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Ofgem's Proposed Final Decision on Gas Cash-Out Reforms

A Report for Centrica plc

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1. Background to Ofgem's Proposed Final Decision

On 31 July 2012, Ofgem issued a "Proposed Final Decision" on the "Gas Security of Supply Significant Code Review"[1] (the "Proposed Decision"). The Significant Code Review (SCR) concerns changes to cash-out arrangements during a Gas Deficit Emergency (GDE). Ofgem bases its Proposed Decision on an Impact Assessment,[2] issued at the same time, which in turn relies on two reports by consultants:

- London Economics (LE) estimates the Value of Lost Load (VOLL) for gas;[3] and
- Redpoint provides the modelling for the quantitative Cost Benefit Analysis (CBA).[4]

In this report, we review the analysis that Ofgem used in its Impact Assessment and identify some deficiencies in the inputs provided by these consultants. Appendix A and Appendix B contain more detail on the consultants' reports.

Our review of the Proposed Decision, the Impact Assessment and the consultant reports behind them reveals that Ofgem has not provided evidence that its proposed cash-out arrangements are in consumers' interests, owing to material errors and omissions in the work of its consultants and in Ofgem's use of their conclusions.

This report proceeds as follows:

- chapter 2 reviews Ofgem's use of the report produced by London Economics on the Value of Lost Load (VOLL);
- chapter 3 reviews Ofgem's use of the modelling by Redpoint of gas market operations;
- chapter 4 reviews Ofgem's Impact Assessment; and
- chapter 5 concludes.

Appendices A to F provide the background to conclusions in the main report.

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1 Ofgem (2012a), *Gas Security of Supply Significant Code Review – Proposed Final Decision*, Ofgem Ref 111/12, 31 July 2012.

2 Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision*, Ofgem Ref 112/12, 31 July 2012.

3 London Economics (2011), *Estimating Value of Lost Load – Final Report to Ofgem*, 5 July 2011.

4 Redpoint (2012), *Gas Security of Supply Significant Code Review: Economic modelling for Ofgem's proposed final decision*, July 2012.

2. Ofgem's Use of the LE Report

In this chapter, we review Ofgem's use of the estimates of VOLL provided by London Economics.

2.1. The Proposed Cash-out Price is Based on Unreliable Evidence

Ofgem relies on the report by London Economics (LE) to identify the Value of Lost Load (VOLL) and uses it to define the administered cash-out price that would be applied under its proposed arrangements when National Grid interrupts firm customers. Significant flaws in the survey method used by LE and errors in the ensuing calculations undermine the reliability of the conclusions in LE's report, which provides a fundamental basis for Ofgem's Proposed Decision.

2.1.1. Methodological problems with LE's stated preference study

LE uses a "stated preference" study to estimate customers' "Willingness-To-Pay" for gas and "Willingness-To-Accept" an interruption, as the basis for estimating the Value of Lost Load of domestic customers and of small and medium-sized enterprises (SMEs). As is often the case with stated preference studies, the exercise carried out by LE suffers from a number of significant failings which render its results unreliable. We describe LE's method and provide a detailed critique of its approach in Appendix A. Here, we note the three most salient points:

- LE estimates VOLL using the wrong figure for gas consumption by domestic customers;
- stated preference studies do not capture evidence from real market transactions and often exaggerate actual Willingness to Pay (WTP) or Willingness to Accept (WTA); and
- LE's survey produced a WTP that is higher than the WTA, a result that is inconsistent with the normal economic model of consumer valuations, and which casts doubt on the robustness of any conclusions of this study.

2.1.2. Incorrect demand level

Ofgem ultimately uses LE's estimates of domestic customers' WTA for interruptions to determine the administered cash-out price. LE estimates WTA by the following method:

- estimating the compensation that domestic customers might require, should they be interrupted *once* over a given *time horizon* (5, 20 or 50 years) for a given *duration* (a day, a week or a month). [5]
- discounting this compensation to obtain an expected *compensation per day* that consumers would require to accept this interruption, and hence the VOLL for one day; and
- dividing this VOLL per day by *average daily consumption* to derive a VOLL per therm.[6]

5 London Economics (2011), *Estimating Value of Lost Load – Final Report to Ofgem*, 5 July 2011, pages 25-27.

6 London Economics (2011), *Estimating Value of Lost Load – Final Report to Ofgem*, 5 July 2011, page 28, footnote 11.

LE's final step, dividing VOLL per day by average daily consumption, biases upwards its estimate of the VOLL, since it is equivalent to assuming that a GDE occurs on the *average day*. LE estimates the WTA separately for winter and summer, and Ofgem adopts a cash-out price that is closer to winter values than summer values. Moreover, study participants are likely to have understood that an interruption will occur on a day when their demand is above average or even at peak levels. Ofgem should therefore have converted the compensation per day into a VOLL per therm, by dividing VOLL per day by *peak day* consumption.

LE and Ofgem divide the VOLL per day by an average daily consumption of 1.54 therms (equivalent to a benchmark consumption of 16,500 kWh per annum divided by 365 days per year). In practice, the load factor of typical domestic customers is approximately 0.4, meaning that their consumption on peak days is about 4 therms (= 1.54 therms ÷ 0.4).[7] The impact of dividing daily compensation by this higher volume of gas consumption is to lower the estimate of VOLL per therm to 40% of Ofgem's estimate, from £20/therm to £8/therm. This is a significant effect, which Ofgem has not handled correctly.

2.1.3. Potential exaggeration of value

In general, stated preference studies are liable to the same criticism that they do not represent actual transactions or market behaviour. Academic literature on stated preference techniques finds repeatedly that they are not a reliable indicator of underlying preferences. As a recent study put it "most research finds significant divergence between stated and actual behaviours".[8] Participants may not fully understand the questions, they may be unable to make the necessary calculations in the time available or they may use the survey as an opportunity to express support for a particular ideal, such as environmental policies or reliable gas supplies (also called the "warm glow effect").[9] In these cases, stated preference studies will overstate consumers' actual Willingness To Pay or Willingness To Accept. Ofgem has not however made any allowance for such effects.

2.1.4. Inconsistent or perverse results

The fact that stated preference studies may not provide accurate estimates of WTA or WTP has particular resonance in the case of LE's report because the study produces counter-intuitive results. LE recognises, in the literature review accompanying its report, that WTA is generally higher than WTP for technical reasons reflecting rational consumer behaviour.[10] In this case, LE studies WTP as well as WTA on the grounds that "WTA may overstate VOLL

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7 Source: Centrica, quoting information on Average Daily Quantity (Presentation entitled "DE0201 Refresh: Demand Destruction by EUC") and load factors by LDZ for domestic customers provided by Xoserve ("Table LF11").

8 Johnston, R. (2006), "Is Hypothetical Bias Universal? Validating Contingent Valuation Responses Using a Binding Public Referendum", *Journal of Environmental Economics and Management* 19(3), page 469.

9 Arrow, K.., Solow, R., et al., Report of the NOAA Panel on Contingent Valuation, 11 January 1993, page 17.

10 London Economics (2011), *Estimating Value of Lost Load – Final Report to Ofgem*, 5 July 2011, page 81. See also discussions in Horowitz, J, and McConnell, K. *Willingess To Accept, Willingness to Pay and the Income Effect,* Department of Agricultural and Resource Economics, Univ. of Maryland. In simple terms, paying compensation in the WTA case makes consumers wealthier, so they would be expected to value energy more highly than in the WTP case, due to the "income effect" on consumption.

in choice experiments, and WTP may be seen as a more conservative estimate". [11] However, in LE's survey, consumers' WTP is higher than their WTA, which is a perverse result.

LE conjectures that this perverse result may have arisen because:

- "consumers have difficulty forming preferences and hence responding to hypothetical scenarios that occur so infrequently"; and
- "respondents may not have properly taken into account the total amount payable per day of outage for very infrequent interruptions". [12]

The doubts expressed in these observations imply that the stated preference study is not an appropriate method for estimating VOLL. Valuing consumers' lost load in the case of a GDE depends crucially on consumers' ability to conjure up a valuation for a very infrequent event. The values that consumers impute to such events will be unreliable, if they cannot easily imagine the circumstances surrounding the event. In any case, the counter-intuitive and unexpected results suggest that this particular exercise may have been compromised and that the results do not accurately reflect consumers' actual VOLL.

2.2. Ofgem's Impact Assessment Applies LE's Results Incorrectly

Ofgem states in its Impact Assessment that it has taken the proposed cash-out price of £20/therm from an estimate of the VOLL for domestic customers based on a Willingness To Accept in the LE report.[13] In fact Ofgem has picked:

1. an incorrect estimate of domestic customers' WTA, because it has taken the VOLL applicable to a duration and frequency of outage which does not match the duration and frequency of a GDE; and
2. an incorrect estimate of the VOLL applicable when firm customers are disconnected, because the selected value applies to domestic customers alone, and they form only one section of the firm customers who will be affected by a GDE.

We explain these points further below.

2.2.1. Ofgem selects the wrong VOLL for domestic customers

LE estimates different values of WTA for different frequencies of interruption in the supply of gas to domestic customers.[14]

- For a domestic customer interruption occurring *once in 20 years*, LE estimates a WTA of:
  - £22.60/therm for a 1-day interruption;
  - £19.40/therm for a week-long interruption; and

[11] London Economics (2011), *Estimating Value of Lost Load – Final Report to Ofgem*, 5 July 2011, page 81.

[12] London Economics (2011), *Estimating Value of Lost Load – Final Report to Ofgem*, 5 July 2011, page 27.

[13] Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 21, para 3.33.

[14] Note: the following bullets all refer to winter interruptions, the most likely time of year for an interruption to occur.

  - £6.90/therm for a month-long interruption.[15]

- For a domestic customer interruption occurring *once in 50 years*, LE estimates a WTA of
  - £12.70/therm for a 1-day interruption;
  - £11.00/therm for a week-long interruption; and
  - £4.50/therm for a month-long interruption. [16]

Since LE's estimate of customers' WTA varies widely, depending upon the frequency and duration of interruption, it is important to select the value that corresponds most closely to the likely frequency and duration of interruptions under a GDE, so that the resulting cash-out price offers an efficient price signal to market participants.

In its Impact Assessment, Ofgem quotes the probability of outages for different customer types produced by the Redpoint modelling under the proposed arrangements.[17] In both "Option 1" and "Option 2", the probability of interruption of "firm NDM customers" (i.e. the category closest to domestic customers) is 1-in-167.[18] Ofgem also states that for the purposes of Redpoint's modelling "we assumed that the minimum period that NDM customers would be interrupted for would be 14 days".[19] Ofgem should therefore have chosen the estimate of WTA in LE's survey that corresponds most closely to the same probability of outage (1 in 167) and the duration of interruption (14 days).

For a 1-in-50 event (the most infrequent interruption included in the study) with a duration of 1 week (closest to 14 days) LE estimates a WTA of £11/therm.[20] This estimate of WTA would be an overestimate of the WTA for a 1-in-167 event lasting 14 days, since LE found that WTAs per therm were lower for interruptions that are less frequent and longer. The WTA of domestic customers shown in LE's report that corresponds to Ofgem's definition of a GDE is therefore at most £11/therm.

The combined effect of (1) taking this lower estimate of WTA and (2) adjusting it to a peak day level of consumption, as discussed in section 2.1.2, is to reduce the estimated VOLL for domestic customers to £4.40/therm. Adopting a higher value would require evidence from some source other than the LE study.

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[15] London Economics (2011), *Estimating Value of Lost Load – Final Report to Ofgem*, 5 July 2011, page 28, Figure 14.

[16] London Economics (2011), *Estimating Value of Lost Load – Final Report to Ofgem*, 5 July 2011, page 28, Figure 14.

[17] Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 16, Table 3.

[18] Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 16, Table 3.

[19] Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 21, Footnote 11.

[20] London Economics (2011), *Estimating Value of Lost Load – Final Report to Ofgem*, 5 July 2011, page 28, figure 14.

2.2.2. Ofgem misapplied the VOLL estimate for domestic customers

To provide efficient signals, the administered cash-out price would have to equal the VOLL of the marginal customer class currently being interrupted, i.e. the highest VOLL of customers interrupted in order of increasing VOLL. This approach would argue for the implementation of a two-step (or multi-step) VOLL, with the cash-out price rising first to the VOLL for industrial customers when they were interrupted, and then to the higher VOLL for NDM customers when they were interrupted.[21]

Ofgem has argued instead in favour of applying an administered cash-out price based solely on the VOLL of a domestic customer from the time when any firm customer is interrupted.[22] Such a cash-out price equal to the VOLL of a domestic customer would only provide efficient signals if only domestic customers were ever at the margin. In practice, when an outage is arranged by isolating (i.e. shutting down) part of a network, the disconnections affect both domestic customers and SMEs simultaneously.

A consistent estimate of the appropriate cash-out price at the time of such a disconnection would be based on the average VOLL of all firm customers being interrupted. That average VOLL would represent the true value of any additional gas that would be (or would have been) made available, because it would be (or would have been) supplied to a mixture of different customer types will different VOLLs. LE estimates WTA for SMEs as well as for domestic customers, and the WTAs for SMEs are substantially lower than those for domestic customers:

- For an SME outage *once in 20 years*, LE estimates a WTA of
  - £0.84/therm for a 1-day interruption;
  - £0.71/therm for a week-long interruption; and
  - £0.19/therm for a month-long interruption. [23]
- For an SME outage *once in 50 years*, LE estimates a WTA of:
  - £0.47/therm for a 1-day interruption;
  - £0.39/therm for a week-long interruption; and
  - £0.11/therm for a month-long interruption.[24]

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[21] Ofgem discounts the prospect of introducing a multi-step VOLL by suggesting that it would "weaken incentives" for signing interruptible contracts, but without further analysis. Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 20, para 3.29.

[22] See for example Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 5. "Under our proposals cash-out would be set at £20 per therm (an estimate of domestic customers' Value of Lost Load or VoLL) in a GDE once gas supplies to firm customers are interrupted.".

[23] London Economics (2011), *Estimating Value of Lost Load – Final Report to Ofgem*, 5 July 2011, page 28, Figure 14.

[24] London Economics (2011), *Estimating Value of Lost Load – Final Report to Ofgem*, 5 July 2011, page 28, Figure 14.

In the case of network isolation, the appropriate VOLL would be an average of these SME VOLLs (where the figure of £0.39/therm corresponds most closely to Ofgem's definition of a GDE) and the VOLL for domestic customers (£11/therm – see above), weighted by the likely mix of the consumption being interrupted. We do not have the data on network configurations needed to identify the relevant proportions of each customer type, but including even a small proportion of SMEs would significantly lower the average VOLL applicable to a case of network isolation. See Table 2.1, which applies these estimates of VOLL *before* adjusting to peak day consumption (section 2.1.2), which would lower the estimates even further.

Table 2.1
Average VOLL (£/therm) Arising From
Isolating Domestic and SME Customers in Different Proportions

Percentage of Total Load Lost Through Network Isolation		Domestic	SMEs
		Individual VOLL/therm	
		£11.00	£0.39
Domestic	**SMEs**	**Average VOLL/therm**	
90%	10%	£9.94	
80%	20%	£8.88	
70%	30%	£7.82	

2.3. Summary

LE's study of customers' Willingness to Pay (WTP) for gas and Willingness to Accept (WTA) an interruption uses a method which is know to be subject to some biases. The unreliability of the method is indicated by the perverse ordering of the results for WTP and WTA.

Even taking the results for VOLL per day at face value, however, LE has miscalculated the corresponding VOLL per therm, and Ofgem has not selected the results which correspond most closely to the definition of a GDE, or applied the values in a way that corresponds to real conditions in cases of network isolation. Correcting for these errors leads to a much lower value of VOLL than the proposed value of £20/therm.

3. Ofgem's Use of the Redpoint Model

In this chapter, we review Ofgem's use of the modelling results produced by Redpoint.

3.1. Redpoint's Modelling for the Quantitative CBA Is Unreliable

Ofgem relies on Redpoint for the modelling to support its quantitative CBA. We provide an explanation of the Redpoint model in Appendix B. Here we summarise the main reasons why Redpoint's model does not provide an accurate picture of the costs and benefits of the proposed arrangements:

- **Redpoint's model of trader's behaviour is myopic and backward-looking:** Redpoint's model contains no forward curve, nor any way in which traders can anticipate the effect of random shocks. Their use of storage on Day X is modelled with respect to the time of year and to an average of prices over days before Day X, but does not allow for any reaction to (for instance) the observation that the failure of an interconnector has made a GDE more likely. This simplification of traders' actual behaviour has important consequences for the modelling of a GDE.
- **Redpoint's analysis underestimates current security of supply**: Redpoint's model assumes that the cash-out price is (always) frozen at the levels applicable to *pre-crisis* conditions (i.e. based on the balance of supply and demand within the day before a GDE occurs), rather than the prices likely to apply when traders anticipate a GDE. The storage component of the model does not hold back additional gas when the prospect of a GDE is looming, because it does not model traders' expectations (see above). Modelling the continued use of gas according to normal seasonal patterns in the days before a possible GDE increases the likelihood that a forced interruption will be necessary later and overstates the actual threat to security of supply. Redpoint's model also embodies the assumption that no consumers in the industrial and commercial (I&C) sector have signed either interruptible gas contracts or contracts that pass through daily prices (or similar short term signals).[25] This extreme assumption is likely to underestimate the actual volume of interruptible (or price responsive) demand available at present. As a result, the model will overstate both the threat to security of supply under the current arrangements, and the net benefit of implementing the proposed arrangements.
- **Redpoint's analysis does not reflect the responsiveness of imports in times of crisis:** Setting the cash-out price higher during a GDE does not call forth much additional supply in the form of additional imports in Redpoint's model. Indeed, Ofgem itself has recently argued that imports do not respond efficiently to price differentials.[26] Most of the benefits come from assuming more efficient interruption of consumers. However, Redpoint's model still overstates the volume, and/or understates the cost, of additional gas that will come through the interconnectors in an emergency under the proposed arrangements, for the following reasons.

[25] Redpoint (2012), *Gas Security of Supply Significant Code Review: Economic modelling for Ofgem's proposed final decision*, July 2012, page 31.

[26] Ofgem (2012c), Open letter: Call for evidence on the use of the gas interconnectors on Great Britain's (GB's) borders and on possible barriers to trade, 1 October 2012, page 2, Figure 1.

- Redpoint estimates the responsiveness of gas prices in times of crisis using data based on normal conditions (i.e. it "extrapolates" behaviour in unusual conditions from reactions to normal price differences).

- Moreover, Redpoint assumes that continental prices are exogenously set equal to oil-indexed prices, independently of conditions in Britain (except in the cases where continental price shocks cause a GDE). In fact, when NBP prices rose dramatically in Britain during the winter of 2005-06, prices also rose on continental gas hubs such as the Zeebrugge hub in Belgium and the TTF hub in the Netherlands, (See Appendix F). NBP and continental hub prices have exhibited even stronger correlations since the winter of 2005-06, with correlations typically exceeding 96% (Appendix F).[27] This reaction to British gas market conditions in European gas markets (which might be supported or compounded by retaliatory measures adopted by European energy regulators) would reduce the volume and increase the cost of gas imports into Britain during a GDE. By omitting this effect, Redpoint's model overstates the benefits of the proposal to raise cash-out prices at such times.

- **Redpoint's assumption about the disconnection order may not reflect National Grid's true emergency procedures:** Redpoint assumes that National Grid would currently disconnect "pivotal" CCGTs (i.e. those needed to "keep the lights on") before disconnecting firm DM gas customers, despite the fact that Redpoint awards firm electricity customers a higher gas-equivalent VOLL than firm gas customers.[28] (In practice, domestic customers may not even be able to consume gas at the desired level, if they have no electricity to operate central heating systems and other controls.) A large part of the benefit of moving to the proposed arrangements (£54.1 million) is attributed to an increase in the security of supply for firm electricity customers, caused by I&C customers choosing to disconnect their own demand when the price rises, and leaving more gas for use in pivotal CCGTs.[29] This suggests a large portion of the benefits of the proposal depends solely on the assumed order of disconnection, rather than the cash-out price *per se*. This reordering may not happen if, in reality, National Grid would choose to disconnect gas customers before disconnecting electricity customers, and the corresponding benefits could in any case be achieved by re-arranging the priority order of such disconnections instead of reforming cash-out pricing rules.

3.2. Ofgem's Use of Redpoint's Modelling is Selective

Ofgem recognised that the Redpoint model used for its Cost Benefit Analysis has a number of limitations including that:

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[27] For example, the opening of the BBL pipeline which connects the Netherlands and UK has resulted in much greater price coupling of the NBP and TTF hub prices from 2007.

[28] Redpoint (2012), *Gas Security of Supply Significant Code Review: Economic modelling for Ofgem's proposed final decision*, July 2012, pages 31-32.

[29] Redpoint (2012), *Gas Security of Supply Significant Code Review: Economic modelling for Ofgem's proposed final decision*, July 2012, page 50.

- "the quantitative CBA does not include any economic knock-on effects, externalities and social costs caused by a GDE";[30]
- "the quantitative CBA assumes risk neutrality and therefore weights all losses and gains equally";[31] and
- "indirect costs, such as impact on competition (through credit requirements, liquidity, barriers to entry and financial distress) are not considered in the quantitative CBA".[32]

Nevertheless, Ofgem relies upon Redpoint's modelling for its *quantitative* CBA. In so doing, Ofgem ignores the impact of the important categories of cost listed above. These impacts are significant and one-sided. For example, Redpoint includes the impact of the proposed arrangements on security of supply for electricity customers in its CBA. Redpoint does not, however, calculate the impact on electricity prices or electricity demand and Ofgem does not discuss such effects in its Impact Assessment.

In its *qualitative* CBA, Ofgem makes selective use of the advantages and disadvantages of the proposed arrangements produced (or ignored) by Redpoint's model. For example, Ofgem highlights the security of supply benefit of allowing higher cash-out prices, which is attributed in part to a reaction in the gas market, but Ofgem does not count the cost to consumers of the resulting increase in gas market prices:

> "In reality, we expect cash-out reform to be more effective at reducing the likelihood and impact of emergencies than predicted by the modelling, as the model does not account for expectations of rising gas prices. We would expect prices to rise to higher levels under cash-out reform compared to current arrangements before any firm customers are interrupted. This is because there would be an expectation that prices would potentially rise to VOLL; in particular in slowly developing emergencies. We anticipate that this would attract additional available supplies of gas into GB which could be sufficient to allow supplies to firm customers to be maintained."[33]

3.3. Summary

We identified some deficiencies in Redpoint's modelling of gas traders' behaviour. They represent understandable simplifications from the modeller's point of view, but they cause the model to underestimate security of supply in current conditions and to over-state the benefits of moving to the proposed arrangements. Ofgem has used Redpoint's results rather selectively, identifying some positive aspects for the proposed arrangements, but not the corresponding negative impacts on customers.

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30 Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 37, para 3.107.

31 Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 37, para 3.107.

32 Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 37, para 3.107.

33 Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 15, para 3.5.

4. Ofgem's Impact Assessment

In this chapter, we review Ofgem's assessment of the impact of the proposed new cash-out arrangements.

4.1. Ofgem Understates the Impact on Customer Bills

Ofgem acknowledges that retail costs are likely to increase as a result of the introduction of an administered cash-out price at a price of £20/therm:

> "The modelling suggests that retail costs are likely to increase slightly. Expressed in average annual consumer bills, this would be £0.46 for option 1 and £0.11 for option 2."[34]

Ofgem does not provide an explicit reference for this claim, but the estimated cost of £0.11 per customer per year for the proposed arrangements (under option 2) matches a similar statement in the Redpoint report.[35] Redpoint explains how it calculates an £0.11 rise in domestic customers' energy bills based on an average consumption of 16,500 kWh per year and an equal allocation of "the retail cost line of the CBA" over "annual NPG gas demand of 57.9bcm".[36]

Redpoint's calculation of the change in "the retail cost line" is the sum of three components:

- the "cash-out liability", Redpoint's term for the compensation payments for involuntary interruptions;
- payments to interruptible customers for DSR contracts; and
- the change in the cost of gas caused by a change in the volume of gas supplied and delivered to consumers.

Redpoint substantially underestimates the payments to interruptible customers for DSR contracts. Redpoint (and hence Ofgem) also misrepresents the "change in the cost of gas". The annual cost to consumers is therefore much higher than £0.11, as explained below.

4.1.1. Ofgem ignores the costs of procuring interruptible contracts

Much of the change in the way in which Redpoint expects the gas market to work under the proposed arrangements depends on extensive use of Demand Side Response (DSR). Redpoint calculates the "payments to interruptible customers for DSR contracts" as the cost to those DSR customers, based on their own VOLL.[37] In practice, shippers will not only

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34 Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision*, (112/12), 31 July 2012, page 23, para 3.41-2.

35 Redpoint (2012), *Gas Security of Supply Significant Code Review: Economic modelling for Ofgem's proposed final decision*, July 2012, page 50.

36 Redpoint (2012), *Gas Security of Supply Significant Code Review: Economic modelling for Ofgem's proposed final decision*, July 2012, page 50, footnote 47.

37 Redpoint (2012), *Gas Security of Supply Significant Code Review: Economic modelling for Ofgem's proposed final decision*, July 2012, page 49.

have to pay customers their own VOLL to interrupt their demand, but will also have to offer customers a substantial further discount to persuade them to accept interruptible contracts. We provide a full and formal description in Appendix C and Appendix D. Here, we outline the main intuitions.

Ofgem assumes that the cost of DSR will equal the VOLL of the customer class being interrupted (or equivalently a discount to the cost of a firm gas contract equal to the expected value of the customer's VOLL in the event of a GDE). In fact, VOLL represents the minimum price at which a customer would be willing to disconnect.

Under the proposed arrangements, firm customers receive compensation for being disconnected at a rate of £20/therm – the supposed VOLL of a domestic customer – which changes their incentives to sign interruptible contracts. Setting aside any concerns about the development of a perfectly competitive market for interruptible contracts (discussed in detail in section 4.2), Ofgem's analysis excludes the impact on the cost of DSR of offering this compensation to firm customers.

Under the proposed arrangements, industrial customers can choose to sign either a firm or an interruptible contract. If customers sign a firm contract, they obtain £20/therm compensation for being interrupted. Therefore, the opportunity cost of signing an interruptible contract consists of two components:

- the opportunity cost of receiving less gas by being voluntarily interrupted, valued at their VOLL; and
- the opportunity cost of foregoing compensation at £20/therm for being involuntarily interrupted.

As a result, the cost of DSR contracts with industrial and commercial customers will include an *additional discount*, over and above what Redpoint and Ofgem have assumed, to account for the opportunity cost of foregoing compensation by signing an interruptible contract. Shippers must ultimately recover the costs of offering these discounts from firm customers, including domestic customers. Ofgem's analysis of the impact of the scheme on domestic customer's energy bills ignores the impact of these additional discounts.

Based on Redpoint's modelling, Ofgem states that the current arrangements will reduce the expected annual volume of unserved energy to NDM customers by 104,000 therms per year.[38] This "reduction in load reduction" represents additional gas supplied to NDM customers. Since Ofgem also quotes its estimates of the costs of the measures, we can estimate how much NDM customers are paying per therm for this increase in security of supply.

Ofgem states that the impact on domestic customer bills would be £0.11 per customer, based on text in Redpoint's report.[39] Assuming 23 million NDM gas customers,[40] and a cost of

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38 Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 16, Table 2. 104,000 is the difference between the volume of unserved energy under current arrangements (722,000 therms) and under Ofgem's proposed arrangements (618,000 therms).

39 Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 16, Table 2.

£0.11 per customer per annum yields a total cost of £2,530,000 or £24.33 per therm of additional gas supplied to NDM customers (£24.33 per therm = £2.53 million ÷ 104,000 therms).[41,42] The proposed arrangements therefore impose a cost on NDM customers which – even by Ofgem's reckoning – lies above their willingness to pay for the additional gas required to improve their security of supply.

4.1.2. Ofgem understates the rise in consumers' energy bills

Ofgem reports the figure of £0.11 per customer per year as if it represented the total increase in the annual energy bill of a typical domestic customer. Detailed review of Redpoint's report shows that this figure represents only a small part of the additional costs that domestic customers will have to pay.

Redpoint provides a detailed description of how it estimates the change in the cost of gas in its report, as follows (*emphasis added*):

> "Firstly, in periods when the cash-out price is allowed to rise to VoLL and extra gas is imported into GB as a result, the cost of the *extra* imported gas is reflected in the total cost of gas line as quantity of *extra* gas imported times the cash-out price. Secondly, in periods when the cash-out price rises above the interruption price of the DM gas demand tranches that become interruptible under the reform options and there is no underlying gas shortage, those tranches are interrupted under cash-out reform but not under the current arrangements. The *reduction* in the total cost of gas purchased by suppliers as a result of cash-out reform is reflected in the total cost of gas line as *quantity of gas interrupted* times the cash-out price under the current arrangements."[43]

Thus, Redpoint's CBA takes into account only the cost of *the difference in gas volumes* delivered to consumers, based on a comparison of total consumption between current arrangements and the proposed arrangements. This calculation excludes any *difference in the price of gas* for the volume of gas that is common to both arrangements. Redpoint's CBA treats any price rise faced by British energy consumers for a given volume of gas merely as a transfer to other members of society represented by upstream shippers, traders, importers and/or producers.[44]

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[40] We assume 23 million NDM customers. According to DECC statistics, there are approximately 22.7 million customers with annual consumption of less than 72,000 kWh. See DECC (2011), *Digest of United Kingdom Energy Statistics*, page 72, table 3.

[41] We assume the same bill impact on SME customers as for domestic customers at £0.11 per customer per annum. Since SMEs might be expected to have a higher demand than domestic customers, this assumption is likely to be a slight underestimate of the impact on customers' bills.

[42] LE assigns a VOLL to both domestic and SME customers that lies below £24.33 per therm. London Economics (2011), *Estimating Value of Lost Load – Final Report to Ofgem*, 5 July 2011, page vi, Table 1. Ofgem adopts LE's valuations.

[43] Redpoint (2012), *Gas Security of Supply Significant Code Review: Economic modelling for Ofgem's proposed final decision*, July 2012, page 49.

[44] In fact, we understand Redpoint's model assumes that any higher prices paid by consumers are captured by shippers and traders within the UK, but only because the model assumes that the proposals do not result in any higher prices being paid to importers and producers. It is not clear whether this assumption reflects a useful simplification (since such effects would in any case be excluded from Redpoint's CBA), or whether it represents a theory about market behaviour.

Allowing the price of gas to rise to £20/therm in a crisis, will not merely affect the price of the *additional* gas that Britain imports but also the price of all gas bought and sold in Great Britain (once existing contracts expire). Gas purchased by shippers during a crisis (additional or otherwise) in spot or prompt markets will cost £20/therm. The price of any gas sold in a forward contract, on the other hand, would reflect the current probability of the price rising during the term of the contract to £20/therm, due to the possibility of a GDE occurring, whether it does or not. This probability might be relatively low (but positive) for many years, but would rise if a gas shortage seemed likely. Hence, consumers would suffer a price impact of the proposals over all their consumption, a factor which Ofgem has ignored when quoting the impact on domestic customers' energy bills. We provide a full diagrammatic description of these missing costs from Ofgem's CBA in Appendix A.

Redpoint's method applies the correct principles for a CBA capturing the benefits to society as a whole (worldwide), but it does not assess the costs and benefits of moving to the proposed arrangement from the point of view of the UK or of energy consumers in Great Britain. It is therefore a mistake to present Redpoint's results as an indication of the total cost of the proposed arrangements to domestic customers.

4.2. Ofgem's Assumptions About the DSR Market Are Inconsistent

Ofgem states in its Proposed Decision and Impact Assessment that its decision depends upon the assumption that a market for interruptible contracts will emerge:

> "Our proposed final decision is based on an assumption that a market for interruptible contracts will develop in the I&C sector. We see no reason why it would not emerge."[45]

Ofgem's statement that it sees "no reason why [a market for interruptible contracts] would not emerge" conflicts with the reasons given elsewhere in the Proposed Decision and Impact Assessment for adopting an administered cash-out price as high as £20/therm. Ofgem justifies this aspect of the proposal as necessary to encourage a DSR market to develop:

- First, Ofgem states that an administered cash-out price of £20/therm provides a "strong incentive" for a market for interruptible contracts to develop; [46] and
- Second, Ofgem rejects the proposal of a two-step VOLL on the basis that it "would weaken incentives for interruptible contracts to be arranged, leading to lesser security of supply benefits than a single VoLL."[47]

Ofgem's assertion that it is important to have a "strong incentive" for DSR is inconsistent either with its assumption that a market for interruptible contracts will emerge, or with the scope of its quantitative cost benefit analysis.

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45 Ofgem (2012a), *Gas Security of Supply Significant Code Review - Proposed Final Decision,* (111/12), 31 July 2012, page 6, para 3.107.

46 Ofgem (2012a), *Gas Security of Supply Significant Code Review - Proposed Final Decision,* (111/12), 31 July 2012, page 6, para 3.107.

47 Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 20, para 3.29.

- On one hand, Ofgem may believe that the DSR market is not frictionless and competitive and that customers face significant transactions costs when agreeing interruptible contracts. Ofgem would then be correct to assert that a "strong incentive" (i.e. a big difference between I&C customers' own VOLL and the £20/therm cash-out price) is needed, to stimulate the development of the market for interruptible contracts.
  - However, Ofgem cannot then argue that there is no reason why a market would not emerge, as by its own admission transactions costs would present a significant barrier.
  - More importantly, Ofgem's Cost Benefit Analysis should have included the costs of overcoming those barriers, such as transactions costs incurred in negotiating the DSR contracts that Ofgem (and Redpoint) expect to emerge. The current CBA does not include these costs.
- On the other hand, Ofgem may believe that the market for interruptible contracts would be frictionless and competitive, without any significant transactions costs.
  - In such circumstances, Ofgem and Redpoint would not need to allow for transactions costs of a market in DSR contracts in a CBA.
  - However, at the same time Ofgem would not need to provide a "strong incentive" for the development of this market, because even a small incentive would be sufficient to encourage it to emerge. Ofgem's argument against a "two-step" cash-out price would then fall away.

Ofgem has therefore adopted two inconsistent positions within the same CBA: (1) that there are no transactions costs associated with the development of a market in DSR; and (2) that this market will not emerge without a large incentive, which is only required to overcome significant transactions costs. These two positions cannot be true simultaneously.

There is further evidence that the CBA should have included transactions costs of DSR. Redpoint assumes in its modelling that Tranche 3 I&C customers with a VOLL of £16.61/therm will not interrupt their consumption, even when the cash-out price rises to £20/therm. Leaving aside the small change in the probability of interruption that a DSR contract would cause, this assumption implies that Tranche 3 I&C customers would incur transaction costs when agreeing a DSR contract of at least 2 to 3 pence per therm (£3.39/therm divided by the probability of interruption for that customer class).[48] Assuming that customers in I&C tranches 1 and 2 incur the same transactions costs to agree DSR contracts yields an estimate of total transactions costs of £93.5 million per annum. Neither Redpoint nor Ofgem have included this cost in their analysis.[49] This omitted cost is much larger than the Net Present Value of the proposed arrangements currently shown in Ofgem's

[48] Probability of a GDE is 1 in 128 according to Redpoint. Redpoint (2012), *Gas Security of Supply Significant Code Review: Economic modelling for Ofgem's proposed final decision*, July 2012, page 47.

[49] Calculation assumes 10.5 kWh/cm, 29.31 kWh/therm and Redpoint's assumption of 27mcm of I&C industrial demand from Redpoint (2012), *Gas Security of Supply Significant Code Review: Economic modelling for Ofgem's proposed final decision*, July 2012, page 47.

Cost Benefit Analysis.[50] It would easily turn the positive Net Present Value into a negative one, indicating that the proposed arrangements are not beneficial to society.

4.3. Ofgem Ignores Potential Impacts on Competition and Credit

Ofgem dismisses concerns about the impact of the new arrangements on competition, liquidity and credit arrangements without providing any analysis of the implications. Ofgem's response to concerns raised by previous respondents include statements (1) that industry did not provide sufficient evidence[51] and (2) that industry could make parallel changes to the credit arrangements if the current arrangements were insufficient. [52] Ofgem does not provide any analysis of its own in response to concerns about liquidity during a crisis, the sufficiency of current credit arrangements, the costs of changing the credit arrangements, or distortions to competition resulting from any remaining credit problems, illiquidity or threats of bankruptcy.

In discussing these topics, Ofgem makes two significant errors when assessing competition and credit arrangements during a GDE: (1) misunderstanding the potential for market power in a GDE; and (2) miscalculating shippers' exposures during a GDE. These errors render invalid its current conclusions on the impact of the proposed arrangements on market power in a GDE, on the risks faced by shippers and on security of supply.

First, Ofgem argues that shippers holding gas in a shortage will not have market power and so cannot withhold gas and force a GDE to occur.[53] However, this argument overlooks the position that shippers will find themselves immediately before or during a GDE, when the total supply of gas is limited. Lack of gas in the market and the growing shortage means that many shippers will become "pivotal" players in the market, capable of triggering an emergency by withholding a little gas – or merely by failing to procure a small additional volume of gas – even if they have a small market share.[54]

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50 Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 39, Table 9.

51 "We note that we asked industry repeatedly for evidence as to its claims regarding the effect of cash-out reform on financial distress and credit arrangements. Unfortunately, little evidence was submitted." Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 25, para 3.54.

52 "We note that the risk of shippers defaulting is with the industry as a whole (through the neutrality mechanism). If industry does not think that the current credit arrangements are fit for purpose (e.g. to discourage the creation of shell companies), then industry can use existing processes that allow participants to suggest changes and Ofgem will consider these if raised.14 We believe that the industry is better placed to review and potentially propose changes to these arrangements", Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 25, para 3.56.

53 "The price available for additional gas would probably be very high and there would be no guarantee of achieving a higher price than the prevailing market price. There is also a question as to whether any supplier of gas holds enough market power to force firm interruptions." Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 18, para 3.21.

54 This possibility may affect the likelihood of a GDE occurring, and of prices reaching VOLL, but it does not change the factors that determine the pricing of gas before and during a GDE, as discussed in Appendix E.

In a related line of argument, Ofgem states that ex post regulation will be sufficient to restrain the abuse of market power.[55] In practice, it would be impractical to identify individual shippers who decided not to procure additional gas, or to hold back gas for future sales, as anti-competitive use of market power, rather than as prudent and pro-competitive anticipation of future market conditions.

Second, Ofgem misrepresents the (credit and bankruptcy) risks faced by shippers. Ofgem calculate a "maximum" exposure to cash-out at £20/therm as £976 million.[56] This analysis, however, does not accurately reflect the risks and exposures during a GDE that shippers would face under the proposals. It only takes into account their exposure and liability for compensating *disconnected* customers. However, the risks faced by shippers extend beyond this compensation, as they would face a volume risk on their continuing level of sales during a GDE. As a result of Ofgem's proposals, shippers may have to purchase large volumes of gas at short notice and at very high prices when confronted with unexpectedly high demand.

Ofgem appears to assume that all shippers will avoid such risks by adopting the appropriate risk mitigation strategies. However, the cost of options to manage such volume risk in infrequent, but severe market conditions will be very hard to estimate and is likely to be dominated by transactions cost, rather than the intrinsic and extrinsic cost of an out-of-the-money option. Arranging such protection would drive up the cost of acting as a shipper or supplier (especially an independent one who does not own substantial interests in gas production), which will have a detrimental effect on competition in the gas market.

These risks, ignored by Ofgem, affect the prospects for shippers' solvency, for market liquidity and for competition in the market, but they do not appear in Ofgem's analysis of these topics.

4.4. Summary

Ofgem appears to have misinterpreted a statement in Redpoint's report and therefore to have underestimated the cost of the current proposals to energy consumers by a significant amount. Ofgem also makes conflicting statements about the prospects for a market in DSR to emerge, which suggest either that the cash-out price need not be as high as £20/therm or that arranging DSR will incur substantial transactions cost which are missing from the CBA. Ofgem also recognises some of the problems related to credit, but underestimates the risk and does not allow for the costs of managing it. Including the transactions costs of DSR and credit control could easily turn the positive net benefit of the current proposals (as reported by Ofgem) into a net cost.

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[55] "Shippers could also be in breach of their licence obligations if they pursue a course of conduct which is likely to prejudice the safe and efficient operation and balancing of the system. Furthermore, shippers could potentially be in breach of their obligations under the Regulation on Energy Market Integrity and Transparency (REMIT)." Ofgem (2012), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 18, para 3.21.

[56] Ofgem (2012b), *Gas Security of Supply Significant Code Review – Impact Assessment for the Proposed Final Decision,* (112/12), 31 July 2012, page 13, para 3.59.

5. Conclusion

Ofgem has failed to provide convincing evidence that a change to cash-out reform in GB is in consumers' interests for the following reasons:

- Ofgem sets the proposed administered cash-out price too high, due to a number of errors in LE's calculation of VOLLs and in Ofgem's selection of the appropriate figure for a GDE;
- Redpoint's quantitative Cost Benefit Analysis does not provide an accurate picture of the costs and benefits of changing the cash-out arrangements, because it does not properly take account of gas traders' behaviour before a GDE;
- Ofgem makes a fundamental error in its understanding and assessment of the costs to consumers, causing a significant underestimate of the cost to consumers attributable to the proposals;
- Ofgem's assumptions about the market for interruptible contracts are inconsistent, such that the CBA ignores either the risk that a market for interruptible contracts will not emerge or that it will emerge but will impose an additional (and unmeasured) cost; and
- Ofgem has also neglected to analyse material factors affecting the costs and benefits of changing the cash-out regime in its analysis.

In addition, material errors and omissions in Ofgem's work and in the work of its consultants cast doubt on the case that Ofgem has made for cash-out reform. Thus, Ofgem has not provided adequate evidence that moving to its proposed cash-out arrangements is in consumers' interests.

Appendix A. London Economics Report

This appendix reviews the report by London Economics entitled "Estimating Value of Lost Load",[57] which Ofgem uses to justify the imposition of a £20/therm cash-out price. This appendix proceeds as follows:

- Section A.1 sets out London Economics' Method; and
- Section A.2 sets outs its results.

We conclude that London Economics' results may be driven, at least partly, by weaknesses in the stated-preference technique used in this study and in the interpretation of the results.

A.1. Method

London Economics (LE) set out to estimate the VOLL for domestic customers, SMEs and a wide range of industrial applications. LE used a different methodology for estimating VOLL for domestic customers and SMEs on the one hand and electricity and I&C customers on the other. We provide a very brief overview of the methods in the sections below.

A.1.1. Domestic and SME Customers

LE used a survey approach for domestic customers and SMEs comprising three components:[58]

- An online survey of 1,000 respondents selected by YouGov to be representative of the British population as a whole;
- A face-to-face survey of 100 domestic respondents from vulnerable groups (pensioners, the disabled and the fuel poor); and
- A survey conducted over the phone for 500 SME respondents, for which LE (or its survey partner) chose the profile of respondents to match the profile of SME gas consumers.

LE asked respondents to answer questions by presenting each respondent with ten choice cards. Each choice card offered the respondent a choice between two alternative options and a "don't know" option.[59] The options on each choice card specified the following attributes:

- duration of interruption;
- season of interruption;
- frequency of interruption; *and*
  - an increase in annual bill (Willingness To Pay method); or
  - a daily compensation amount to be paid while the gas supply was interrupted (Willingness To Accept method).

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[57] London Economics (2011), *Estimating Value of Lost Load*, 5 July 2011.

[58] London Economics (2011), *Estimating Value of Lost Load*, 5 July 2011, pages 9-10.

[59] London Economics (2011), *Estimating Value of Lost Load*, 5 July 2011, page 7.

LE estimated a Willingness To Pay and a Willingness To Accept from the choices made by respondents.

A.1.2. Electricity and I&C customers

For electricity generators and I&C customers, LE calculated the VOLL using a Gross Value Added (GVA) approach. In practice, Ofgem does not use LE's calculations for electricity customers, as Redpoint's model includes endogenous fuel switching in the electricity sector and uses a standard VOLL for electricity customers in its CBA.

LE's method for assessing the VOLL of I&C customers works divides the Gross Value Added of a particular industry by the volume of gas it consumes and adjusts that value for a "critical factor", as follows:[60]

$$VOLL_i = \frac{GVA_i}{GU_i} \times CF_i$$

Here, $VOLL_i$ is the VOLL for industry i, GVA_i is the Gross Value Added for an entire industry, GU_i is the number of therms used by industry i, and CF_i is the "critical factor" for the industry. The critical factor is a measure (whose source is not fully explained) of the extent to which being denied gas actually holds up production and reduces profits in the industry concerned.

A.2. Results

LE's headline estimates of VOLL measured by Willingness To Accept (WTA) are around £20/therm for a *one-week duration* with a 1-in-20 probability for domestic customers, but much lower for SMEs. (See Table A.1.) Oddly, LE finds that customers' WTP is much larger than their WTA. LE also finds that, as the probability of a disruption *increases*, customers' WTP *decreases* but their WTA *increases*. (See Table A.2.) These perverse results call into questions the reliability of the survey.

LE's estimates for I&C customers form a wide range from £0 to almost £24 per therm. (See Table A.3.) The higher number applies to "Other Industries".

60 London Economics (2011), *Estimating Value of Lost Load*, 5 July 2011, page 67.

Table A.1
LE's Estimates For Domestic Customers Show that VOLL in p/therm Decreases As Outages Become (1) More Frequent and (2) of Longer Duration

Table 1: Daily VoLL estimates for domestic and SME customers for outages in the winter occuring once in 20 years (p/therm)

Sector	WTA methodology	WTP methodology
Domestic (1 day duration)	2,260	4,800
Domestic (1 week duration)	1,940	4,380
Domestic (1 month duration)	690	2,750
SME (1 day duration)	84	3,753
SME (1 week duration)	71	3,356
SME (1 month duration)	19	1,834

Source: London Economics

Source: London Economics[61]

Table A.2
LE's Estimates of WTP Are Higher Than Its Willingness to Accept And Move In the Inverse Direction As Outages Become More Likely

Figure 14: VoLL per therm estimate - based on WTA per day using discounted payments

	1 Day		1 Week		1 Month	
	Summer	Winter	Summer	Winter	Summer	Winter
1 in 50	-0.9	**12.7**	-0.3	**11.0**	**1.9**	**4.5**
1 in 20	2.3	**22.6**	2.4	**19.4**	**2.9**	**6.9**
1 in 5	**9.3**	**35.2**	**8.1**	**29.6**	**3.5**	**8.5**

Note: Numbers in bold are statistically significant.
Source: London Economics

Figure 15: VoLL per therm estimate - based on WTP per day with discounted annual payments

	1 Day		1 Week		1 Month	
	Summer	Winter	Summer	Winter	Summer	Winter
1 in 50	11.8	**95.6**	13.5	**85.4**	**19.9**	**46.3**
1 in 20	-2.2	**48.0**	0.6	**43.8**	**11.6**	**27.5**
1 in 5	**17.8**	**33.8**	**15.7**	**29.4**	**7.6**	**12.7**

Note: Numbers in bold are statistically significant.
Source: London Economics

Source: London Economics[62]

61 London Economics (2011), *Estimating Value of Lost Load*, 5 July 2011, page vi.

62 London Economics (2011), *Estimating Value of Lost Load*, 5 July 2011, page 28.

Table A.3
LE Estimates a Wide Range of VOLL for I&C Customers From £0 to £23.98/therm

Table 2: VoLL estimates for I&C customers (range p/therm)

Sector	Low	High
Electricity (1hr interruption)	108[2]	135[1]
Electricity (24hr interruption)	48[2]	59[1]
Non-Ferrous Metals	854	1,139
Iron and Steel	1,312	1,715
Chemicals	272	362
Petroleum Refineries	303	378
Agriculture	0	148
Mineral Products	425	638
Textiles, Leather etc	370	616
Other Industries	1,799	2,398
Food Beverages etc	681	1,021
Paper, printing etc	490	735
Vehicles	1,708	2,277
Electrical Engineering etc	824	1,099
Mechanical Engineering etc	1,122	1,870
Construction	0	923
Fertilisers	322	322

Note: 1) baseload units, 2) peak units.
Source: London Economics and Nexant
Source: London Economics[63]

[63] London Economics (2011), *Estimating Value of Lost Load*, 5 July 2011, page vii.

Appendix B. Welfare Effects in the Redpoint Report

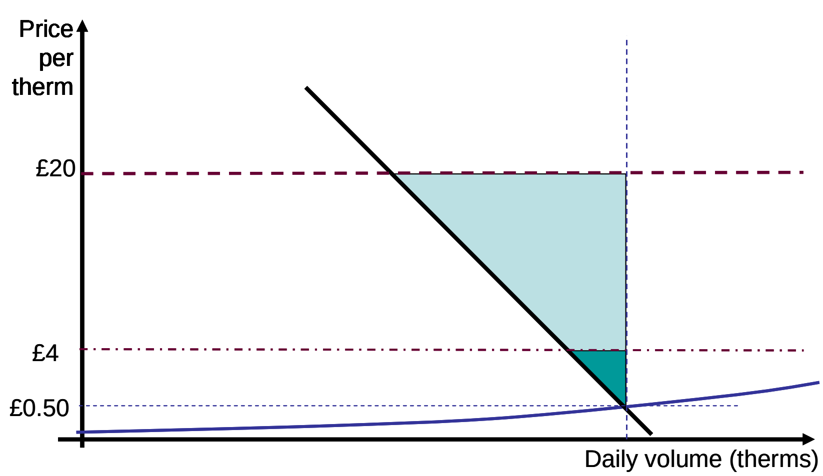
This appendix provides a high level description of the Redpoint model and its method of capturing welfare effects for a cost benefit analysis (CBA) of the proposed new cash-out arrangements.

B.1. DSR Under Different Cash-Out Prices

Redpoint assumes that, under the current cash-out arrangement, the capped price applicable during a Gas Deficiency Emergency (GDE) does not provide signals for shippers to supply gas efficiently prior to or during a GDE. Redpoint also assumes that when the cash-out price is frozen below the Value Of Lost Load (VOLL) to customers, shippers are unable to capture the full value of gas during a GDE, and thus have no incentive to provide sufficient gas storage, negotiate interruptible contracts etc.[64]

Figure B.1 shows the aggregate supply and demand schedule for gas under normal conditions. The normal (retail and wholesale) price of firm gas supplies is £0.50/therm but the cash-out price might reach £4/therm during a GDE under current arrangements. The dark blue triangle shows the potential benefit to customers of negotiating an interruptible contract (before allowing for the probability of a GDE). Implicit in Redpoint's assumption of no DSR under current arrangements is another assumption, that this benefit is insufficient to cover the transaction costs associated with writing interruptible contracts. If the cash-out price during a GDE were to rise to £20/therm, the light blue area would represent the additional benefit to customers who value uninterruptible load less than £20/therm. The retail price of firm gas supplies will rise somewhat to cover this new risk. The new cash-out price of £20/therm gives customers a much greater incentive to negotiate interruptible contracts, rather than having to cover the higher cost of gas during a GDE.

Figure B.1
Normal Prices are Insufficient to Encourage DSR



Source: NERA Analysis

[64] Redpoint (2011), *Gas security of supply Significant Code Review: Economic Modelling*, page15.

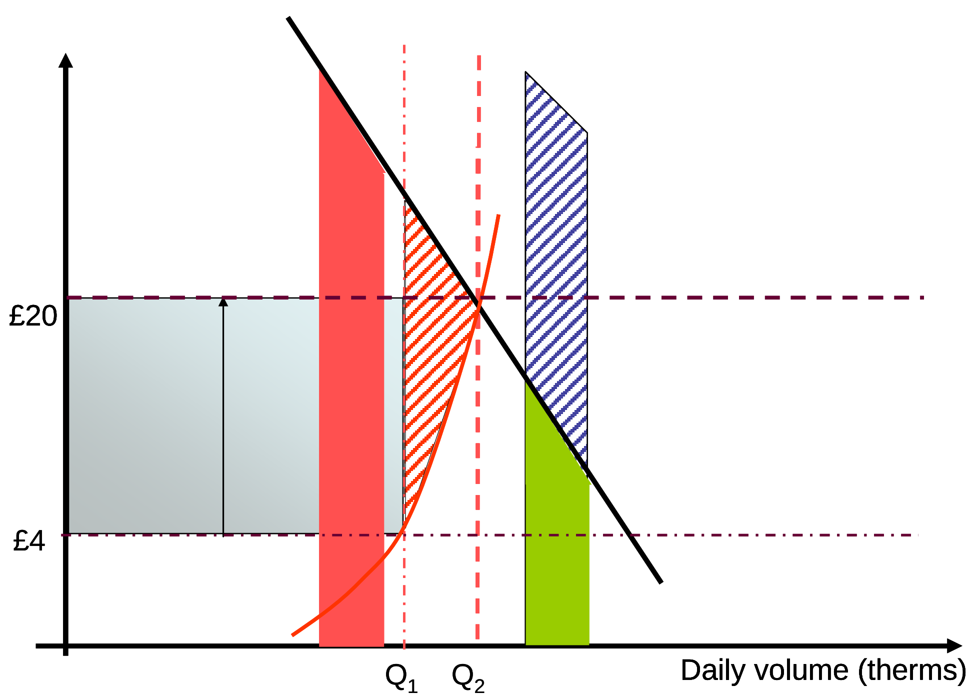
B.2. Redpoint's Estimate of Costs and Benefits in a GDE

Figure B.2 shows the changes in social welfare resulting from the proposed policy change. There are three major welfare changes resulting from the proposed arrangements, which are explained further below:

- a higher cash-out price offers a signal for shippers to supply more gas during a GDE, which is efficient if the price reflects customers' willingness to pay for gas (or to avoid an interruption);
- due to the replacement of the current arrangements with more widespread DSR, a higher cash-out price produces a more efficient pattern of customer interruptions and also transfers gas consumption from the (green) customers with a low VOLL who would otherwise consume gas to the (red) customers with a high VOLL who would otherwise be interrupted; and
- a higher cash-out price will ultimately result in higher contract prices and transfers from consumers to either suppliers or producers.

When the cash-out price increases to £20/therm, more gas is supplied to the market. The policy increases social welfare as gas consumption increases (gas volumes increase from Q_1 to Q_2 as shown in Figure B.2), at a price greater than its cost (i.e. surplus to producers) but less than its value to customers (i.e. surplus to consumers). The net gain in social welfare is indicated in Figure B.2 by the hatched red triangle.

Figure B.2
Redpoint Assumes the Proposed Arrangements Will Encourage a Larger Gas Supply and More Efficient DSR During a GDE



Source: NERA Analysis

The policy also results in net transfers of social welfare from customers with low VOLL to those with high VOLL. The current arrangement results in inefficient patterns of consumption because interruptions do not reflect the Value Of Lost Load. Under the current arrangements, interruptions follow certain rules which result in high VOLL customers (red) being disconnected earlier than low VOLL customers (green). The new arrangement is intended to incentivize efficient patterns of interruption, by increasing the benefit to customers of negotiating interruptible contracts. As a result, low VOLL customers (green) would be disconnected in preference to high VOLL customers (red). Welfare will thus decrease by the green shaded area, but increase by the red shaded area. The resulting net benefit to society is represented by the hatched blue parallelogram above the green demand in Figure B.2. It represents the welfare gain from high VOLL customers no longer being displaced by low VOLL customers.

Redpoint finds that customer bills will rise by £0.11 per customer per annum, which it calculates as the total change in the retail costs represented by the following three components:

- The "cash-out liability", i.e. the payments for involuntary DSR services (not shown)
- Payments to interruptible customers for DSR contracts (the area below the demand curve and to the right of the market clearing price); and
- The change in the cost of gas, calculated as the change in the gas volume (Q_2-Q_1) times the new market price.

Redpoint's analysis takes into account the effect that the new arrangements will have on marginal customers (i.e. those who would be disconnected under the current arrangements, but who are not disconnected under the proposed new arrangements, and vice versa) but it does not consider the effects on all customers whose contract prices will now reflect the higher cash-out price. This effectively increases the cost borne by all customers who would have been supplied under the current arrangements. This additional cost to consumers is shown as the grey rectangle between the current (£4/therm) and proposed (£20/therm) cash-out prices in Figure B.2. Adjusted for the probability of this case arising, it represents a welfare loss to consumers that is transferred to either suppliers, traders, importers or producers operating further upstream.

B.3. Redpoint's Estimate of Costs and Benefits in Other Shortages

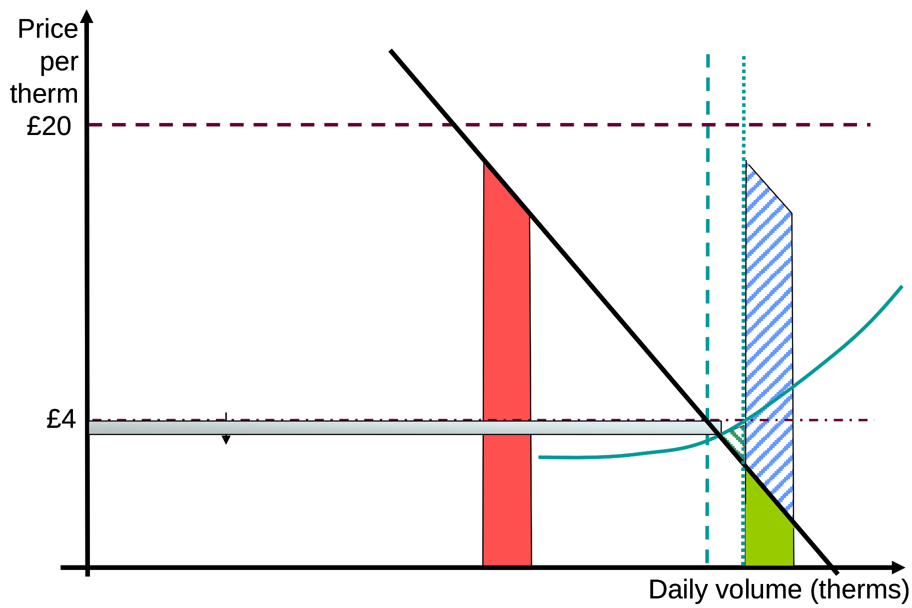
Figure B.3 shows the welfare effects under the new regime where the market equilibrium price lies *below* the frozen cash-out price of £4/therm. This situation arises specifically when voluntary DSR makes it unnecessary (under the new arrangement) to call a GDE (that would occur under the current arrangement).

Under the proposed new arrangement, voluntary disconnections increase efficiency and social welfare to the extent shown by the small hatched green triangle in Figure B.3. This welfare gain results from the cost savings realized by preventing *inefficient oversupply* of gas, when consumers take gas that costs more than they are willing to pay for it. This outcome can occur under the current arrangements, when the cash-out price is frozen at £4/therm, by encouraging supply of gas above the Value Of Lost Load.

This benefit is augmented by the benefit arising from an efficient interruption schedule that reflects the Value Of Lost Load. Under the proposed new arrangements, low VOLL customers (green) would be disconnected before the high VOLL customers (red), producing a welfare gain marked by the blue hatched parallelogram in Figure B.3.

Finally, all customers gain the benefit of lower prices in this case, resulting in a transfer of welfare from producers to consumers, which is represented by the grey rectangle in Figure B.3. As with the price increase in Figure B.2, Redpoint's CBA does not allow for this small decrease in prices to consumers, as it represents a transfer from shippers, traders, importers or producers operating further upstream.

Figure B.3
Redpoint Assumes The Proposal Will Encourage More Efficient DSR And Lower Consumption When The Gas Market Is Tight



Source: NERA Analysis

B.4. Conclusions

Redpoint's model and CBA capture the costs and benefits to society of *changes in the volume of gas supplied* to consumers in different conditions, and the effect of *reallocating* gas from low VOLL customers to high VOLL customers. This approach is consistent with standard methods of cost benefit analysis. However, it omits the major impact on energy consumers caused by potentially large increases (and small decreases) in the price that they pay for all their gas. Redpoint classifies such effects as transfers between members of society, not costs to society. They would count as a cost, however, if the boundary of the CBA were limited to the interests of energy consumers, rather that the interests of (worldwide) society as a whole. If some of the transfers passed upstream to foreign producers (e.g. because the proposals to reform cash-out prices in Britain led to higher prices for importing gas from European gas hubs), they would even count as costs in a CBA limited to effects within Britain (i.e. CBA from the point of view of "GB plc").

Appendix C. Cost of Demand Side Response

This Appendix illustrates a method for calculating the cost of Demand Side Response.

- Section C.1 sets out an alternative calculation for the cost of providing DSR.
- Section C.2 concludes.

We note in passing that the total costs imposed by the proposed arrangements should really be compared with the total costs being incurred under the current arrangements. Our model does not provide such a comparison, unless there is no DSR at present (as indeed Redpoint and Ofgem assume). If there is a market for DSR at present, the results below represent an initial approximation of the costs imposed by the proposed arrangements, i.e. an upper bound before allowing for any margin of error in input data. Taking as a starting point the Ofgem view that there are currently no interruptible I&C contracts, and leaving aside the effect of the proposed arrangements on prices for firm contracts at the NBP, this method estimates the cost of arranging DSR with I&C Tranche 1 and 2 customers.

C.1. Modelling I&C Decisions

In this section, we set out a "game" showing the impact of compensation arrangements on customers. The model continues to use probabilities drawn from the Redpoint modelling, but, since we do not have a full set of Redpoint's data and outputs, it must still be considered as an approximation, even for the world modelled by Redpoint.

C.1.1. Firm compensation payments result in discounts for interruption

Every year (say), each DM customer takes part in a two-period game. The DM customer chooses between an interruptible and firm gas contract at the start of the year, which then offers the following payoffs (shown in Table C.1) during the course of that year:

- If the customer chooses a **firm contract** now, and is **interrupted** (which happens with probability 1-in-128), he receives compensation of £20/therm *minus* "p" (the gas price in the contract, which in principle he pays in return for being credited with an ECQ);
- If the customer chooses an **interruptible contract**, and is **interrupted** (which happens with a probability of 1-in-55), he receives compensation of some amount £X/therm *minus* "p" (the gas price in the contract, paid in return for being credited with an ECQ); and
- Whatever kind of contract he has, if he is **not interrupted**, the customer obtains the benefit ("payoff") of using gas, which is equal to his own VOLL *minus* "p" (the gas price in the contract, paid for gas received).

Table C.1
Payoff Matrix for Interruptible and Firm Contracts
(Relative Probabilities – not to scale – and Payoffs per therm)

Firm	
Probabillity	Payoff
1/128	£20 - p
127/128	£VOLL - p

Interruptible	
Probabillity	Payoff
1/55	£X - p
54/55	£VOLL - p

Source: NERA Analysis

To be indifferent between a firm contract and an interruptible contract, the minimum compensation that a (risk-neutral) customer will require in the event of being disconnected is the compensation that makes his *expected payoff* exactly equal under both contracts. The technical solution of the game is set out in Appendix D. The solution to the problem set out above is that the customer would be willing to choose an interruptible contract, if it offered the followed compensation:[65]

- **I&C Tranche 1 customers:** £10.41/therm in the event of interruption for the interrupted volume, equivalent to an upfront discount of 19p/therm for accepting costless interruptions when the market price exceeds their VOLL (£3.18/therm); and
- **I&C Tranche 2 customers**: £12.40/therm in the event of interruption for the interrupted volume, equivalent to an upfront discount of 23p/therm for accepting costless interruptions when the market price exceeds their VOLL (£6.68/therm).

The same figures assuming a 1-in-30 outage probability for interruptible customers would be somewhat lower, at £7.12/therm and 13p/therm for I&C Tranche 1 customers and £9.80/therm and 18p/therm for I&C Tranche 2 customers. (These figures all assume that Tranche 1 and Tranche 2 customers are equally likely to be interrupted.)

Given some perception of the likely scale of interruptions, it is possible to derive from these upfront compensation payments the minimum discount against a firm contract price that an interruptible contract would have to offer an industrial customer. The discount depends on the volume of gas that would be affected by an interruption, relative to the total volume of gas included in the firm contract. For instance, if an I&C Tranche 1 customer anticipated the

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65 These upfront volumes ignore the impact of discounting for receiving the upfront payments 1 year in advance. However, the impact of these measures is likely to be small.

possibility of losing 1% of its annual gas consumption after signing an interruptible contract (e.g. 3 days of peak consumption out of 365 days total consumption), it would demand an upfront discount of 0.19p/therm on a yearly contract (that is, 1% of 19p/therm).

C.1.2. Change in contract prices for firm customers

The analysis in section C.1.1 explains how a given set of assumptions defines the gap between the price of firm contracts and the price of interruptible contracts under the proposed arrangements. It is not possible to infer from these calculations how the proposed arrangements would affect average price levels, without making further assumptions about how competition would work in practice and a detailed analysis of the risks for shippers. However, the modelling by Redpoint (and hence Ofgem's appraisal of the proposal) is predicated on the view that there are currently no interruptible contracts with I&C customers (since Redpoint and Ofgem treat all voluntary interruption of I&C customers as an efficiency gain attributable to the proposal).

Taking the absence of interruptible I&C contracts as a starting point, and leaving aside the effect of the proposed arrangements on prices for firm contracts at the NBP, it is possible to say that the method set out above estimates the cost of arranging DSR with I&C Tranche 1 and 2 customers.

C.2. Conclusion

DM customers' decisions can be explained in a simple two period game, where agents select a contract in period 1 to maximise their expected utility in period 2. The figures used here (which derive from Redpoint's report) indicate that the compensation for interrupting an I&C customer would be quite large – £10.41 to £12.40 per therm. However, the equivalent discount on a firm contract price would be smaller (0.2p/therm), once it is multiplied by the probability of a GDE (i.e. 1-in-128 in a typical year) and converted into an annual charge (i.e. charged on the volume lost, but spread over an annual contract volume).

Without adopting further assumptions about how competition would work in practice and how the costs and risks of operating a gas company would change after the introduction of the proposed arrangements, it is not possible to infer what the impact would be on the average price of gas in the market.

Appendix D. Technical Appendix Calculating the Cost of Demand Side Response

Consider a two period game, which a DM customer may, of course, repeat. The customer can choose between an interruptible gas contract and a firm gas contract, with the following payoffs for each therm that the customer consumes or would have consumed:

- If the customer chooses a firm contract, he receives upon interruption, which happens with probability 1-in-128, £20/therm less the price in the contract;
- If he chooses an interruptible contract, he receives upon interruption, which happens with probability 1-in-55, compensation of some amount £X less the price in the contract; and
- Whenever he is not interrupted, he obtains a payoff equal to his own VOLL minus the contract price for the gas he receives.

In order to be indifferent between the firm and interruptible contracts, the minimum compensation of £X/therm that a (risk-neutral) customer must receive in the event of being disconnected must be sufficient to render his expected payoff the same under either contract. An expected payoff is defined as the payoff the customer receives when an event occurs multiplied by the probability of that event occurring, summed over all of the possible events (Σ p.x, where Σ is a sum, p is the probability of an event and x is the payoff received in that event). The formula below defines the expected payoff in this case, with the left hand side showing payoffs from a firm contract (probability of interruption 1-in-128) and the right hand side showing payoffs from an interruptible contract (probability of interruption 1-in-55):

$$\frac{1}{128}\times(£20-p)+\frac{127}{128}\times(£VOLL-p)=\frac{1}{55}\times(£X-p)+\frac{54}{55}\times(£VOLL-p) \quad [1]$$

£VOLL is £3.18/therm for I&C Tranche 1 customers and £6.68/therm for I&C Tranche 2 customers. The price "p" drops out of the equation, as the formula contains "1 times p" on both sides. Rearranging the remaining terms in equation [1] by subtracting the term on the far right from both sides yields the following expression:

$$\frac{1}{128}\times £20+\left(\frac{127}{128}-\frac{54}{55}\right)\times £VOLL=\frac{1}{55}\times £X \quad [2]$$

Reversing equation [2], multiplying both sides by 55 and simplifying the expression yields:

$$£X=\frac{55}{128}\times £20+55\times\left(\frac{127}{128}-\frac{54}{55}\right)\times £VOLL \quad [3]$$

Substituting in the value of VOLL for Tranche 1 customers yields a compensation payment (X) of £10.41/therm. Substituting in the value of VOLL for Tranche 2 customers yields a compensation payment of £12.40/therm.

In the interruptible case, an interruption occurs in period two with a probability of 1-in-55. The compensation payment needed to induce a customer to accept an interruptible contract, and paid as a discount in advance, is therefore one fifty-fifth of the compensation that would be paid when an interruption actually occurs:

- 19p/therm multiplied by the likely interruption volume for Tranche 1 customers; and
- 23p/therm multiplied by the likely interruption volume for Tranche 2 customers.

The equivalent figures assuming a 1-in-30 outage probability for interruptible customers would be

- £7.22/therm and 24p/therm for Tranche 1 customers; and
- £9.80/therm and 33p/therm for Tranche 2 customers.

The required compensation per therm in the event of an interruption is lower, but the upfront discount is higher, because of offsetting arithmetic effects.

Appendix E. Gas Price Dynamics During a GDE

Centrica asked NERA to set out the dynamics of the cash-out price, and consequently a gas supplier's exposure, in the case of a Gas Deficit Emergency (GDE), assuming that the arrangements currently proposed by Ofgem come into force.

E.1. Outline

This appendix contains our response and proceeds as follows:

- Section E.2 summarises our findings;
- Section E.3 provides a brief description of gas markets in normal conditions;
- Section E.4 provides a brief description of gas markets during an emergency;
- Section E.5 sets out the likely paths of gas prices in the lead-up to different types of emergency; and
- Section E.6 sets out our conclusions and defines the conditions in which different price paths will emerge.

E.2. Findings

Under the proposed arrangements, a GDE would start when firm loads have to be interrupted, and from the next day onward the cash-out price would be set at £20/therm (an estimate of VOLL for household customers) until the GDE ended. During a GDE, the price for all spot or prompt trades for gas would be equal to or close to VOLL.

In advance of a GDE, traders of gas would react to the prospect of such high cash-out prices in different ways, depending on circumstances. If a GDE occurred due to lack of flexibility in the gas market, traders would have limited ability to act in anticipation of an emergency and gas prices would rise to VOLL only for the period of the GDE. On the other hand, if traders could foresee that a GDE was about to be triggered by a lack of gas supplies, the prices for spot and prompt trades would rise towards VOLL in advance of any decision to shed firm load. The prices in forward contracts covering deliveries over the anticipated period of a GDE would also rise by an equivalent amount.

The scale of the increase in forward contract prices would depend on the expected duration of the GDE and the probability of a GDE occurring. Forward contract prices would move closer to VOLL as a GDE became more likely. In fact, forward contract prices (on the NBP) would always include the expected (*probability-weighted*) opportunity cost of serving customers during a future GDE (i.e. VOLL multiplied by the probability, whatever it may be, of an involuntary interruption of firm load).

Shedding a large amount of firm load during a GDE may push the British gas system into a physical surplus. However, as long as the market for "entry-paid" gas continues to be short – because of the load that is imputed to customers who have been interrupted – spot or prompt gas prices at the NBP will remain around £20/therm, and will raise forward contract prices accordingly.

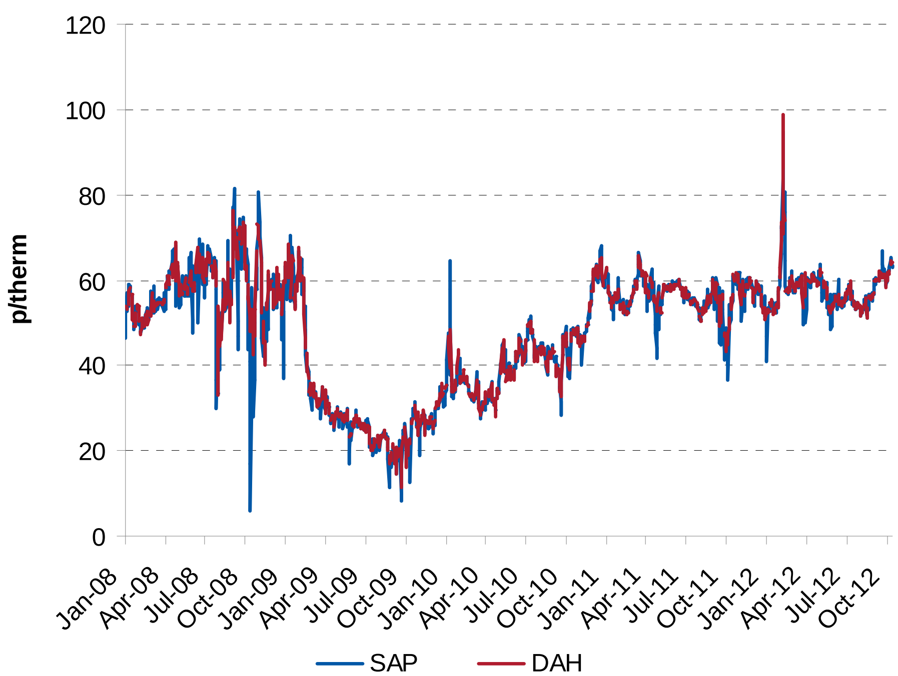
E.3. Gas Markets in Normal Conditions

Shippers can choose one of two methods to balance their injections into the gas network against their withdrawals from it. They can balance their own gas supplies by trading with other shippers and paying the market price. Alternatively, they can allow a deficit (or surplus) imbalance to arise and pay (or receive) the cash-out price offered by the system. The cash-out price for short/long shippers is set equal to the marginal cost of the gas that National Grid has purchased/sold for balancing, plus/minus a small penalty.

Demand for gas is higher in winter than in summer and gas prices also tend to be higher in winter than in summer, in order to attract additional supplies and to provide some incentive to put gas in storage over the summer.

Figure E.1 shows the close relationship between cash-out prices (specifically, the System Average Price, SAP, which is an indicator of the two cash-out prices applying within each day) and prompt prices for each day (i.e. the Day Ahead Price, DAH) over the period 2008-11. Comparing the movements in one price with movements in the other by calculating the correlation coefficient (using prices on weekdays, when there is a single Day Ahead Price corresponding to the SAP) shows that 99% of movements in the DAH price are reflected in the SAP and vice versa.[66]

Figure E.1
System Average Price and Day Ahead Prices, 2008-11



Source: Centrica

[66] Correlation coefficient between DAH and SAP is 0.9904.

Unlike in electricity markets, flexibility in gas markets gives a profit-maximising shipper the opportunity to arbitrage across time. The key sources of flexibility available to gas shippers are (1) storage, (2) gas in tanks in LNG terminals, and (3) variation in deliveries, particularly deliveries of LNG.

Given this flexibility, a shipper does not have to sell all of the gas it has imported today, but can choose to hold back some gas and to sell it in the future. The gas prices expected in the future therefore affect the opportunity cost – and price – of gas today. In such circumstances, the price at any time during the winter will be set by supply and demand on the day but will also depend on the forecast balance of supply and demand over the winter as a whole. In normal conditions therefore both the market price of gas and the cash-out price will depend on:

- **Balance of supply and demand:** In general, if the market is short of gas, then prices will trend upwards.
- **Availability of flexibility:** If flexibility (storage or variability in deliveries) is available, and if it is forecast that the market will be short in the future, then the price today depends crucially upon market participants' expectations of prices tomorrow.

Below we explore how these factors affect gas prices during a GDE and in the periods before and after a GDE.

E.4. Gas Prices During a GDE

In emergency conditions shippers in Great Britain would be short of gas relative to the load of their customers, and would record a net negative imbalance overall. National Grid would have to disconnect customers in order to balance supply and demand. However, when National Grid sheds firm load, a consumption is imputed to the customer as an "Estimated Curtailment Quantity" (ECQ). Under Ofgem's proposals, the ECQ process would, for the first time, apply to NDM loads as well as DM loads. Inclusion of ECQs ensures that the market for "entry-paid" gas (i.e. gas eligible to be traded at the NBP) would continue to be short during a GDE.

The shortness of this market, and hence the net overall imbalance incurred by shippers, drives up the market price of gas during a GDE. Under Ofgem's proposed arrangements, all shippers face the same opportunity cost of "entry-paid" gas at the NBP during an emergency, namely £20/therm:

1. if they are short, they must pay the "short" cash-out price for a deficit imbalance, which the proposed arrangements would set at £20/therm; or
2. if they try to buy gas from a shipper or another supplier, excess demand will drive up spot prices to the level that suppliers are willing to pay to avoid the short cash-out price; or
3. if they are long, they can sell any surplus gas at the market price set by the short suppliers who are competing for gas and facing the short cash-out price.

Shippers would therefore only be willing to sell balancing gas to National Grid at a price of £20/therm. The cash-out and market prices will remain at £20/therm throughout the period whilst the market is short and whilst National Grid is shedding firm load.

In the later stages of a GDE, National Grid may have shed more firm customers than necessary, more gas may become available, and the ECQ demand imputed to household customers will fall away after the first day. Shippers may then be able to nominate more entry-paid gas into the system than the remaining connected customers can consume. Given the high market price, they would try to do so, but the system cannot accommodate a physical inflow of gas that exceeds the physical outflow (except through increased linepack). In such circumstances, National Grid would first probably try to reconnect customers. If that could not be done quickly enough to absorb the additional gas supplies, National Grid would undertake balancing actions, such as asking shippers to buy surplus gas (a) to put into storage (or to reduce withdrawals out of storage) or (b) as an alternative to a physical inflow over the interconnectors. We would expect these balancing actions to keep the market for entry-paid gas in a situation of "tight" supply, and market prices at the NBP up at or near the deficit cash-out price. The prices paid for physical gas delivered to shippers at particular locations would not affect the price at which shippers trade entry-paid gas at the NBP.

E.5. Gas Prices In Periods Before/After a GDE

The price of gas in normal conditions depends on the balance of the supply and demand and on the availability of flexibility. The conditions surrounding a GDE affect the dynamics of the gas price in the days leading up to and during the crisis. In particular, the likely price paths depend on whether the GDE is caused by:

- **a winter supply constraint:** insufficient gas to meet aggregate demand over a number of days; or
- **a deliverability constraint:** lack of flexibility resulting in daily supply (i.e. "deliverability") being insufficient to meet demand on a given day or days.

As an illustration of these cases, a major storage outage could cause either a deliverability constraint (because of the loss of its withdrawal capacity) or a winter supply constraint (because the gas held in storage is no longer available and other storage facilities with adequate deliverability are low on gas).

These two different scenarios have different implications for prices before a GDE.

E.5.1. Winter supply constraint

A GDE may be caused by a lack of gas, even when shippers can use storage to shift deliveries between days. For example, events in the global gas market might prevent gas supplies from reaching Great Britain from a major gas export country. Available import capacity plus storage withdrawal capacity might be sufficient to meet peak demand, but the total volume of gas available to Great Britain might not be enough to meet demand on every day of the winter. In such circumstances, shippers face a trade-off between selling their gas today and selling it in the future. As soon as it becomes clear that National Grid will have to shed load, and even before the shipper is unable to meet demand, the opportunity cost of gas to shippers will rise to the price that they would *expect* to receive in the future, including an allowance for the probability of an emergency.

In other words, by selling gas in advance of an emergency, shippers have to give up gas that they could otherwise sell during the emergency at a price of £20/therm. They will only sell gas now if the price compensates them for giving up that opportunity. If there is a 50% probability of the emergency occurring, the expected future value of gas is 50% of £20/therm, or £10/therm, less the cost of storing gas between now and the start of the emergency (which is very small. We ignore this adjustment for storage costs hereafter.) plus 50% of the price that would apply if an emergency can be avoided. As soon as an emergency becomes inevitable, the probability rises to 100%, and shippers would be unwilling to sell at any price below £20/therm even before an emergency is declared. The price on the spot market and the price on forward markets for delivery during an emergency would both rise immediately to that level.

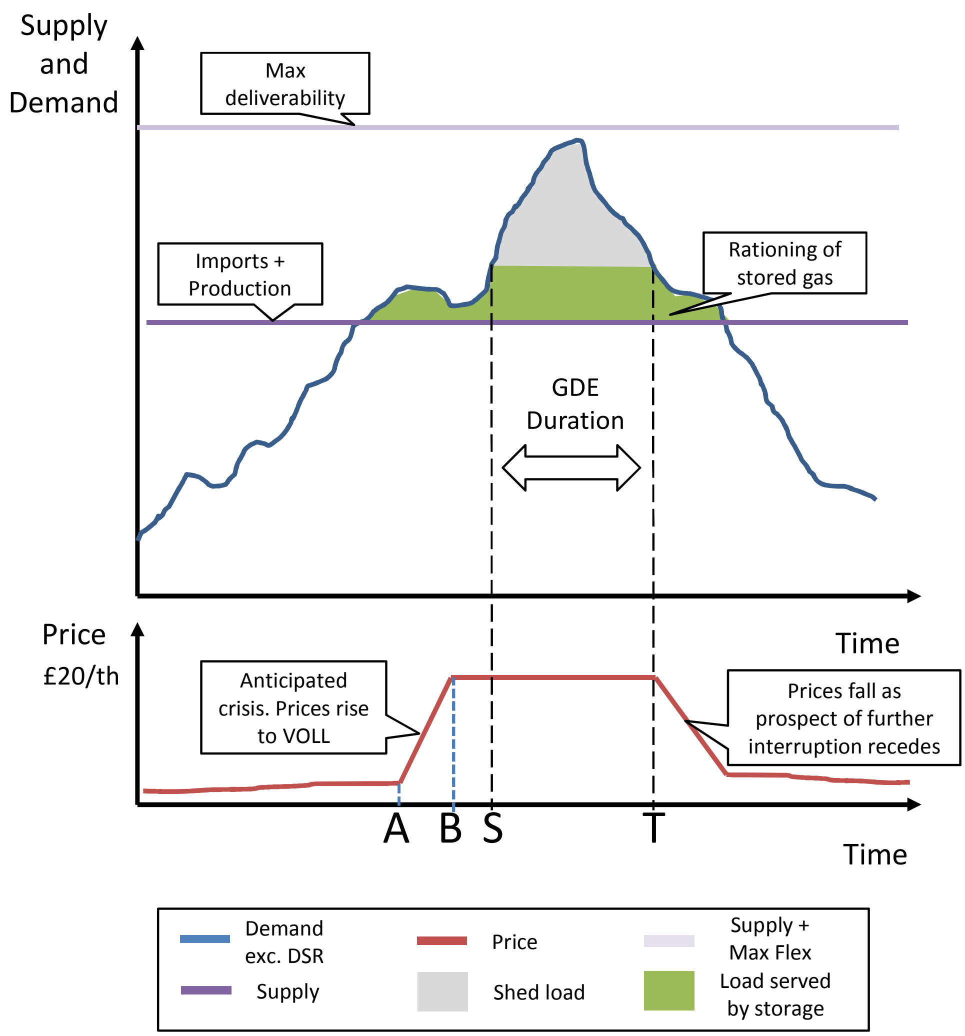
Figure E.2 shows a schematic diagram of demand, supply and the price of gas in the period around a GDE, when there is sufficient flexibility to allow arbitrage between periods, but insufficient gas to meet total demand. The blue line represents total demand and the horizontal mauve line shows how much can actually be met by imports and (domestic) production. The dark green area shows how much demand can be supplied from gas taken out of storage. The light blue area represents the peak load that must be shed.

The GDE applies during the period of load shedding so it starts at time S and is terminated at time T. However, prices (the red line at the bottom of the graph) start to rise even before this load shedding occurs, from time A (when an emergency can be anticipated with non-negligible probability). From time B (when the emergency becomes inevitable), the opportunity cost of gas in storage (or of any gas that can be held in reserve upstream) equals the Value of Lost Load (£20/therm) and shippers will only buy and sell gas at that price. The opportunity cost will be £20/therm from time B, because shippers know that they would be able to sell any gas they hold onto for that price during the emergency. Before the emergency is inevitable, but when it has a high probability attached to it, the price will be lower, but the price will head upwards towards £20/therm, as a GDE becomes more probable.

In a market that could perfectly foresee the length of the emergency, market prices of gas would only fall to normal levels when customer demand fell, or supply increased, to the point where it was not necessary to take gas out of storage to supply the market. Given perfect foresight, storage facilities would then be empty – otherwise shippers would have made more profit by taking more gas out of storage during the GDE. In practice, shippers are unlikely to know exactly how long the GDE will last, or whether it will return. In the immediate aftermath of the GDE, therefore, some gas is likely to remain in storage and gas prices may remain above normal market levels, in anticipation of the next emergency. Hence, even though the cash-out price will cease to be £20/therm once load is no longer being shed, the market price may remain around £20/therm (or at least at high levels) for some time after a GDE has finished.

During November and December 2005, daily, month-ahead and quarter-ahead contracts all exhibited similar and very high prices (on average). This pattern of prices shows how gas today has a similar value to the expected value of gas to be delivered in the next month or quarter, as long as there is space in storage to allow arbitrage. (See Appendix F.)

Figure E.2
Insufficient Gas Supplies Will Cause Prices to Rise Before Load Shedding Starts



Source: NERA – illustrative only

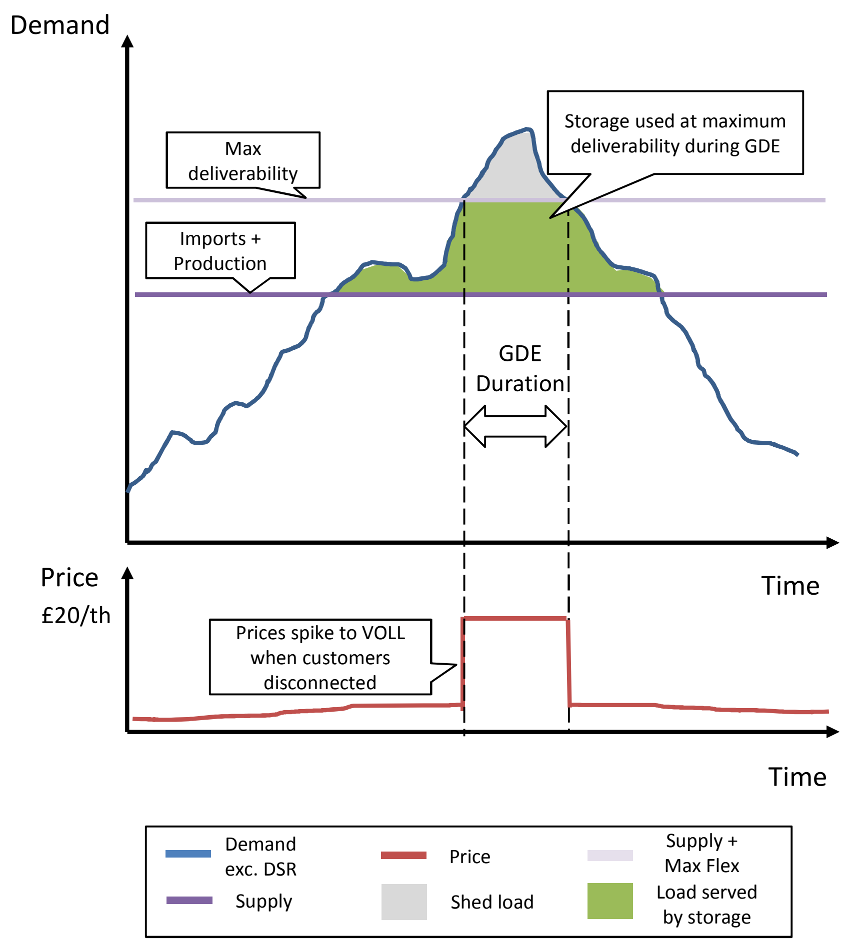
E.5.2. Inadequate flexibility – peak day demand exceeds deliverability

A lack of flexibility at peak times, such as limited storage withdrawal capacity or inflexible LNG deliveries, could also cause a GDE, even if the market has substantial amounts of gas to offer. In such circumstances, the holders of gas would not be able to meet more demand at peak times by putting more gas into storage beforehand. The opportunity cost of gas *before* an emergency would not equal the anticipated value of gas *during* the emergency, because shippers who held gas before an emergency would not be able to sell the same gas for higher prices later. Therefore, prices would rise to £20/therm only on the days when National Grid was shedding customers' load, as explained in section E.4.

Figure E.3 shows the pattern of market prices likely to emerge when flexibility is constrained, so that traders cannot shift gas into the period of the GDE from earlier periods. Any supply from storage remains an addition to deliverability (instantaneous supply), but storage does not provide a means for arbitrage across time periods.

These conditions might arise if a GDE was triggered by the failure of a major source of flexibility, such as the Rough storage facility, at a time when other storage facilities were full. During the GDE, prices would rise to £20/therm, as in the previous case. Before the GDE, forward prices for deliveries over the expected period of the GDE would also rise, but spot prices would not. Shippers would want to hold back more gas, anticipating the higher price later, but they would be unable to do so, so today's spot gas would be no substitute for gas during the GDE.

Figure E.3
Insufficient Flexibility May Prevent Prices from Rising Ahead of Disconnections



Source: NERA Analysis – illustrative only

From August to October 2005, the gas market was anticipating a shortage of gas over the coming winter of 2005/06, as indicated by high prices for month-ahead and quarter-ahead forward contracts. However, the daily price of gas remained much lower. That combination of prices suggests either that injection capacity was fully utilised or that the available storage capacity at Britain's gas storage facilities was already full, so that shippers could not put more gas into storage. As a result, the daily price of gas did not rise until later that winter, when the current level of demand rose. (See Appendix F.)

E.6. Conclusion

Our analysis shows that the price of gas in short term markets depends on the opportunity cost of gas to shippers. During a Gas Deficit Emergency, that opportunity cost – and the short term market price – will be VOLL (£20/therm). Before a Gas Deficit Emergency that opportunity cost will depend on circumstances:

1. **Winter supply constraint:** When a GDE is due to the insufficiency of total gas supplies, the price of gas will rise to £20/therm in advance of firm load shedding and the price will remain at £20/therm whilst the emergency persists.
2. **Deliverability constraint:** When a GDE is due to lack of flexibility in gas supplies, and shippers cannot withhold gas in the days before a GDE, the market price would be defined by the current state of supply and demand on each day. The increase in gas cash-out prices to £20/therm would persist only for the days of the GDE, on which National Grid was shedding firm load.

In GDEs characterised by condition 2, the period when market prices settle at £20/therm may be quite short-lived. In GDEs characterised by condition 1, however, the market price may rise towards £20/therm from some time in advance. The price path in those conditions will depend on the evolution of traders' expectations, the probability that they attach to a GDE happening in the near future, and the extent to which they can use storage/flexibility in anticipation of an emergency.

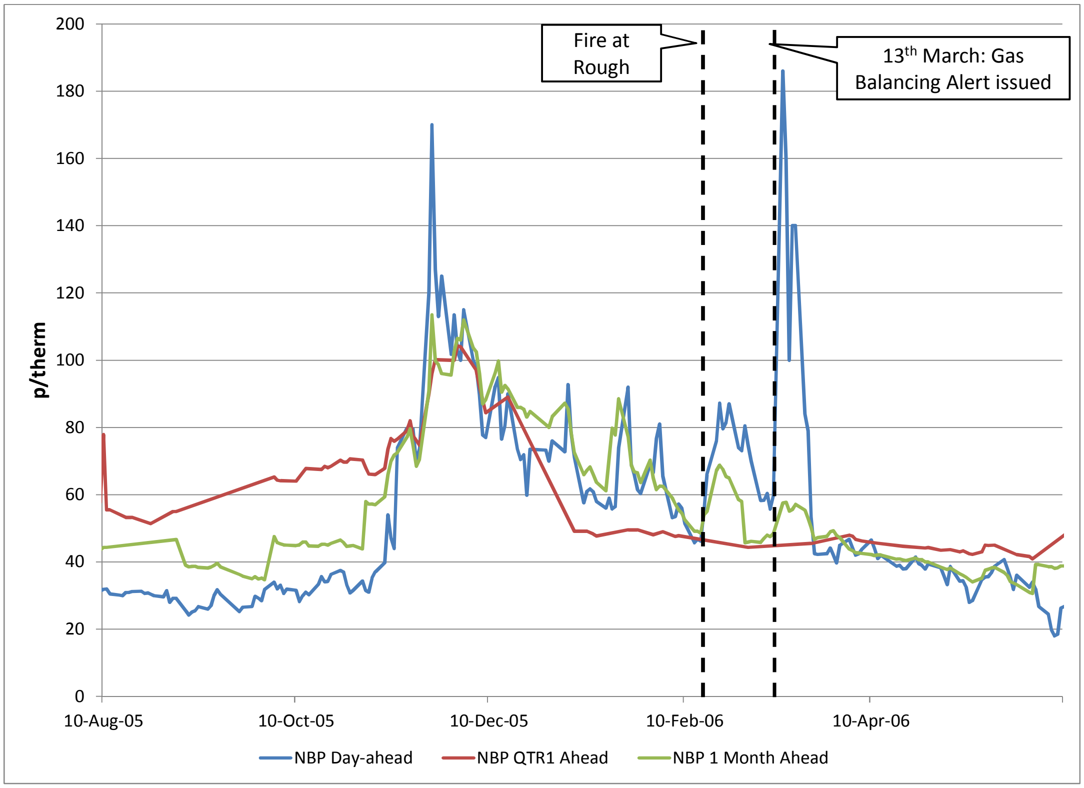
Appendix F. Gas Price Spikes in Winter 2005-2006

Since Great Britain has never suffered a GDE, there is limited data available on the price response to an emerging crisis in the gas market. The most recent relevant evidence comes from the winter of 2005-2006, when cold weather coincided with an outage at the Rough storage facility, and gas prices leapt to over £1.80/therm.

Figure F.1 shows the day-ahead, month-ahead and quarter-ahead NBP prices over the course of winter 2005-2006. In the early part of the winter, quarter-ahead contracts were around twice as expensive as the day-ahead price, indicating a lack of intertemporal arbitrage between day-ahead and quarter-ahead prices in the autumn of 2005. That may have been due to congestion at existing storage facilities – either they were full, or they were already being filled as fast as possible.

Later, when a cold snap occurred, day-ahead prices began to rise. The day-ahead price peaked at £1.70/therm on 22 November 2005. Quarter-ahead and month-ahead prices were settling at similar levels to day-ahead prices throughout most of November and December, suggesting that by that time market participants were arbitraging their sales of gas between the prompt and forward markets (perhaps by varying the rate of withdrawal from storage).

Figure F.1
Prompt and Forward NBP Prices in the Winter of 2005-6

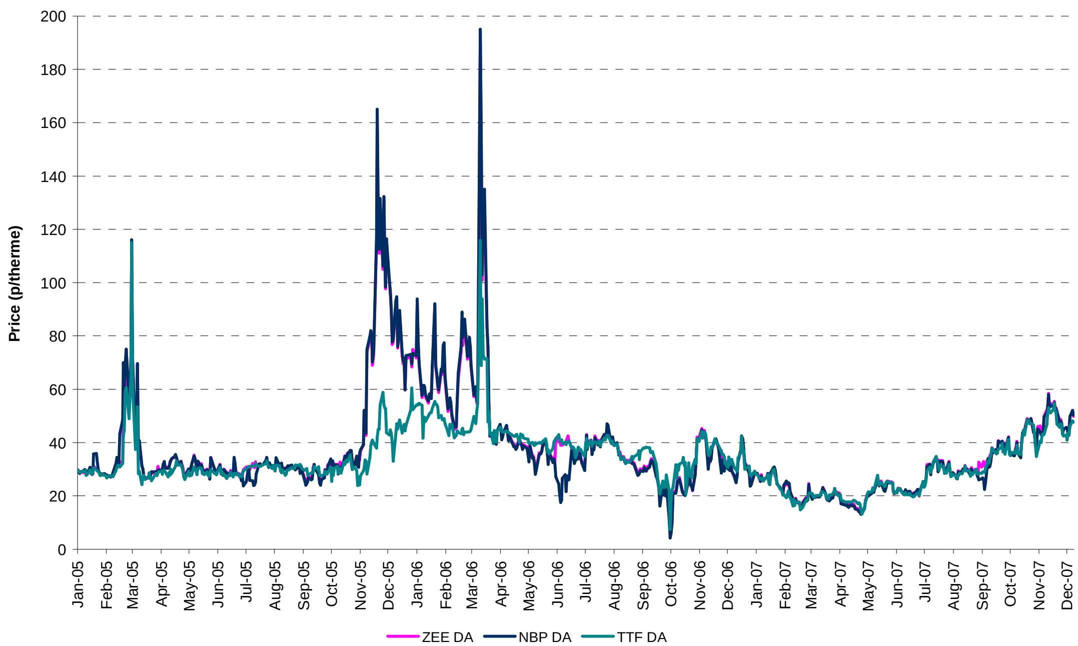


Source: Bloomberg

On 16 February 2006, the fire at Rough caused a price rise of around 20p/therm in the prompt market, but quarter-ahead markets remained flat, most likely because traders expected the storage outage to end before the start of the next quarter. Prompt markets spiked again on 13 March 2006 in the wake of National Grid issuing a Gas Balancing Alert. The spike in prompt prices did not cause a spike in forward markets, again possibly due to the expected short run nature of the problem, as falling demand during the spring of 2006 made the reduction in deliverability at Rough less important.

Figure F.2 shows the relationship between the day-ahead prices on the NBP (dark blue), Zeebrugge (pink) and TTF (green) hubs. As Figure F.2 shows, the prices in these hubs are highly correlated due to the ability of traders to exploit arbitrage conditions, albeit subject to transmission constraints. During the winter of 2005/06, the shocks observed at the NBP were almost identical to those observed at the Zeebrugge hub.

Figure F.2
Gas Prices in European Hubs are Closely Correlated,
Although NBP and Zeebrugge Prices Diverged from TTF Prices in 2005-06



Source: NERA Analysis of Heren Data

TTF prices did not exhibit shocks of the same magnitude, due to transmission constraints, but TTF prices did rise, following the movements in NBP and Zeebrugge prices. On 1 December 2006, the BBL pipeline connecting Netherlands and the UK became operational. This new pipeline has, at least in part, eased transmission constraints between the British and Dutch gas markets, so that differences in prices have been arbitraged away. Table F.1 shows that hub prices move very closely in line with one another, with correlation coefficients above 96%.

Table F.1
Correlation Matrix - NBP, TTF and Zeebrugge

	NBP DA	ZEE DA	TTF DA
NBP DA	1.000	0.991	0.961
ZEE DA	0.991	1.000	0.971
TTF DA	0.961	0.971	1.000

Source: NERA Analysis of Heren Data.

Redpoint's analysis assumes an indefinite supply of gas in Europe at oil-indexed prices. The data above shows that, shortages in one market will translate into higher prices on the markets in neighbouring countries. By not taking into account the high correlation across European gas hubs, Redpoint is overstating the responsiveness of imports to shocks in the NBP, and understating the costs of additional gas supplies.

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