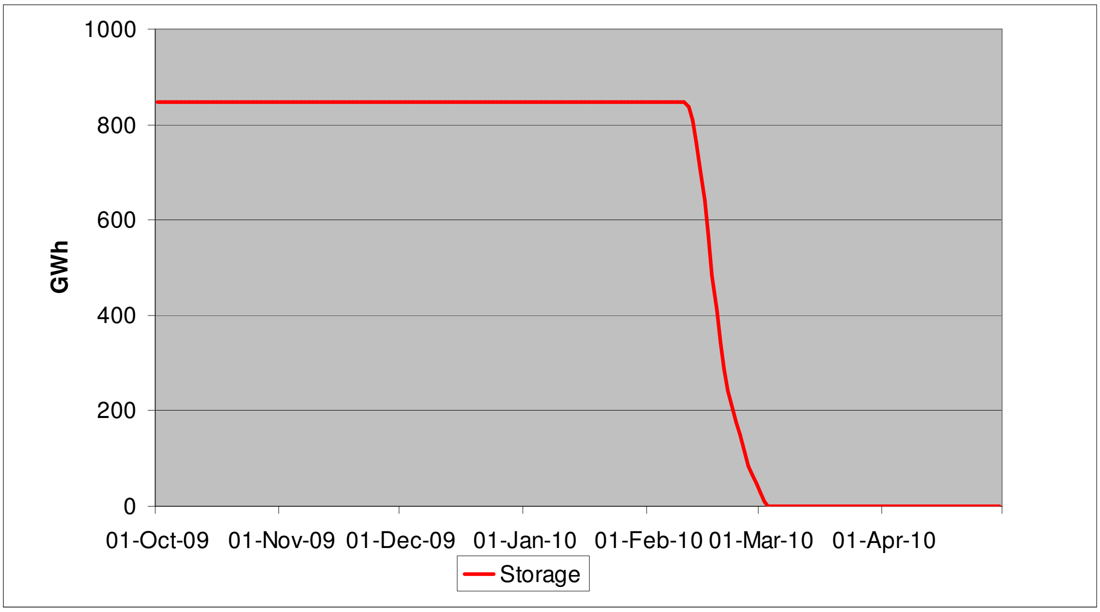


The green horizontal line indicates the revised threshold temperature of -2.4°C for the 'Protected by Monitor' component of storage required. It is the winter of 1928/29 that has the latest 5th-from-last day with a national average temperature lower than -2.4°C, and the date of this occurrence was 13 February. Therefore for the storage monitor to support the likely latest potential occurrence of cold temperatures associated with a 1 in 50 severe winter, the supply-demand component of the monitor must be at 100% as late as 13 February.

The profile of the supply-demand component of the safety monitor is derived by firstly calculating the total number of days for all 81 years on record where National average temperature is below the threshold temperature, but only for days from 13 February inclusive onwards. This gives a date range from 13 February to 27 February. The rate of decay of the monitor is then equal to the distribution of these days across the period, with seven day average smoothing applied to create the final profile.

Figure 10 shows the supply-demand for 'protected by monitor' component of the safety monitor space profile.

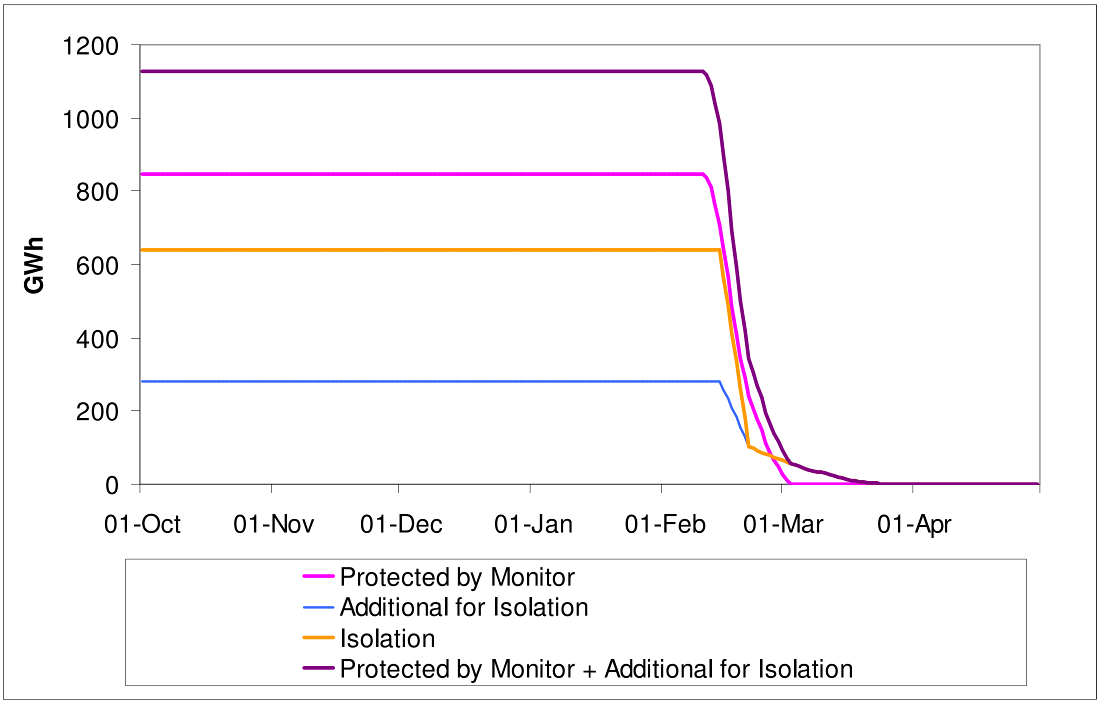
**Figure 10: Safety Monitor Winter Profile – Supply-Demand for 'Protected by Monitor' Load**




### 3.2.3 Safety Monitor Space Requirement – Aggregated Winter Profile

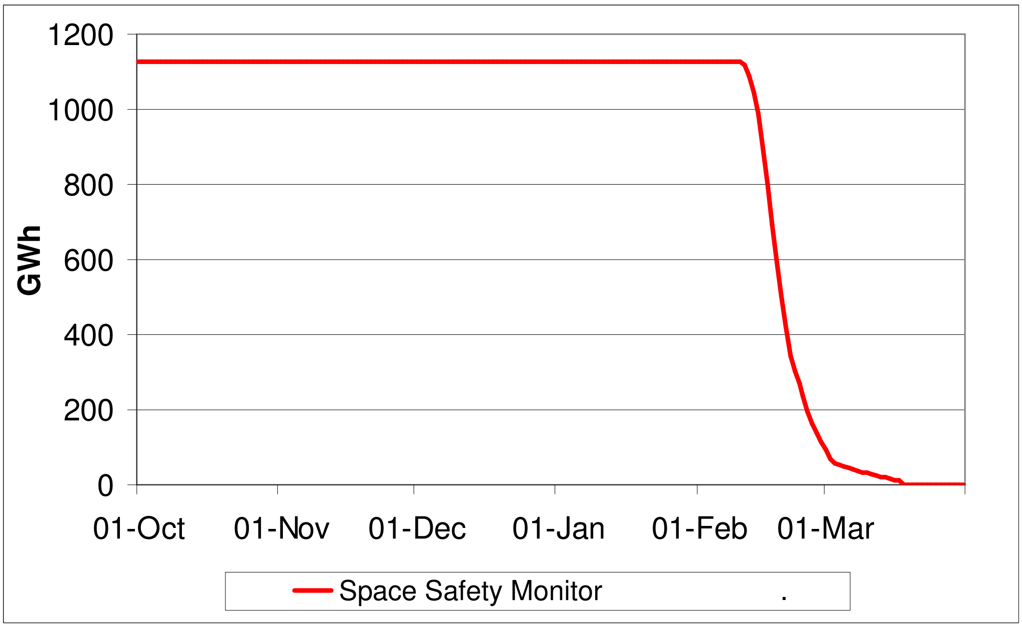
The aggregated winter profiles are not simply the summation of the 'protected by monitor' and 'protected by isolation' profiles. As explained in Section 3.1.3, to avoid double-counting, the total requirement for a particular type of storage on a particular day of the load duration curve is less than the sum of the two components for that day. The total requirement for any given day is therefore the supply-demand component plus an additional element for the isolation process. On certain days, it is possible for the full isolation profile to exceed the sum of the 'protected by monitor' profile and the additional isolation requirement. The final profile therefore incorporates the greater of these two profiles at each point of the curve. This is best explained by reference to Figure 11, which shows the individual components for the safety monitor space monitor.

**Figure 11: 2009/10 Safety Monitor space requirement – component profiles**




As can be seen in Figure 11, in this particular instance the full ‘protected by isolation’ profile is always less than the sum of the ‘protected by monitor’ profile plus the additional requirement for the isolation process. Hence no adjustment is required to the sum of the ‘protected by monitor’ profile plus the additional requirement for the isolation process. The aggregated safety monitor space profile is as shown in Figure 12.

**Figure 12: 2009/10 Safety Monitor – Aggregated Space Profile (GWh)**

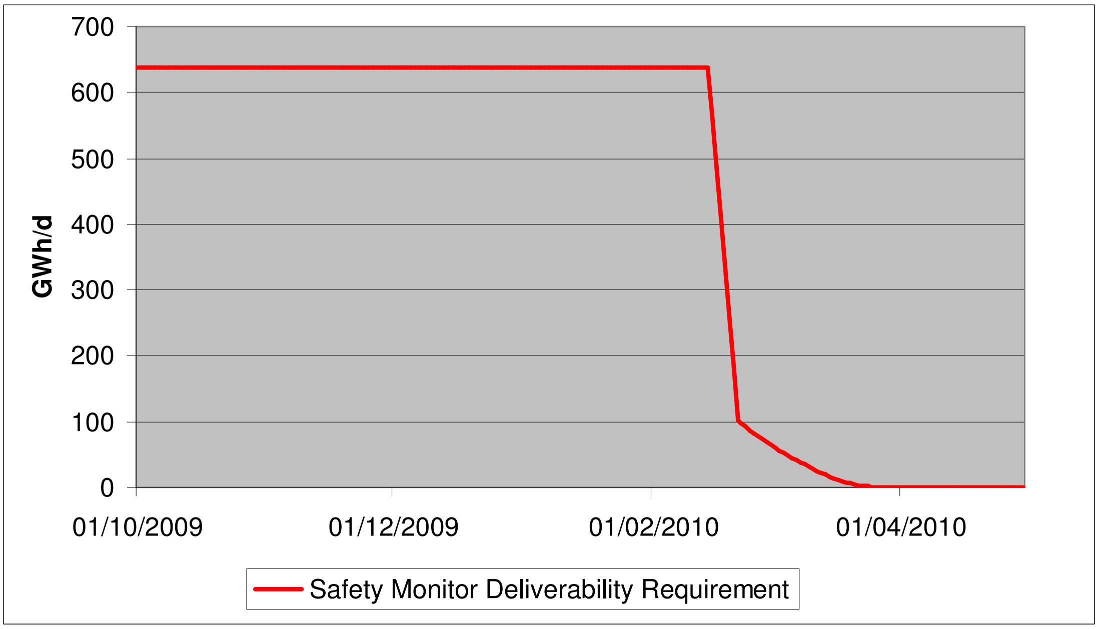


### 3.2.4 Safety Monitor Deliverability Requirement – Winter Profile

As explained in Section 3.1.4 the deliverability requirement for each day is that required to meet the supply demand requirement plus any additional for isolation on that day. As shown in Figure 4 and Table 6, for winter 2009/10, the maximum safety monitor deliverability requirement is 639 GWh. The day-based approach shown in Figure 4 can then be converted to a date-based winter profile by using the same methodology as that used in Section 3.2.1

Figure 13 shows the safety monitor deliverability profile. The maximum deliverability requirement of 639 GWh is required out to 15 February, as this date is considered as the latest date for the possible occurrence of a Day 1 on the severe load duration curve.

**Figure 13: Safety Monitor Deliverability Requirement**

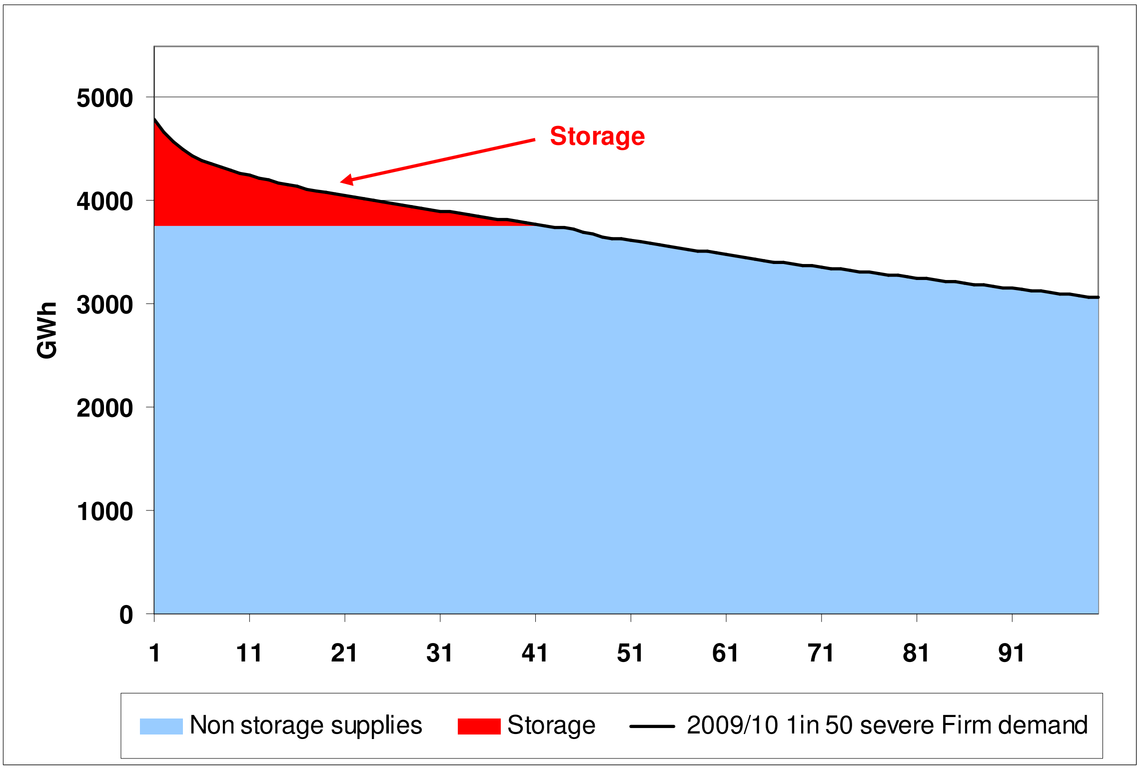


# 4.0 Firm Gas Monitor Calculation Process

## 4.1 Firm Gas Storage Requirements

As with the supply-demand for 'protected by monitor' component of the safety monitor, the firm gas storage requirement is calculated using a traditional approach of matching supplies to demand. The demand is based on the diversified 1 in 50 load duration curve. Figure 14 illustrates the approach, whereby supplies are matched to demand on a "bottom-up" basis using the same hierarchy of supply sources as described in Section 3.1.1.

**Figure 14: Firm Gas Storage Requirements**




It should be noted that the Firm Gas Monitors are calculated using the same supply and demand assumptions as used for calculating the safety monitor.

**Table 8: Firm Gas Storage Requirements**

| Supply | Deliv. (GWh/d) | Space Available (GWh) | **Space Required (GWh)** | **Space Required (%)** | Maximum Days (Day No.) |
|---|---|---|---|---|---|
| Non storage supplies | 3761 | | | | |
| Storage | 1360 | 49597 | **13965** | **28.2%** | 42 |

## 4.2 Firm Gas Storage Monitor – Winter Profile

Section 4.1 (Figure 14 and Table 8) explains the calculation of the initial storage requirements for the firm gas storage monitor.

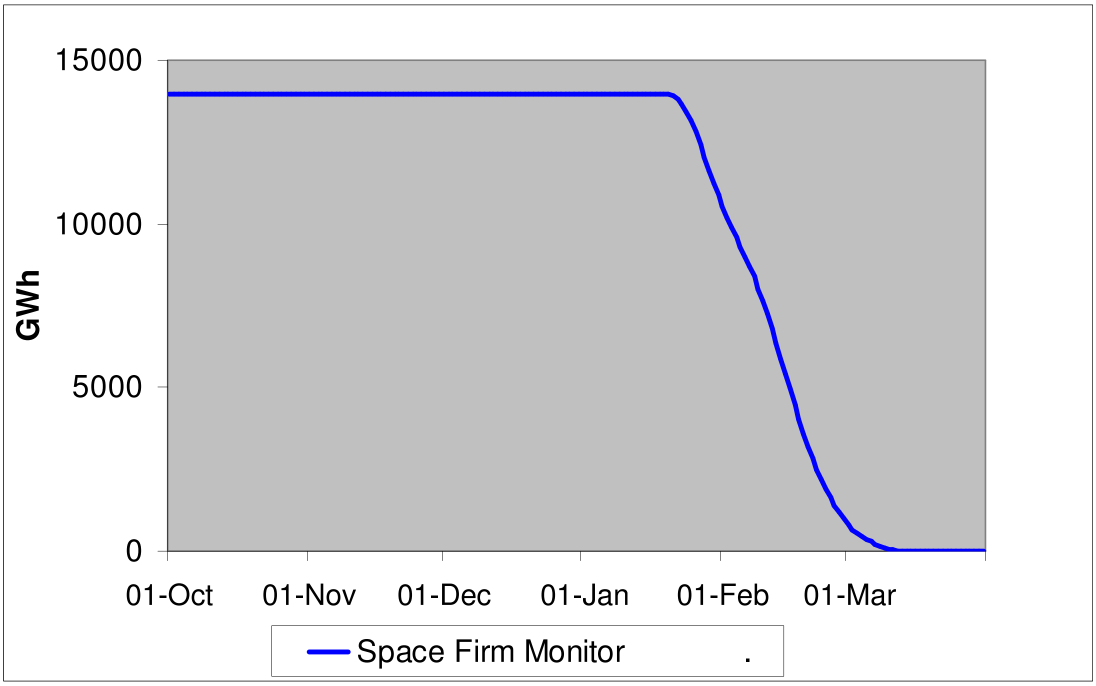
The methodology to determine the firm demand winter profiles is the same as that detailed in Section 3.2.2 for the supply-demand component of the safety monitor, i.e. the latest possible occurrence of each day from the 1 in 50 severe load duration curve when storage is required needs to be calculated. Table 9 shows the threshold temperature and maximum number of days required.

**Table 9: Firm Gas Storage Monitor - Setting Parameters**

| Supply | Maximum Days (Day No.) | Threshold temperature (°C) |
|---|---|---|
| Storage | 42 | 0.4 |

The resultant firm gas storage monitor is shown in the following chart.

**Figure 15: 2009/10 Firm Gas Storage Monitors (GWh)**



# 5.0 Safety & Firm Monitor Temperature Adjusters

As the previous sections have explained, the profile of the storage monitors is designed to cater for the possibility of cold weather conditions relatively late in the winter. However, weather patterns could be very different from this in practice, so storage withdrawals may be required at higher levels earlier in the winter than implicitly assumed within the storage monitors. To recognise this, an adjustment mechanism is required through which the monitors can be adjusted downwards within-winter when sufficiently cold conditions are encountered. Without such a mechanism, the monitors would potentially reflect a condition more severe than 1 in 50, thereby going beyond the intended and established standard. The adjustment mechanism that we use is known as a ‘temperature adjuster’.

## 5.1 Safety Monitor Temperature Adjuster – ‘Protected by Isolation’ Load

The storage requirement of the ‘protected by isolation’ loads is calculated as a “one-off” requirement, hence there is no reduction required to this component of the monitor level for the occurrence of cold weather.

## 5.2 Safety Monitor Temperature Adjuster – Supply-Demand for ‘Protected by Monitor’ Load

The storage requirement for supply-demand for ‘protected by monitor’ loads represents a “winter long” requirement, hence for the occurrence of cold weather there can be a need to reduce the safety monitor storage levels. This mechanism is assumed to be temperature dependent and is triggered if temperatures fall below the threshold temperature for storage. These threshold temperatures are determined from the relationship between temperature (CWV) and Day number as shown on the severe WDC (Figure 5). Though storage is assumed to be used for up to Day 5, Day 6 is used for the threshold temperature as the theoretical first use of storage falls somewhere between these temperatures. This is shown in Table 10 below.

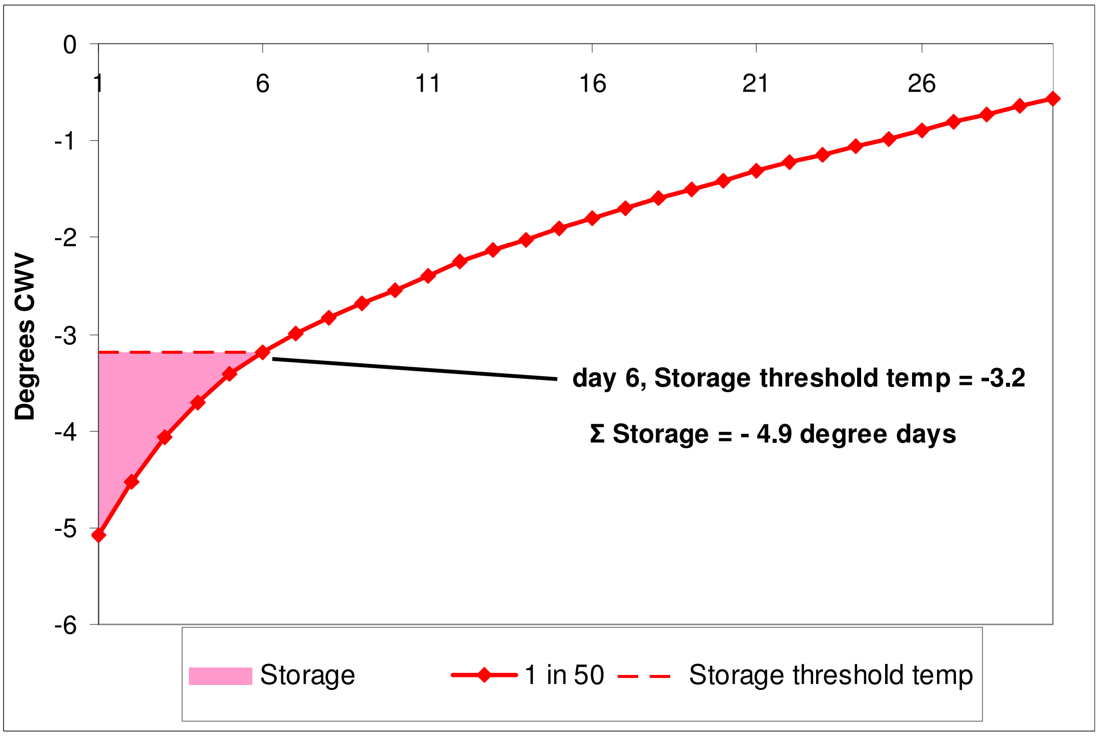
**Table 10: Temperature Threshold for ‘Protected by Monitor’ Load**

| Supply | Maximum Days (Day No.) | Temperature Threshold (°C) |
|---|---|---|
| Storage | 5 | -3.4<br>**Day 6 -3.2** |

The temperature adjusters are derived from the threshold temperatures (Table 10), the storage requirement (Table 2) and the severe WDC (Figure 5).

Figure 16 shows the portion of the severe WDC from Day 1 to Day 30.

**Figure 16: Weather Duration Curve, Day 1 to Day 30**




As indicated in Table 10, storage for supply-demand for 'protected by monitor' loads is assumed to be used up to Day 5, corresponding to when temperatures are below -3.2℃. In determining the temperature adjuster, days of greater severity (Days 1 to 4) also need to be considered. These and Day 5 are accounted for by summing all the incremental temperatures below the threshold temperature of –3.2℃. i.e. as shown in the shaded pink area in Figure 16 and the following formula:

$$\sum_{Day1}^{Day5} CWV - (-3.2) = -4.9°C$$

With the storage requirement for 'protected by monitor' load at 847 GWh, the resultant temperature adjuster is therefore:

847 GWh / 4.9℃ = 172.9 GWh/℃

That is for every ℃ that the temperature is below the threshold temperature of –3.2℃, the storage monitor will reduce by 172.9 GWh.

This is summarised in Table 11.

**Table 11: Temperature Adjusters for Safety Monitors**

| Supply | Temperature Threshold (℃) | Temperature Adjuster (GWh/℃) |
|---|---|---|
| Storage | -3.2 | 172.9 |

## 5.3 Firm Gas Temperature Adjuster

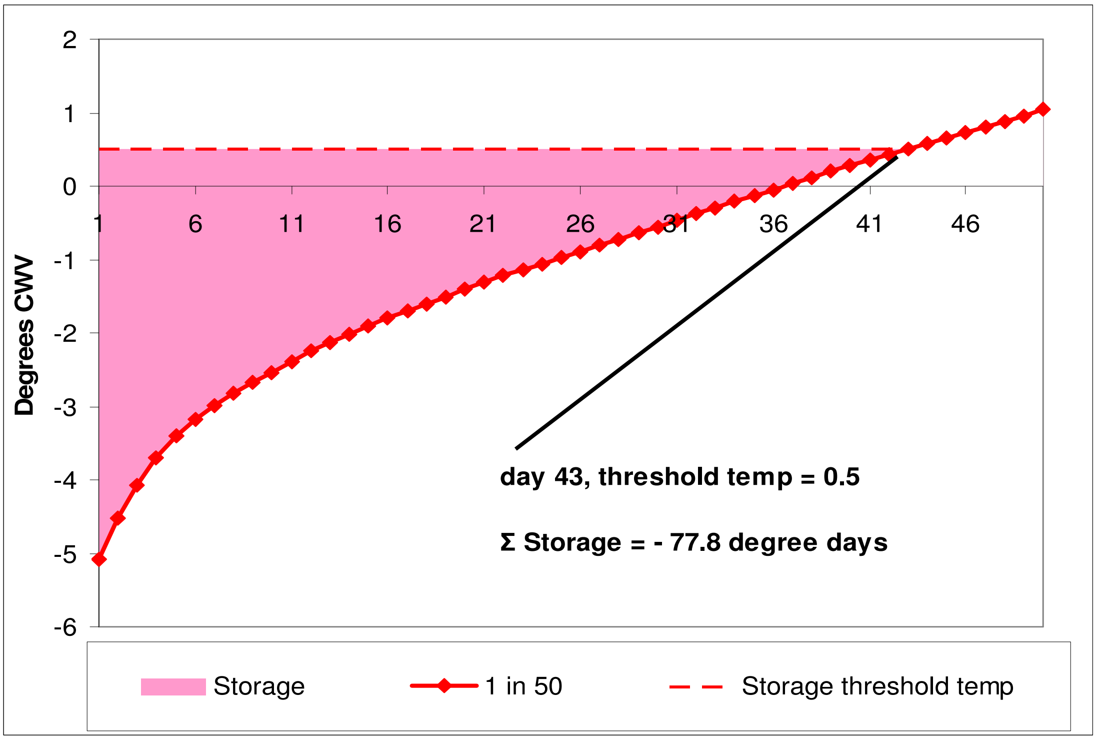
The methodology for the calculation of the temperature adjusters for the firm gas storage monitors is the same as that for safety monitor temperature adjusters. The threshold temperatures are again determined from the relationship between temperature (CWV) and Day number as shown on the severe WDC (Figure 4). Storage is assumed to be used for up to Day 42, with Day 43 used for the threshold temperature. This is shown in Table 12 below.

**Table 12: Temperature Threshold for Supply-Demand for 'Protected by Monitor' Loads**

| Supply | Maximum Days (Day No.) | Temperature Threshold (°C) |
|---|---|---|
| Storage | 42 | 0.4<br>**Day 43 0.5** |

Figure 17 shows the portion of the severe WDC from Day 1 to Day 50.

**Figure17: Weather Duration Curve, Day 1 to Day 50**




As indicated in Table 12, storage for firm loads is used for up to Day 42, corresponding to when temperatures are below 0.5°C. In determining the temperature adjuster days of higher severity (Days 1 to 41) also need to be considered. Hence the total incremental temperature for storage for firm loads, below the threshold temperature of 0.5°C, i.e. as shown by the pink shaded area in Figure 17 and the following formula:

$$\sum_{Day1}^{Day42}(CWV - 0.5) = -84.2°C$$

With the storage requirement for firm load at 13965 GWh, the resultant temperature adjuster is therefore:

13965 GWh / 84.2℃ = 165.8 GWh/℃

That is for every ℃ that the temperature is below the threshold temperature of 0.5℃, the firm storage monitor will reduce by 165.8 GWh.

The firm temperature adjuster is summarised in Table 12.

**Table 12: Temperature Adjuster for Firm Monitors**

| Supply | Temperature Threshold (℃) | Temperature Adjuster (GWh/℃) |
|---|---|---|
| Storage | 0.5 | 165.8 |