UKERC Response to the Energy and Climate Change Committee's Call for evidence on the Impact of Shale Gas on Energy Markets

Part 2

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UKERC Response

This document sets out part two of a two part response of the UK Energy Research Centre (UKERC) to the Energy and Climate Change Committee's call for evidence on the Impact of Shale Gas on Energy Markets.

The overall submission of both parts is under the control of Professor Michael Bradshaw from the University of Leicester.

Summary

This response addresses the first two questions of the call for evidence on the impact of shale gas on energy markets: firstly what estimates exist for the amount of shale gas in place in the UK, Europe, and the rest of the world, and what proportion is recoverable; and secondly why estimates for shale gas are so changeable.

UKERC recently conducted a comprehensive review of 62 studies that provide original estimates of regional and global shale gas resources [1]. While the majority of these studies focus upon North America, the review found 11 studies that provided estimates of global shale gas resources. Each of these covered different countries and regions, however none provided a truly global estimate since each excluded some regions. Relatively few studies were found to have provided estimates of the recoverable shale gas resource within Europe and even fewer studies provide shale gas resource estimates for the UK. Only one country wide estimate of the shale gas in place in the UK has been undertaken (2.7 Tcm). Recovery factors that have been applied to gas in place estimates by various sources vary widely from 15-40%.

The main conclusions of the UKERC study were the very high level of uncertainty in existing estimates, the inadequate treatment of this uncertainty by the majority of studies, the difficulties in comparing and combining estimates from different studies, and the limitations of currently available estimation methodologies. Given the absence of production experience in most regions of the world, and the number and magnitude of uncertainties that currently exist, estimates of recoverable unconventional gas resources should be treated with considerable caution.

What are the estimates for the amount of shale gas in place in the UK, Europe, and the rest of the world, and what proportion is recoverable?

1. To answer this question it is necessary to both present and compare the currently available resource estimates for shale gas and to critically examine the competing definitions of 'resources' upon which these estimates are based.

Resource Definitions

2. A number of terms are used to define unconventional gas resources, and an additional set of terms is used to define unconventional gas reserves. The definition of these terms is far from standardised and there is considerable overlap between estimates of different types of resource/reserve from different sources. The use of imprecise or ambiguous terminology is commonplace and confusion frequently results from employing terminology that has been developed for conventional oil and gas but is not necessarily appropriate for unconventional resources. For example, the term 'undiscovered resources', is much less appropriate for continuous shale gas formations than for discrete reservoirs of conventional gas, since the existence of those formations is usually well-known and most of the formation may be expected to contain at least some recoverable gas.
3. Our interpretation of these different terms is summarised below and in Table 1.
4. *Original Gas in Place (OGIP)* is the total volume of natural gas that is estimated to be physically present in a given field, play[1] or region, prior to development. The percentage of this gas that is estimated to be technically recoverable is a key variable in resource estimates and is commonly referred to as the *recovery factor*. Given the relatively early stage of development of shale gas resources, recovery factors remain highly uncertain. Moreover, these factors can vary widely between different geological formations and depend upon the technology that is employed.
5. *Ultimately Recoverable Resources (URR)* is the sum of all gas expected to be produced from a field or region from when production begins to when it finally ends. Estimates of URR are commonly understood to include discovered gas that is not economically producible at present but is expected to become so in the

[1] A geological play is defined as *'A set of known or postulated oil and gas accumulations sharing similar geologic, geographic, and temporal properties, such as source rock, migration pathway, timing, trapping mechanism, and hydrocarbon type.'* [2]

future. Estimates of URR at the regional level also include undiscovered gas that is expected to be both discovered and produced in the future. In principle, therefore, this definition is sensitive to assumption about future gas prices, technological developments and discovery rates. An alternative term for URR is *Estimated Ultimate Recovery (EUR),* with the latter being more commonly used to refer to a single well.

6. *Technically Recoverable Resources (TRR)* is the gas estimated to be producible with current technology, ignoring economic constraints. When applied at the regional level, there is some ambiguity as to whether this classification includes undiscovered gas, with contradictory statements appearing in some reports [3]. However the majority of evidence suggests that regional estimates of TRR include undiscovered gas. There is comparable ambiguity regarding whether cumulative production is included in TRR estimates, but for most regions of the world this makes little difference. If necessary, *Remaining Technically Recoverable Resources (RTRR)* can be used to explicitly exclude cumulative production.

7. *Economically Recoverable Resources (ERR*) is a subset of TRR and defines the resource that is estimated to be both technically *and* economically producible from a field or region. Such estimates are sensitive to assumptions about technical and economic conditions and may be expected to change over time. Since at least some estimates of regional ERR include undiscovered resources [4–8], we include them in our definition.

8. *Reserves* refer to a subset of *discovered* resources that are estimated to have a specified probability of being produced. Reserve estimates are commonly quoted to three levels of confidence, namely *proved* reserves (1P), *proved and probable* reserves (2P) and *proved, probable and possible* reserves (3P) although these terms are interpreted in different ways by different organisations. Under a probabilistic interpretation, 1P (or P90) reserves represent an estimate that is considered to have a 90% probability of being exceeded, 2P (P50) estimates have a 50% chance of being exceeded, and 3P (P10) estimates a 10% chance. Shale gas resources are only classified as proved reserves in North America and these currently comprise only a small proportion of the estimated TRR.

Table 1: Interpretation of resource and reserve definitions for natural gas

Name	Short description	Includes gas in undiscovered formations	Includes gas not economically recoverable with current technology	Includes gas that is not recoverable with current technology	Includes gas that is not expected to become recoverable
Original gas in place	Total volume present	✓	✓	✓	✓
Ultimately recoverable resources	Total volume recoverable over all time	✓	✓	✓	
Technically recoverable resources	Recoverable with current technology	✓	✓		
Economically recoverable resources	Economically recoverable with current technology	✓			
1P/2P/3P reserves	Specific probability of being produced				

Shale gas resource estimates

9. The majority of studies from UKERC's comprehensive review [1] focus upon North America, where exploration is most advanced. The review demonstrated that there are multiple and substantial uncertainties in assessing the recoverable volumes of shale gas at both the regional and global level. Even in United States, there is significant uncertainty over the size of the resource for currently producing regions and considerable variation in the available estimates for those regions. For undeveloped regions where less research has been conducted there may only be a single estimate of resources available, making it impossible to characterise the range of uncertainty. For several regions of the world there are no estimates at all, but this does not necessarily mean that such regions contain only insignificant resources.

10. It is important to recognise that there are two predominant methods used to generate estimates of the recoverable resources of shale gas. The first is based upon a bottom up analysis of geological parameters and generates an estimate of the shale gas in place to which a 'recovery factor', the estimated fraction of

the OGIP that is recoverable, is applied. The second bypasses the need to generate separate estimates of the gas in place and recovery factor and directly estimates recoverable resources either through extrapolating production data from adjacent areas for which data is available to undeveloped areas of the same region, or through the use of data from a geologically similar region.

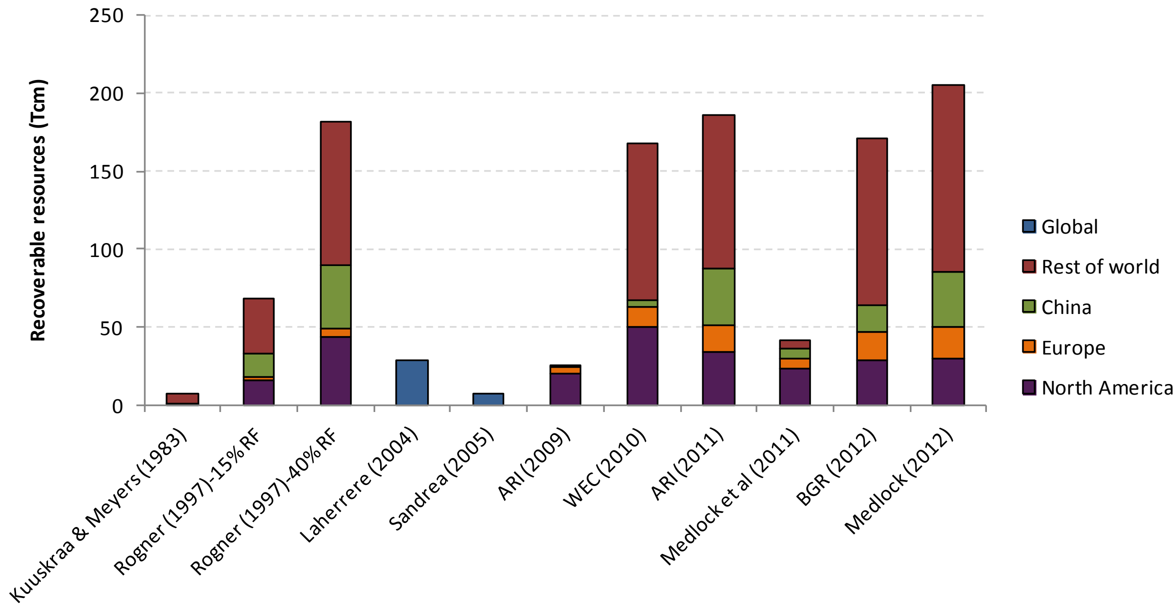
Global resources

11. The UKERC review found 11 studies that provided estimates of global shale gas resources, either in aggregate or broken down by region (Figure 1). Each of these studies covered different countries and regions and none provided a truly global estimate since each excluded some regions. For example, ARI [9] ignored regions where there were large quantities of conventional gas reserves (Russia and the Middle East) or where there was insufficient information to carry out an assessment.

12. The earliest and most cited global estimates are by Rogner [10], but these were produced using a relatively crude methodology and in the absence of any significant drilling experience for any region of the world. Rogner only estimated OGIP and made no assumptions about recovery factors. However, several authors have subsequently applied recovery factors to Rogner's figures to generate estimates of the TRR, including 15% by Mohr and Evans [11], 10–35% by MIT [6], and 40% by ARI [12] and the IEA [13].[2] For comparison, ARI [9] uses a range of 15% – 35% for the recovery of shale gas from different geological areas while recovery factors for conventional gas can be as high as 70–80% [14]. In Figure 3 we present estimates applying both 15 and 40% recovery factors to Rogner's OGIP.

[2] The IEA does not explicitly state the recovery factor used for each of the three unconventional gases, but provides figures from which it can be calculated.

Figure 1: Estimates of global shale gas resources

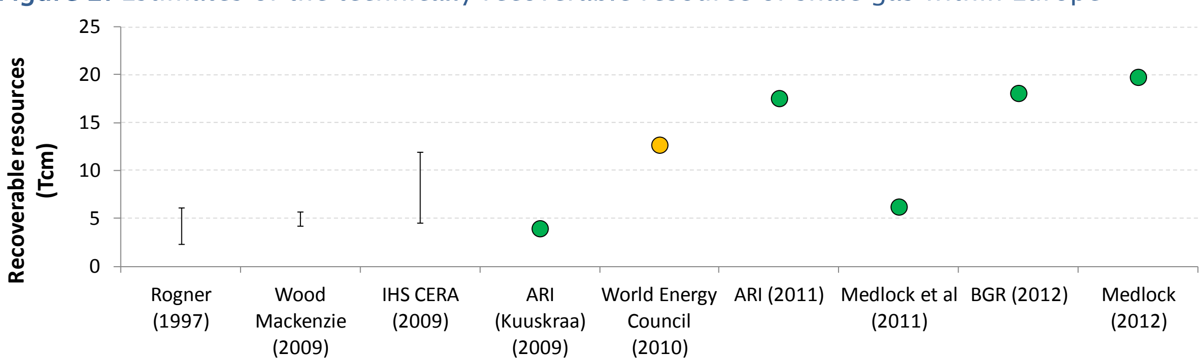


Note: Resource definitions also differ; both in terms of what is reported and how this is defined and estimated. Laherrere's estimate is URR, while Medlock's are likely to be closer to ERR. The OGIP estimate by Rogner is converted to TRR using 15% and 40% recovery factors and the WEC's estimate to ERR using a 40% recovery factor.

European resources

13. Relatively few studies have provided estimates of the technically recoverable shale gas resource within Europe. The available estimates are summarised in Figure 2, and range from 2.3 Tcm to 19.8 Tcm, with a mean of 10.6 Tcm. Note that ARI's estimate from 2009 ignored a number of plays.

Figure 2: Estimates of the technically recoverable resource of shale gas within Europe

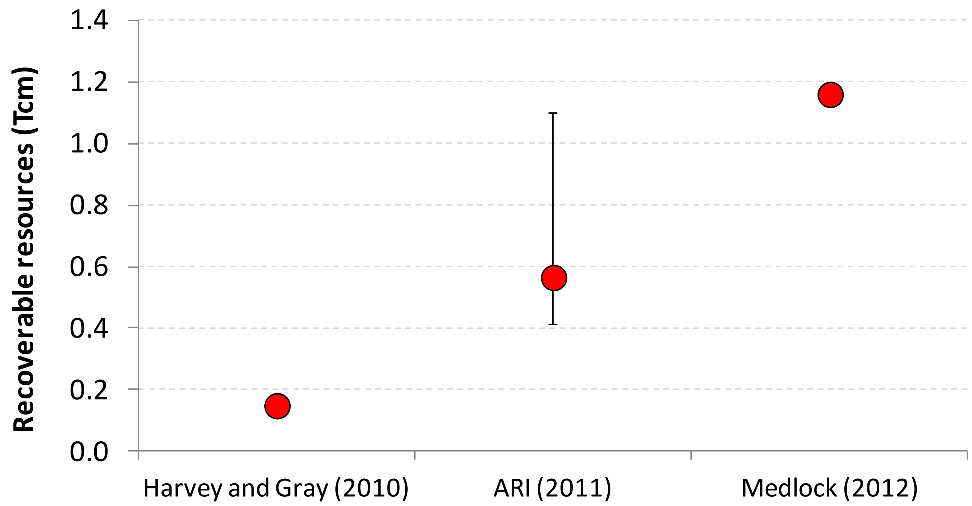


Note: Range for Rogner's estimate is derived using a 15-40% recovery factor within Western and Eastern Europe. Values for Wood Mackenzie and IHS CERA are from Weijermars et al. [15]. Point in yellow corresponds to an estimate of ERR

UK resources

14. Even fewer studies provide shale gas resource estimates for the UK (Figure 3). The three estimates represented by red data points [9, 16-17] are for TRR and range from 0.15 Tcm to 1.15 Tcm. The range around the ARI (2011) estimate represents the range derived by applying the 15 – 40% recovery factor range to the OGIP estimate of this study.

Figure 3: Estimates of the technically recoverable resources of shale gas within the UK



Note: The range for ARI (2011) is derived using a 15 – 40% recovery factor applied to an estimate of OGIP (95Tcm). All other estimates are TRR. Medlock [16] indicates the economics of extraction of different proportions of the resource, using 3-step cost curves. This concludes that the last proportion of the resource indicated in this figure will be significantly more expensive. Medlock (2012) then estimates on the basis of this cost curve that the ERR is 60% of the total TRR. Harvey and Grey [17] use simple analogues from the United States to generate their estimate.

Best Estimates

15. Our summary of current 'best' estimates of regional technically recoverable resources is presented in Table 2. This suggests that the global TRR of shale gas may be in the region of **193 Tcm.** For comparison, the global technically recoverable resource of conventional gas is estimated at **432 Tcm** (of which around 190 Tcm are classified as proved reserves). Combined with estimates of tight gas and coal bed methane (~**90 Tcm**) this implies a global TRR for natural gas of >**700Tcm**. These figures refer to technically recoverable resources and a range of factors could lead the economically recoverable resource to be <u>substantially</u> less. However, the main conclusions of the UKERC study are the very high level of uncertainty in these estimates, the inadequate treatment of this uncertainty by the majority of studies, the difficulties in comparing and

combining estimates from different studies, and the limitations of currently available estimation methodologies.

16. The UKERC review suggests the United States holds around 10% of the global TRR of shale gas, while Europe holds around 8%. While shale gas may provide around 28% of the global TRR of all natural gas it can be much more important at the regional level. For example, using our best central estimates, shale gas may represent 34% of the remaining TRR of natural gas in China, 36% in Canada, 48% in Europe and 31% in the United States. As an illustration of the uncertainty in these estimates, the high and low US shale gas estimates are 246% and 72% of the best central estimate respectively – and this is the best characterised resource.

Table 2: Estimates of the remaining technically recoverable resources of conventional, CBM, tight and the ranges resulting from choosing the most appropriate current estimates for shale gas (Tcm)

Region	Shale – Best estimates		
	Low	Central	High
Africa		29.3	
Australia		11.2	
Canada	3.6	12.0	28.3
China	6.5	17.8	36.1
CIS		11.6	
CSA		35.6	
Europe		15.9	
India	0.2	1.8	2.4
Japan		0.0	
Middle East	2.8		28.7
Mexico	4.2	11.4	19.3
ODA	1.3		22.1
South Korea		0.0	
United States	13.8	19.3	47.4
Global		**193.2**	

Notes: CSA = Central and South America, CIS = Commonwealth of Independent States, ODA = Other Developing Asia

Notes:

a) *In some regions it was not possible to develop a central estimate due to an absence of sufficient information, but we provide here a mid-point of high and low estimates for these regions*
b) *All estimates refer to technically recoverable resources, they take no account of economic viability or any other constraints on resource recovery*
c) *The reasons for choosing these particular estimates and/or manner in which they were derived are discussed in detail in [18]*

Why are the estimates for shale gas so changeable?

17. Shale gas is a new resource and the production experience to date is relatively limited. This, together with limited geological information and rapidly evolving technology leads to considerable uncertainty over the potential size of the recoverable resource – even in regions where production is relatively advanced. This uncertainty is hidden by the majority of studies which provide point estimates of resource size, rather than a range.

18. Further complications are introduced by the continuing ambiguity over resource definitions, thereby creating the risk of comparing 'apples and oranges'. As indicated above, the use of different resource definitions will lead to very different resource estimates for the same geological formation. It is not uncommon for different definitions to be compared as though they were equivalent, creating further disagreement and confusion.

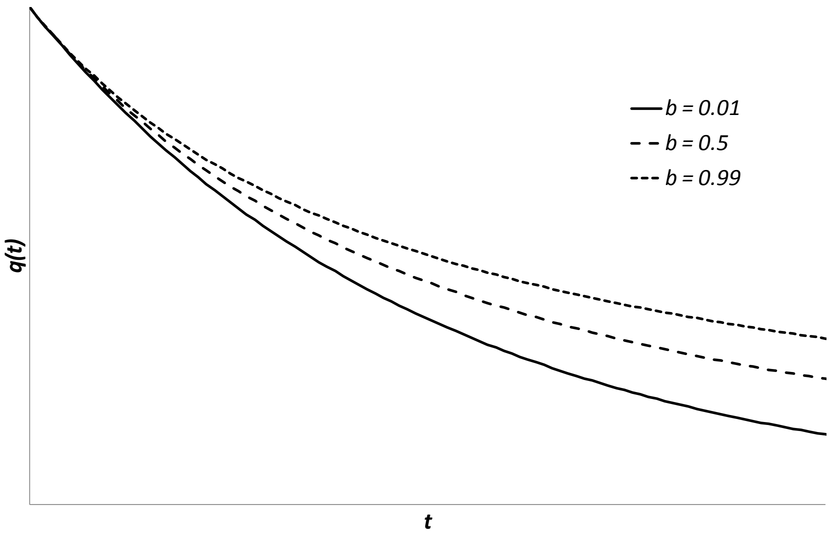
19. For most shale gas formations, there is a paucity of reliable geological data. Many of the formations which are thought to contain shale gas have not had extensive analysis through the drilling of wells, the testing of core samples and the assessment of well bore pressures and other variables key to estimating the OGIP and its producible fractions (ERR, TRR, URR, etc.). As first hand geological knowledge of these formations improves the uncertainty surrounding the potentially available resource should begin to reduce.

20. In the absence of new geological data, desk-based studies applying new assumptions to older studies are often produced. This is the most common approach to developing estimates for regions outside North America, but many of those regions continue to lack sufficient geological information. The results are also sensitive to the assumptions used, including the recovery factor. As demonstrated above (Figure 1), average recovery factors between 15 and 40% are plausible, but this produces global TRR estimates in the range 70 to 180 Tcm. At present there is little evidence to suggest which end of this range is more likely.

21. Once production in a region is underway, more reliable resource estimates may be derived by analysing the production experience to date and extrapolating this experience to undeveloped areas of the same region. As discussed above, a similar approach can be used to estimate resource size in separate but geologically similar regions (analogues). Given the wide variations in productivity within and between shale plays and the difficulty in estimating some geological parameters, the results are very sensitive to the particular analogue that is chosen.

22. Regional resource estimates using this approach are dependent upon the assumed EUR from individual wells. These are typically estimated by statistically fitting a curve to the historical production from a well or group of wells and extrapolating this forward into the future (Figure 4). These ‘decline curves’ are commonly used to predict the point at which the well will cease production, together with total gas that will be produced over its operating life. When combined with assumptions about average well spacing within the region, this analysis can be used to provide an estimate of the regional TRR. However, the appropriate shape of this ‘production decline curve’ has become a focus of considerable controversy in United States, with several commentators suggesting that the rate of production decline has been underestimated and hence both the longevity of wells and the EUR per well has been overestimated. To the extent that regional resource estimates are based upon EUR estimates for individual wells, this creates the risk that the regional URR will be overestimated as well. Other commentators have contested this interpretation, but the empirical evidence remains equivocal to date owing to the relatively limited production experience.

Figure 4: Variation of hyperbolic decline with the value of b



23. An example of these uncertainties can be seen in the controversy surrounding two recent resource estimates for the Marcellus Shale in the United States. The United States Geological Survey (USGS) estimate the technically recoverable resources of the Marcellus to be 2.4 Tcm while the consultancy INTEK estimated a much higher figure of 11.6 Tcm. There are three major reasons for this difference. First, the two organisations, subdivided the Marcellus in different ways. Second, the USGS excluded the shale gas in less productive areas of the play, despite this making up 57% of the total INTEK estimate. Third, INTEK assumed that the EUR from wells in the most productive areas would be three times greater than was assumed by the USGS.
24. Overall, given the absence of production experience in most regions of the world, and the number and magnitude of uncertainties that currently exist, estimates of recoverable unconventional gas resources should be treated with considerable caution.

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