The Cost of Longer-Run Gas Supply to Europe

PETER R. ODELL

Gas in Europe has always been sold above its long-run supply price. Recent lower prices, however, still permit profitable indigenous supply expansion and, as further reductions in production and transport costs from technological advances are expected, this will continue based on the exploitation of large proven and probable reserves. By 2025, indigenous output will be 60% up on 1995.

Nevertheless, an average 2.2%/annum growth in gas demand will increase import dependence from 130 to 320 BCM over this period. Future international oil prices indicate gas-equivalent border values adequate to secure profitable supply from a range of external sources, leading to continuing competition for markets and the diversification of imports.

En Europe, le gaz s'est toujours vendu plus cher que son prix d'offre à long terme. Toutefois, les baisses de prix récentes permettent toujours une expansion rentable de l'approvisionnement sur le plan local et, avec les progrès technologiques qui, prévoit-on, entraîneront des réductions de coût supplémentaires dans la production et le transport, ce phénomène se poursuivra en se basant sur l'exploitation des grandes réserves prouvées et probables. D'ici 2025, la production locale aura augmenté de 60% par rapport à 1995.

Néanmoins, une croissance annuelle de 2.2% de la demande de gaz augmentera la dépendance des importations de 130 à 320 milliards de mètres cubes durant cette période. Les prix futurs du pétrole à l'échelle internationale indiquent que les valeurs frontières équivalentes au gaz suffisent à assurer un approvisionnement rentable à partir de toute une gamme de sources externes, entraînant ainsi une concurrence permanente sur les marchés et la diversification des importations.

1. Antecedents

Over the more than 30 year history of the European natural gas industry to date, long-run supply costs have hardly mattered. To the east of the former "Iron Curtain," East European countries' gas was imported in the context of COMECON trade agreements within which, of course, prices were unrelated to western economic concepts (Dienes and Shabad, 1979: Hoffman, 1985; and Park, 1979). Within the rest of Europe,[1] the effectively state-owned, controlled and/or regulated gas industry has generally evolved under the influence of planned developments, rather than market forces (Odell, 1969; Estrada, 1988). Supply side opportunities were controlled and constrained as, indeed, were market developments. In the absence of competition, market values have been generally unrelated to long-run supply prices. Economic rents, collected

Peter Odell is Professor Emeritus, Erasmus Universiteit Rotterdam and formerly Director of the University's Centre for International Energy Studies. He is currently a visiting Professor at the London School of Economics.

1/ Designated in this paper as Western Europe, comprising all European member countries of the OECD - except Iceland, which is irrelevant to issues of gas, and Turkey, which provides a bridge for natural gas imports from the Middle East and Central Asia and is thus an external actor in the emerging European natural gas market.

partly by producing and distributing companies, but mainly by the governments of the gas-rich countries, have constituted a formidable percentage of total revenues generated by the industry since 1965; the year in which the exploitation of the super-giant Groningen gas field, with extremely low costs of production, began (Odell, P.R., 1969 and 1988).

2. The Link between Oil and Gas

The deliberate and definitive link between international oil prices and the prices paid to indigenous gas producers—and for most gas subsequently imported into western Europe—was established in the early 1960s through the strategy jointly evolved between the Dutch government and the Shell/Esso consortium responsible for the discovery and development of the Groningen field (Odell, 1969 and 1988). This created a barrier to the expansion of Europe's gas markets in the period of low and falling oil prices through to the early 1970s. Thereafter, with the onset of OPEC's control over international oil prices, gas prices in Europe were enabled to rise to levels of more than an order of magnitude above the costs of supply.

This, in itself, curbed demand, but, in addition, for reasons related to a perception of gas scarcity, policies designed to limit natural gas use were imposed.[2] Moreover, the Netherlands, Britain and Norway, also imposed restraints on potentially highly profitable gas production so artificially equilibrating the market at a scale which was well below that which would have been achieved under competitive market conditions (Odell, 1988 and 1992).

The subsequent two-thirds fall in the oil price (from its peak level in 1981/82) has brought gas prices tumbling by approximately the same percentage. Given that gas has gradually come to be recognised as a preferred source of energy—for environmental as well as for strategic/security reasons—and given that such considerations are often reflected in favourable tax conditions for gas *vis-à-vis* other fuels, then gas demand has been stimulated (from 200 BCM in 1981 to over 300 BCM in 1995). On the other hand, the fall in the price of gas appears to have had virtually no impact on the availability of supply. At most, the price fall led to the premature termination of production from a few small fields in France, Germany and elsewhere as they became uneconomic to continue in operation. Meanwhile, as far as production potential in Europe is concerned, this has, as shown in Table 1, continued to strengthen, related essentially to the continuity of investments which have ensured reserves additions in excess of year by year depletion. This is expressed in the continuing temporal build-up of proven and probable reserves.

3. Indigenous Reserves Development

Table 1 shows the four decades' long evolution of Western European reserves since 1956 through a period, that is, of energy sector traumas arising from the volatility of the international oil market. For the 30 years to 1986 the data show how demand limitations and production constraints led to reserves building up very strongly. Reserves additions were a multiple of the volumes of gas produced in each of the successive decades. Even in the decade since the price collapse of 1986, gross additions to proven and probable reserves amount to almost 4000 BCM, compared with the 10 year cumulative production of only some 2000 BCM. Of the total presently-indicated original recoverable reserves of 13,000 BCM from the fields discovered, almost two-thirds remain to be used. Even in the context of $17/bbl oil (see Table 2), Western Europe's potential to produce natural gas remains formidable with an approximate 35 years reserves to production ratio at the 1995 rate of production. Supply prospects for indigenous gas will be examined later in this paper, but it is first necessary to set the framework of prices and demand within which that supply needs to be evaluated. The bases and assumptions

2/ National policy steps to achieve this objective were subsumed in a European Economic Community decision in 1975 to restrict the use of gas in power stations, namely, *EEC Directive* no. 75/404 (see Odell, 1988).

Table 1: Evolution of Western Europe's Natural Gas Production and Reserves 1956-1995 (BCM)

Period	Cumulative Production to Date	Cumulative Production in Previous Decade	Period-End Remaining Recoverable Reserves	R/P Ratio (years) at End of Period	Indicated Total Original Recoverable Reserves	Gross Additions to Reserves in Decade	Net Additions to Reserves in Decade
Pre-1956	50	35	c.500	c.40	550	not known	not known
1956-1965	225	175	c.1,900	c.76	2,125	1,575	1,400
1966-1975	1,550	925	c.4,350	c.27	5,500	3,375	2,450
1976-1985	2,700	1,550	c.6,500	c.36	9,200	3,700	2,150
Forecast for:							
1986-1995	c.4,715*	c.2,015*	c.8,325**	c.35*	c.13,040	c.3,840	c.1,825

* Assuming the continuation of present gas production and use policies.

** On the basis of estimates of the reserves in fields already discovered by 1993: and with an assumption that they will appreciate by 5% by the end of 1995. In addition, of course, there is also a near-zero probability that no more fields will be discovered, given the continuation of an extensive and intensive exploration effort for natural gas in many Western European countries and their off-shore areas.

Sources: Compiled by the author from various sources, notably the annual publications of the governments of Denmark, Norway, The Netherlands and the United Kingdom on the activities of the oil and gas industries in those countries.

Table 2: Oil Price Assumptions and Related Gas Price Equivalents (1995 $)

		1995	2005	2015	2025
a.	Forecasts for the Average Price of Internationally Traded Crude ($/bbl) f.o.b. [1]	17.05	17.40	19.60	25.65
b.	Nominal Value of Gas at f.o.b. Crude Oil prices + $0.50/bbl freight costs. ($/mmBTU) [2]	3.22	3.29	3.69	4.80
c.	Average Gas Price Equivalent at the Frontier/Beach ($/mmBTU) [3]	2.67	2.85	3.45	4.75
d.	Forecasts for Ex-refinery Oil Products Prices ($/ton) [4]				
	i. Gas Oil	151	160	190	255
	ii. Low Sulphur Fuel Oil	104	110	125	165
e.	Equivalent Gas Price, based on 50% Gas Oil and 50% Fuel Oil ($/mmBTU) [5]	3.21	3.39	3.95	5.28
f.	Weighted Average Gas Price to End Users ($/mmBTU) [6]	5.68	5.45	5.95	7.35

1/ The 1995 value is the US Dept. of Energy calculations of the average price of the 26 most-traded crudes for the period October 1994 to September 1995. See P.R. Odell, *Global Economic/Energy Prospects*, 1994-2020 prepared for the IIASA/Stanford International Energy Workshop, 1995 for the derivation of the forecasts.

2/ Based on calorific equivalent of 5.45 million BTU per barrel.

3/ See Table 3 for the source of the 1995 values. Assumptions for other years are related to author's oil price forecasts.

4/ Author's own forecasts for annual average prices for cargoes ex-Rotterdam and Mediterranean refineries. From unpublished work for private clients.

5/ Based on gasoil with 40.55 million BTU/ton and 7.5 bbls/ton and low sulphur fuel oil with 39.23 million BTU/ton and 6.7 bbls/ton.

6/ See Table 3 for the derivation of the 1995 price. Assumptions for the other years are based on a continuing exchange rate of DM 1.46 to 1 US dollar, and a 10% reduction per decade in the relationship between the average gas price to end users and the average gas price at the frontier/beach.

from which these are derived are set out in Table 2.

4. Contemporary Prices for Gas in Europe

Aspects of the contemporary pricing of gas in Western Europe's six major consuming countries (responsible for about 93% of total West European gas use in 1995) are set out in Tables 3, 4 and 5.[3] In Table 3 note, first, the relatively small (a maximum of just over 5%) variation from country to country in the average border or beach/well-head price of gas; second, that that border price for gas in 1995, at an average of about $2.67/mmBTU, was below the equivalent of the landed internationally traded crude oil price of $17.55/bbl; and, third, that there are major variations in end-user gas prices (excluding all taxes) both between types of users and, for the same category of users, between the six countries. A calculation of the average end-user price per country (weighted by the percentage of use in each of the sectors designated in Table 3) shows a much wider variation (of up to 15%) between countries than the variation in border prices. If one relates the former to the latter (shown in the final line of the Table) then, compared with Italy, where user prices are least marked-up from border prices, gas prices to consumers in France and Germany are, respectively, 15.3% and 13.3% more expensive. And, even for Italy, the costs of inland transmission, distribution, sales and profit margins total almost as much as the delivered costs of gas from the suppliers. The data appear to indicate the existence of not inconsiderable "fat" in many gas end-user prices in much of Western Europe, suggesting that the contemporary limited competitiveness of gas may well be as much related to the structure and organization of internal national markets as to possible overpricing by suppliers. Note, in passing, that these data on prices do not indicate that market liberalisation in the UK had, by 1995, produced the lowest overall pre-tax consumer prices: Italian and Dutch prices remained below those of the UK. The weighted average prices for the six countries taken as a whole are shown in Table 4. On average, users pay more than twice, and domestic users well over three times, the border price: even without taking end-user taxes into account.

Table 5, on the other hand, contrasts fully tax-paid end-user gas prices with the equivalents for competing sources of energy. Major differences in the incidence of taxes on energy between countries pick out the UK as the country with lowest prices. But in as far as this low-tax situation applies generally to energy, other energy sources there are still generally lower priced than gas (on a calorific basis, without taking contrasting efficiencies in use into account). But the price differentials working against gas relative to other fuels are usually even worse in the other countries: except for the Netherlands. There, only power station coal is significantly lower priced than gas. Significantly, natural gas' 42.6% share of total energy use in the Netherlands stands at well over twice the European average of 18.8% (BP, 1995a), indicating how far gas' substitution for other sources of energy could go in the rest of Europe under gas pricing policies which are more competitive with alternative energy sources.

In Belgium, other sources of energy are generally very competitively priced. Gas thus has no significant price advantage in any sector (except over low sulphur fuel oil in power generation), so it is hardly surprising that gas use is restricted to 18% of total energy use. The same is true for Germany (where gas also accounts for 18% of energy use), except in respect of coal as a consequence of the continued use for political reasons of much higher cost indigenous production. In France (with only 12% gas use), cheaper alternatives to gas are available in most sectors. In other words, over much of Europe gas pricing policies (sometimes including energy taxation policies) inhibit the expansion of gas demand. This limits the economies of scale which could otherwise

3/ Based on research by Energy Advice Ltd (London) for its contribution on *European Gas Markets; Prospects to 2020* to the study by Prognos AG, Basel on *Die Energiemärkte Deutschlands in Zusammenwachsenden Europa–Perspektiven bis zum Jahr 2000* for the German Federal Ministry of Economics, 1995.

Table 3: End-User Prices in the Six Main Gas Using Countries Indexed to Border (Beach) Prices of Gas, October 1994 - September 1995

	Germany	U.K.	NL	France	Italy	Belgium
a. Border Prices						
i. In $/mmBTU	2.67	2.63	2.64	2.73	2.70	2.70
ii. In Pf/kWh	1.34	1.32	1.32	1.37	1.35	1.35
Index: Lowest = 100	*101.5*	*100*	*100*	*103.7*	*102.4*	*102.5*
b. End-User Prices (Pf/kWh excl. VAT and all taxes); figures in brackets show % of total use in each sector						
i. Domestic	4.74 (30)	3.75 (48)	3.81 (35)	4.75 (37)	4.17 (30)	4.58 (32)
Index: Border Price = 100	*355*	*287*	*289*	*348*	*310*	*340*
ii. Commercial	3.34 (15)	2.37 (13)	3.55 (13)	3.45 (16)	3.32 (10)	3.44 (10)
Index: Border Price = 100	*250*	*181*	*270*	*253*	*247*	*255*
iii. Medium Industry – Firm	2.90 (8)	2.04 (6)	2.09 (6)	2.04 (10)	2.14 (9)	2.26 (8)
Index: Border Price = 100	*217*	*156*	*169*	*149*	*159*	*168*
iv. Large Industry – Firm	1.73 (23)	1.84 (7)	1.73 (14)	1.67 (14)	1.83 (15)	1.91 (13)
Index: Border Price = 100	*129*	*141*	*131*	*122*	*136*	*142*
v. Large Industry – Interruptible	1.67 (6)	1.41 (7)	-	1.62 (14)	1.75 (15)	1.57 (13)
Index: Border Price = 100	*125*	*108*	-	*119*	*130*	*116*
vi. Power Stations	1.94 (16)	1.46 (16)	1.59 (25)	1.62 (2)	1.70 (19)	1.54 (17)
Index: Border Price = 100	*145*	*112*	*121*	*119*	*126*	*114*
vii. Feedstocks	*1.60 (2)*	*1.40 (3)*	*1.49 (7)*	*1.60 (7)*	*1.61 (2)*	*1.53 (7)*
Index: Border Price = 100	*120*	*106*	*113*	*117*	*120*	*113*
c. Weighted *Average Price (Pf/kWh)*	*3.00*	*2.73*	*2.66*	*3.12*	*2.67*	*2.81*
as % of Border Price	*224.6*	*207.4*	*202.0*	*228.6*	*198.2*	*208.3*
d. Index to Lowest Value in c.						
i. Indexed by Weighted Absolute Prices	*112.7*	*102.6*	*100*	*117.3*	*100.4*	*105.6*
ii. Indexed by Weighted Prices relative to Border Prices	*113.3*	*104.6*	*101.9*	*115.3*	*100.0*	*105.1*

Sources: Border prices are derived from the monthly data reported by *World Gas Intelligence* in the absence of official data either from governmental or industry sources. End-user prices are from *European Energy Pricewatch* and *Energy Advice's* own research.

Table 4: Weighted Average Gas Prices in West Europe's Six Main Gas-Using Countries October 1994–September 1995

a. Average Border Price	
$/mmBTU	2.67
Pf/kWh	1.34
b. End User Prices (Pf/kWh)	
Domestic	4.19
Commercial	3.06
Medium Industry	2.25
Large Industry–firm	1.76
Large Industry–interruptible	1.62
Power Stations	1.66
Feedstocks	1.57
c. Weighted Average[1] Overall (Pf)	2.83
as % of Average Border Price	211

1/ Weighted averages based on total gas use per country shown in Table 6 and percentage use per sector shown in Table 3

Source: Derived from Table 3

be achieved and so adds yet another factor making the border supply price of gas less significant to the prospects for the evolution of the European gas market than is often portrayed.

5. Demand Expansion and Implications for Supply

Notwithstanding the continuing constraints on gas use, the European market for gas is, and will remain, in an expansionist mode (Pauwels, 1994; Prior, 1994; Stern, 1990). The potential for such expansion is considered in depth in other contributions. Here, as a background only to considerations of the prospects for the supply price, we predicate an expansion of gas use in Europe over the 30 years to 2025 as

Table 5: Comparative Prices of Gas and Competing Fuels by Sector in the Six Main Gas-Using Countries, First Quarter 1995 (gas prices in Pf/kWh including VAT where applicable and all taxes)

Sector:	Germany	UK	NL	France	Italy	Belgium
a. Domestic: Gas	5.90	4.11	4.84	5.62	8.38	5.81
Indexed Gas Oil (Gas = 100)	***63.7***	*69.6*	*102.7*	*93.4*	*127.9*	***52.8***
b. Commercial: Gas	3.74	2.38	3.86	3.88	6.32	3.44
Indexed Gas Oil (Gas = 100)	***74.9***	*108.0*	*95.4*	*102.3*	*136.2*	***66.0***
c. Medium Industry: Firm Gas	3.29	2.04	2.36	2.20	2.42	2.28
Indexed Gas Oil (Gas = 100)	***83.6***	*117.6*	*146.2*	*159.5*	-	***96.5***
" L.S.F.O. (Gas = 100)	***56.8***	*92.6*	*104.7*	*94.5*	*87.6*	***75.0***
" Coal (Gas = 100)	*117.0*	*87.7*	-	*72.7*	***57.9***	***48.2***
d. Large Industry: Firm Gas	2.06	1.89	1.88	1.87	2.06	1.92
Indexed L.S.F.O. (Gas = 100)	*90.8*	***90.5****	-	*108.0*	*100.0*	***87.0***
" Coal (Gas = 100)	*186.9*	***63.0***	-	*85.6*	-	***53.6***
e. Large Industry: Interruptible	2.01	1.57	-	1.84	2.05	1.57
Indexed L.S.F.O. (Gas = 100)	***93.0***	*108.9*	-	*109.8*	***100.5***	*106.4*
" Coal (Gas = 100)	*191.5*	***75.8***	-	*87.0*	-	***65.6***
f. Power Stations	*2.28*	*1.45*	*1.73*	*1.84*	*1.74*	*1.54*
Indexed L.S.F.O. (Gas = 100)	***82.0***	*117.9**	-	*109.8*	***94.8***	***108.4***
" Coal (Gas = 100)	***92.1****	***87.6***	***80.3***	***87.0****	***64.9***	*77.9*

N.B. The *lower* the indexed value for alternative fuels, the *greater* the price competition for gas. The two lowest values for each alternative fuel are in bold. Belgium and Germany appear to have the least price-competitive gas in most sectors.

* Fuel oil in large industry and power stations in the UK is 2% sulphur.
** Coal price to German and French power stations is calculated after allowance for subsidies to indigenous coal.

Sources: See Table 2.

shown in Table 6.[4]

Overall, this involves a near 100% increase in gas use in Western Europe and a two-and-a-half times increase in its use in Eastern Europe from estimated 1995 levels. These increases imply a cumulative use of gas over the 30 year period of more than 16,000 BCM, compared with the cumulated use of under a third of this amount over the 40 year period from 1956-95. Meeting this potential demand clearly involves not only the discovery or addition of large additional reserves within Europe, but also access to increasing volumes of imported gas. Thus, for the first time in the history of the European gas industry, demand increases will directly influence upstream activities and, in due course, reduce the contemporary highly favourable gas reserves-to-production ratios to more modest levels.

Under these demand circumstances the cost of longer-run supplies could thus become a critical variable in the further evolution of the industry. We shall argue below, however, that such a development is very unlikely during the time period under consideration in this paper. In order to test this it is necessary to look separately at the indigenous supply potential, on the one hand; and, on the other, at the imported gas contribution. Undue dependence on the latter may well be viewed as a serious enough problem to justify demand-side constraints, irrespective of considerations of relative prices (Pauwels, 1994).

6. Indigenous Supply Prospects and Prices

This historic importance for Western Europe of

4/ This is derived from research by the author for his contribution to Prognos, 1994. It is compatible with other recent forecasts of European gas demand (as, for example, by Williams, 1993; Pauwels, 1994), and as reported in Prior, 1994, though note that these studies were generally confined to the period to 2010. For consideration of the long-run supply price issues this is, from a 1995 base, too short a period. Hence the need in this paper to extend the period by another 15 years.

Table 6: The Evolution of European Gas Use by Country, 1995-2025 (BCM)

Country	Actual 1995	Potential use in: 2005	2015	2025
a) Western Europe:				
Germany	72	85	102	118
United Kingdom	75	95	105	116
Italy	52	67	84	96
The Netherlands	40	43	45	48
France	35	43	52	62
Belgium	13	17	22	27
Spain	10	19	25	34
Austria	8	10	11	13
Finland	4	7	9	10
Denmark	4	6	8	10
Ireland	3	5	6	7
Switzerland	2	4	5	6
Sweden	1	3	6	8
Luxembourg	1	1	2	2
Greece	-	2	5	8
Norway	-	2	3	5
Portugal	-	5	7	12
Sub-Total	321	414	497	582
b) Eastern Europe:				
Romania	20	24	27	30
Poland	10	18	24	30
Hungary	11	14	16	22
Czech Republic	8	13	16	23
Slovakia	6	8	10	14
Bulgaria	6	7	9	12
Former Yugoslavia	3	6	8	11
Albania	-	2	3	4
Sub-Total	64	92	113	146
c) Overall Total	385	506	610	728

Source: see text, footnote 4.

its indigenous gas resources is shown in Table 7. Such indigenous resources have always provided most of the gas used and continue to do so to the extent of almost 70% of the gas supplied. Given the indicated expansion of demand over the next three decades, the role of indigenous production will become even more important to the secure evolution of the market and in helping to maintain a competitive supply situation. This presupposes, of course, that indigenous gas is not only profitable to produce, but also that continued investment in the exploration for, and the exploitation of, additional reserves is economically viable. Given the prolific nature of the occurrence and the potential massive availability of external resources, enhanced gas-on-gas competition could well drive gas prices down so that the economic producibility of the European reserves become an issue of importance and concern.

Of the total remaining proven and probable reserves shown in Table 1, over 60% fall into the proven category; and, by definition (BP, 1995b), are thus recoverable at present costs, prices and technology. Given the relative maturity of the North Sea oil and gas province within which most of these reserves are located—and within which there exist production and transportation systems which will continue to be usable and/or expanded and extended at modest cost—there is a known availability of at least 5,500 BCM at costs which require no (real) price rises to make the operations profitable. Beyond this, there are the probable reserves (which given their occurrence in a large number of individual fields have an overall high probability of being available) of at least another 3,000 BCM which can also be brought profitably to market within the constraint of present prices. And this already favourable situation for larger-scale future production from known reserves is made yet more attractive by the continuing prospect of real-costs' reduction as a result of further progress in exploitation technology (Handley, 1995; Williams, 1992).

Even more important, as indicated in the footnote to Table 1, these reserves estimates relate only to the gas in fields already discovered and declared commercial by 1993, with a modest 5% allowance for reserves' appreciation by the end of 1995. This is a highly conservative view of their ultimate potential given, first, the certainty that, on average, the statistical population of discovered fields will continue to exhibit the phenomenon of reserves' appreciation. Even the 36 year old Groningen field—for which the estimates of its initially recoverable reserves have been up-graded so many times that they are now declared at twice the level of 1965 when production began—still has some potential for further upward reappraisal (Odell, 1992). There is a similar prospect for

Table 7: Natural Gas in Western Europe, 1961-1994

Year	Indigenous Production (BCM)	Imports (BCM)	Total Use (BCM)	% Dependence on Imports	No. of Countries Using Gas	Gas Use as % of Energy Use
1961	16	0	16	0	5	1.8
1966	24	1	25	3.8	7	3.3
1971	104.5	1.5	106	1.4	8	9.7
1976	164	19	183	10.4	10	13.4
1981	176	24	200	12.0	11	14.7
1986	179	39	218	17.8	15	15.2
1991**	198	72	270	26.7	15	19.4
1994**	210	95	305	31.1	15	20.9

* Primary and nuclear electricity calculated on the heat value of the output.

** Includes data for the former East Germany.

Source: Compiled by the Author from various sources.

the largest and long-since discovered offshore gas-fields in the southern basin of the North Sea; while, for the to-date little exploited fields of the central basin, the process of effective reserves' evaluation—based, as it must be, on production experience—has barely begun (Kemp, 1994; Stoppart, 1994).

In the Norwegian sector of the North Sea a recent upward revision of the estimates of reserves (Norwegian Petroleum Directorate, 1993) has not only greatly enhanced the length of period over which plateau rates of production can be maintained, but has also pushed the country's potential peak production above 100 BCM/year. Except for the Ekofisk and Frigg groups of fields, Norway's gas exploitation history is, indeed, still in its early stages. Given, however, the massive scale of the investment that has already been made in both new production facilities (as, for example, in the Troll fields) and in pipelines to transport the gas to the mainland of Europe (Royal Ministry of Industry and Energy, 1995), coupled with the modest marginal costs which will be incurred in due course in the additional exploitation of the fields, the depletion of whatever volumes of gas are eventually defined as producible is not in doubt at the netback values from today's beach/border prices (see Table 2), measured in real terms.

In addition, there is a second major reason for noting the conservatism of current indigenous reserves' data for Europe, namely, the certainty of a continuing process of discovery of new fields in western Europe in the context of high exploration expenditures in both known and prospective gas rich provinces. Outside the North Sea, the mid and north Norwegian and the west of Shetlands basins have already been proved hydrocarbons rich (Norwegian Petroleum Directorate, 1993; Department of Trade and Industry, 1995). The former, in particular, has been shown to be gas prone so that proposals for the initial developments of the already discovered fields are already under way. Other areas around the coast of Europe have been demonstrated as having more modest resources, but these could eventually be developable in appropriate locations, relative to emerging gas demand patterns, given the ability of advancing technology to lower field development costs. These, however, will only become 'necessary' to sustain increasing European gas production in the long term.

Meanwhile, on the assumption that indigenous gas will only be able to secure about 60% of future west European gas markets in the face of competition from external suppliers, then the reserves which are known, probable and possible (within the limits set by expected market values expressed in real terms) from the exploitation of existing and planned fields' developments will not only meet the total cumulative requirements to 2025 (some 8,000 BCM), but will also provide at least the minimum carry-over of reserves of about 4,000 BCM for an adequate R/P ratio of 10 to 12

years at that date. This implies additions to reserves over the next 30 years which are equal only to the gross additions to reserves during the last 10 years.

The exploration and exploitation history of Europe's upstream offshore gas industry is still relatively short so that the learning process for effective production continues. Thus, the inevitability of rising costs through the reserves' depletion process seems likely to continue to be offset in whole or in large part by the downward pressures on costs engendered by technological advances (Adelman, 1990: Handley, 1995). And as this is starting—in 1995—from a situation in which prices are well above the long-run supply price (so that sizeable rents, taken mainly in the form of taxation and, less so, as super-normal profits, are still being achieved), then, under increasingly competitive conditions, a downward trend in the border/beach price of indigenous gas over the rest of the century towards a lower base level is more likely than not. Note that this development is, indeed, already under way in the UK where current beach prices for gas are only about half those of earlier contracts. On the other hand, expected rising real international oil prices post-2000 (see Table 2) will eliminate the validity of that lower gas supply-price as the most appropriate base from which to price European gas. As throughout the past 40 years, the profitability of indigenous gas production seems likely to remain assured by the expected development of the price of international oil. On the basis of this range of considerations the potential most likely evolution of European gas production is as shown in Table 8. Growth continues throughout the period—albeit at a much reduced rate after 2005—to give an overall increase of over 60% over the next three decades.

Table 8: European Gas Production Potential; 1995 to 2025 (BCM)

Country	Actual 1995	Potential in: 2005	2015	2025
a. Western Europe				
The Netherlands	71	70	66	58
United Kingdom	70	98	116	128
Norway	35	69	90	105
Italy	21	23	25	25
Germany	17	16	13	10
Denmark	6	9	10	11
France	3	2	2	2
Ireland	2	3	4	4
Others	1	2	2	5
Sub-Total	226	292	328	348
b. Eastern Europe				
Romania	17	25	28	32
Hungary	5	7	8	10
Poland	4	6	7	6
Former Yugoslavia	1	2	2	4
Others	1	4	5	10
Sub-Total	28	44	50	62
c. Overall Total	254	336	378	410

Sources: see text.

7. Europe's Gas Imports

Concern for higher priced gas imports—sometimes expressed as "the inevitability of higher prices" (Williams, 1993)—relate in part to exaggerated expectations for the volumes of gas which Europe will have to import. These expectations emerge from the forecasts of much more limited prospects for indigenous production than those indicated above (Pauwels, 1994; Prior, 1994). Conventional wisdom has long been pessimistic in this respect. For example, views presented through to the late-1980s indicated that the level of indigenous production would have passed its peak by 1990 (International Energy Agency, 1986) so that after only another decade, even within the context of a slow growth in gas use, Western Europe would depend principally on gas imports. Most forecasts on indigenous gas prospects remain relatively pessimistic; differing only in their views on the rate of decline in production from the late 1990s (Prior, 1994). As shown above, we do not share this view—indeed, have never shared the view—because of the existence of the very extensive potentially petroliferous areas and of the ready availability in Europe of financial and technological resources whereby long continuing exploration efforts can be sustained (Odell, 1969 and 1988). The success of those efforts in finding and adding to reserves thus enables

output to keep moving ahead. Table 7 above shows that this view has to date been fully justified—in spite of deliberately constrained production policies from time to time by the main producing countries.

The process will, as argued above, continue and, as shown in Table 9, severely restrain the rate of increase in import needs. Thus, from an estimated 131 BCM of imports in 1995 (almost three quarters from Russia and most of the rest from Algeria), there will be a modest increase to 170 BCM in 2005, 232 BCM by 2015, and 318 BCM by 2025. The 30 year cumulative volume of gas involved will be no more than 6,500 BCM. Assuming the continuation of Russia and Algeria as the only suppliers and of the present 75:25 split between them, then the call on the former's currently proven reserves of 48,000 BCM would be under 10%, but would be 45% of the 3,600 BCM of Algeria's presently declared reserves. The latter will have to be expanded if Algeria is to maintain its present contribution to Europe's imports.

7.1 The Supply and Price of European Imports until 2004

To date, both Russia's and Algeria's access to European markets has been made easy, partly by the political constraints on production in Europe and partly because Germany and Italy, respectively, have, in return for gas imports, achieved important economic advantages in respect of the markets they have secured for goods and services required by the gas industries of the two countries (Estrada, 1988). Germany and Italy, in turn, ensured success in the construction of the capital intensive transportation infrastructures required to get Russian and Algerian gas to Europe. For the two gas supplying countries there were equally important gains. Its export contracts with European customers enabled Algeria to produce gas with significant economies of scale and thus to secure low-cost gas for use in its own economy. For the former Soviet Union—and, more recently, Russia—the role of gas exports in sustaining the country's hard-pressed economy has been crucial (Dienes, Dobozi and Radetzki, 1994).

Table 9: Gas Production, Use and Trade in the West and East European Gas Markets, 1995-2025 (BCM)

	Actual	Forecasts for:		
	1995	2005	2015	2025
a) Western Europe				
Gas Use	321	414	497	582
Gas Production of which	226	292	328	348
– *used in the Countries of Production*	*156*	*189*	*206*	*215*
– *exported to other West European Countries*	*70*	*95*	*108*	*115*
– *exported to East European Countries*	*0*	*8*	*14*	*18*
Imports from External Supply Sources	95	130	183	252
Import Dependence (%)	29.6	29.8	37.1	43.3
b) Eastern Europe				
Gas Use	64	92	113	146
Gas Production of which:	28	44	50	62
– *used in Countries of Production*	*28*	*42*	*47*	*58*
– *exported to other East European Countries*	*0*	*2*	*3*	*4*
Imports from West Europe	0	8	14	18
Imports from External Supply Sources	36	40	49	66
Import Dependence	56.3	43.5	43.4	45.2
c) Total Europe				
Gas Use	385	506	610	728
Indigenous Production	254	336	378	410
Imports from External Sources	131	170	232	318
Import Dependence (%)	34.0	33.6	38.2	43.7

Sources: See Tables 6 and 8 for gas use and gas production by country, respectively. Forecasts of intra-European trade and gas imports to Europe are derived as indicated in footnote no 4.

These considerations—for both Germany and Italy, on the one hand, and for Algeria and Russia, on the other—continue to apply: though now, of course, in the context of enhanced political problems (Estrada, 1995). Ignoring the latter, the call on the resources of the two exporters—in terms not only of their gas reserves, but also of their resources of management and finance whereby they can achieve the potential for this higher level of

exports to Europe as specified above—remains modest compared with the benefits which the exports will generate.

The two countries will thus be highly motivated to secure the largest share possible of the European gas markets open to imports. As shown above, at least through the two decades to 2015, the markets for imports will remain quantitatively restricted from a combination of quite modest increases in demand and by the expansion of Europe's own output; most notably from the North Sea and adjacent areas, but not excluding proportionately larger, though volumetrically limited increases in gas production in a range of both west and east European countries. This is consequent upon the enhanced exploration and development efforts which will occur, especially in Eastern Europe where opening the upstream gas industry to international expertise, management and investment will, first, stop and, then, reverse the decline in output which has been under way since 1988.

The outlook for prospective exports of gas to Europe will be particularly restricted for the first decade—with, as shown in Table 9, a forecast requirement for only an additional 39 BCM in 2005 compared with 1995. Contracts are already in place sufficient to meet most of this modestly increased requirement for imports—mainly on the basis of the oil-related prices as used in the existing system. In the current situation of energy over-supply it seems unlikely that the external suppliers will be able to improve on this method of pricing. Indeed, excess supply relative to demand, coupled with the sellers' strong motivation to try to sell more gas, seems more likely to lead to gas prices which move independently of oil on the down-side, though still restricted on the up-side to oil equivalents (see Table 2) in the event of the market unexpectedly strengthening over the coming decade. Given their already existing gas production and transport infrastructure, either in place or under construction, whereby most of the expected 2005 level of exports can be handled, neither Algeria nor Russia seem likely to face any problems of economic viability in fulfilling their obligations and opportunities to supply gas at prices which are no higher, in real terms, than those of today.

For Russia, in particular, the continuing national decline in gas use will free up both the gas itself and the infrastructure capacity required to make it available for export (Stern, 1995). Thus, the profitable export of all the Russian gas for which markets are likely to be found in Europe by 2005 is hardly in doubt: except, of course, in the context of internal political problems which would disrupt the supply/transportation system and significantly increase costs.

For Algeria, neither the economics of, nor the capacity for, enhanced exports up to the contracted level for 2000 of 60 BCM/year, compared with the approximately 30 BCM which is being exported to Europe in 1995, appear to pose any problems (Estrada, 1995). It is once again only political problems leading to the partial break-down of the country's gas production and transmission systems, which could pose a physical restraint on gas availabilities and/or the imposition of higher costs.

7.2 The Supply and Price of Imports, 2005-2014

For this second future decade uncertainty over Europe's gas imports increases: in a period, moreover, when, as can be calculated from the data in Table 8, the rate of increase in indigenous production falls to about 1.2%, well below the rapid rate of expansion (of 2.8%/annum) foreseen until 2005. Though all but one of Algeria's contracts extend beyond 2005, this is not the case with Russia's contracts, most of which are valid only until the early years of the 21st century. Of the indicated demand for imports of about 200 BCM by the middle of this period (extrapolated from Table 9), less than one half is already contracted under contemporary supply and pricing criteria.

Algeria, we have suggested above, may have been able to increase its approximate present 25% share of Europe's total imports to as much as 35% by 2005, but its ability to maintain its enhanced position thereafter depends on the necessary expansion of its proven reserves base and on the level of costs at which larger volumes of gas can be exploited and

moved to markets via new or expanded pipelines to southern Europe. However, within the context of an oil price rising from today's levels (in real terms) through to $19.60/bbl by 2015 (see Table 2) there will be scope for real increases in the delivered gas price up to a maximum of approximately $3.35/mmBTU. Such a price would provide a powerful economic motivation for further investment in Algerian gas exploration, production and transportation and thus provide for the expansion of supplies to Europe to the ±90 BCM which Algeria might wish to try to secure in competition with supplies from Russia (Pauwels, 1994). However, alternative North African supplies—which, in part, could make use of the same trans-Mediterranean transmission lines—could also offer a significant potential addition to the flow of gas to southern Europe by that time. Libyan and Western Desert Egyptian gas provide these possible competing alternatives. This gas lacks effective alternative external markets so that there will be no competing demands for it and thus no upward pricing pressures on the supplies.

Russia, however, seems likely to aim to provide up to two-thirds of external gas supplies to Europe in the 2005-14 period as a result of both economic considerations and from the viewpoint of the policy interests of supplier and customers. In the context of the plenitude of Russia's gas reserves, the basic technical competence and the organisational strength of its gas industry (measured by Russian standards) and the interest of international oil and gas companies in the exploitation of Russia's gas resources, it is impossible to forecast just how development will proceed and what specific projects will be completed so as to deliver gas to Europe in the decade beginning in 2005 (Stern, 1995). There are a number of gas resource development opportunities which could be exploited to provide more than sufficient gas to meet the prospective European demand for Russian gas (rising from about 120 BCM in 2005 to at least 145 BCM in 2014). It does, however, seem more likely than not that the continuity of the rehabilitation process in respect of both the pre-existing production and transmission systems will continue to be central to the profitable export of additional gas to Europe after 2005. This will be in the likely context of an internal demand for gas which even then remains below historically higher levels (as a result of the achievement of a price-motivated increased efficiency in use by that time) and of a renewed pipeline system in which transportation losses will have been much reduced from today's high levels by the application of western technology, so offering greater throughput capacity (Dienes, Dobozi and Radetzki, 1994; Pauwels, 1994; Stern, 1995).

Such gas will be low cost relative to the border price (of up to $3.35/mmBTU) which the European gas market will bear in the context of the slowly rising international oil price after 2005. The availability of enough Russian gas sufficient to equilibrate the European market through such relatively low-cost supplies, seems highly probable early in the decade when about 120 BCM a year will be required. Beyond 2005, however, it is conceivable that initial developments in major new gas regions—notably Yamal and the Barents Sea—will be poised to make a contribution to Russian gas supplies. Even if these new supplies have a price of more than $3/mmBTU and may thus initially have to be "eased" into the market on the basis of a degree of cross-subsidisation from the profits on the use of "rehabilitated" gas, then this still could be in Russia's interests so as to be ready for the time later in the decade when economies of scale in the new areas and through the new lines will become effective enough to sustain the profitable exploitation of the new gas in its own right.

North Africa plus Russia will thus be able, politics permitting, profitably to supply Europe's import requirements through the decade from 2005 to 2014 at border prices which reflect internationally traded oil equivalent values. Over the decade, as shown in Table 2, these seem likely to rise from $2.85 to about $3.45/mmBTU. This oil equivalent value does, of course, only set the upper limit to gas prices imported into Europe, so that gas markets will be able to expand in competition with oil and coal. Under competitive gas market

conditions, as seems not unlikely given the plethora of potential supplies, gas prices could well, however, fall below this upside restraint. How far below depends on the degree of competition which emerges between the main external players, namely, Algeria and Russia (both, by that time, with a possible range of individual supplying companies), and between these external suppliers and the competing indigenous producers. The potential battles for market shares could, of course, produce very different contributions to supplies from those shown in Tables 8 and 9. Central Asian gas suppliers, namely, Turkmenistan and Kazakhstan, would also like and, indeed, expect to be additional competitors for a share of European gas markets in the 2005-2014 period. Given, however, both the geo-politics and the economics of Central Asian to Europe transmission lines, investments in this gas for European markets, even at the oil equivalent prices indicated above, seem likely to be marginally viable at best. Even with the utilisation of best international gas industry practices, the most modern technologies, the required political will and only modest claims for transit fees from Turkey and other intervening countries, getting a gas production and transportation system in place and working effectively so to enable Central Asian gas to be economically deliverable to Europe so early in the 21st century currently seems unlikely; except in the event of a cooperative arrangement whereby Russia transits the gas to the border with Europe. This would be a lower-cost option, but it implies Russian control over, and hence limitations on, the deliveries of Central Asian gas in a situation in which Russia would see the gas as competing for its own export opportunities.

7.3 The Supply and Price, 2015-2024

In speculating on the third future decade, uncertainties multiply, but so do the number of possibilities for serving the then still growing Euro-gas market. Accessible resources by 2015 will have multiplied as a result of continuing exploration and development investment in the meantime in response to market challenges. Cumulative use in the decade will most likely exceed 6,600 BCM, of which less than 60% are likely to come from indigenous resources, leaving almost 2,700 BCM to be provided by imports; rising from some 230 BCM in 2015 to about 320 BCM by the last years of the decade.

Such a larger market will clearly have space for Libyan and Egyptian, as well as Algerian, gas from North Africa. The main expansion of Russian supplies from 2015 will have to be derived from the then recently developed resources of the Yamal Peninsula, the Barents Sea and other regions of the country, depending on where Russian and foreign companies decide to make their investments over the next twenty years. Furthermore, the initial development of gas in Turkmenistan and Kazahkstan for export to European markets will at last be stimulated by the much larger-scale market opportunities and thus be able to secure significant economies of scale in the operations. And, finally, even some low-cost Middle East gas—from Iran and Qatar particularly—could well have been developed for export by pipeline to Europe. Thus, Europe's expanding gas markets will become served by a much expanded—and lengthened—transport network implying, of course, higher average transmission costs compared with the earlier decades, albeit in the context of low-cost gas at the well-head, compared with the likely supply costs of indigenous gas by that time.

The ability of such longer-distance gas to profitably enter the European market will be related, in part, to its low supply price at the production locations and, in part, to the higher real prices at which international oil will then be traded—as a consequence of tighter supply/demand relationships emerging in the international oil market by that time from the high and still growing demand for oil products in South Asia, the western Pacific Rim and other parts of what is now the developing world. Over the 10 year period from 2015, we forecast the oil price to rise from $19.60 to $25.65/bbl (in 1995$). In this oil price context the competitive entry price for gas at the borders of Europe will increase from $3.25 to

$4.75/mmBTU (also in 1995$).

Though the increase in the size of the Euro-gas market for imports will have become considerable by this third decade in the future, the volume of gas involved will remain, nevertheless, relatively modest in relation to the volume and diversity of gas reserves' developments which will be stimulated by the opportunities offered by European outlets. Thus, investments in the meantime by national and international interests in many regions capable of supplying Europe after 2015, in the context of an anticipated higher price for gas as a result of oil market developments, could lead to a situation in which too much infrastructure capacity is created and thus to a potential over-supply of gas. The continuation in such circumstances of a squeeze on prices arising from gas-on-gas competition would, of course, lead to an average border price for the 230 to 320 BCM of gas required per annum, which is below the oil equivalent prices indicated above.

Large though an import of up to 320 BCM of natural gas to Europe may seem compared with the present situation (of only 130 BCM), it is worth noting that in energy terms the volume of imported gas demanded pales into relative insignificance in the perspective of Europe's relatively recent history as an energy importer. Over 20 years ago—in 1973—Europe imported well over 800 million tons of oil, the energy equivalent of almost three times that which will be provided by 320 BCM of natural gas imports some 30 years hence.

8. Conclusions

The issues and arguments which underpin the thrust of the paper can be summarised as follows:

- the assumption of a growth market for gas in Europe predicated on the basis of a fundamental shift in the perception of gas availabilities and on gas' role in the energy market; and the argument that this shift will undermine the structure of the industry as it has evolved to date, whereby both supply and demand have been curtailed by monopoly and monopsony to levels below those which would have developed in a competitive market;
- the argument that Europe itself is gas-rich beyond present general perceptions and that the economics of developing indigenous supply over the next 30 years to a level 60% higher than in 1995 are soundly based;
- the view that oil-equivalent prices will continue to set the upper limit to well-head/beach/border prices for gas and that this expectation creates the prospects for an "easy" gas supply situation throughout the 30 year period under review;
- the claim that Europe is favoured by the existence of a set of external gas-rich regions with a total potential for supplying gas well beyond the highest possible market prospect, and that it is Europe, rather than any other market or markets, which provides the best opportunities for those suppliers to achieve returns from the exploitation of their gas;
- the argument that in the context of a highly competitive supply side prospect, actual well-head/beach/border prices for gas in Europe will normally be under the upper limit set by oil-price equivalence;
- the idea that, in this situation, the supply price for gas may not be the main pricing problem facing European gas users. It is the non-competitive structure and behaviour of gas sellers which have kept prices high and restricted market growth. The competitive gas supply development predicated in this paper will need to be matched by a degree of market liberalisation whereby the 'fat' created by the protected sellers' behaviour is eliminated.

References

Adelman, M.A. (1990) 'Mineral Depletion with Special Reference to Petroleum,' *Review of Economics and Statistics*, Vol.72, pp.1-10.

Ausems, A. (1994) 'Prospects for North Sea Oil and Gas: The Netherlands,' *The Study Group for Internaional Commercial Contacts, Energy Week Conference* (London).

BP (1995a) *Statistical Review of World Energy* (London).

—(1995b) *Review of World Gas* (London).
Department of Trade and Industry (1995) *The Energy Report; Oil and Gas Reserves of the United Kingdom,* (London: HMSO).
Dienes, L. and T. Shabad (1979) *The Soviet Energy System* (Washington: Winston).
Dienes, L., I. Dobozi and M. Radetzki (1994) *Energy and Economic Reform in the Former Soviet Union,* (Basingstoke, UK: MacMillan).
Estrada, J., H. Bergesen, A. Moe and A. Sydnes (1988) *Natural Gas in Europe, Markets, Organisation and Politics,* (London: Pinter Publishers)
Estrada, J., A. Moe and K.D. Martinsen (1995) *The Development of European Gas Markets* (Chichester, UK: J. Wiley and Sons).
European Commission (1994) *Energy in Europe, 1993 Annual Energy Review* (Brussels).
Handley, R.L. (1995) 'Upstream Opportunities created by the new Gas Markets,' *Petroleum Review,* 48:574:500-03.
Hoffman, G.W. (1985) *The European Energy Challenge: East and West* (Durham N.C.: Duke Press).
International Energy Agency (1986) *Natural Gas Propsects* (Paris: OECD).
—(1991) *Natural Gas Prospects and Policies* (Paris: OECD).
Kemp, A.G. and L. Stephen (1994) 'Low Oil Prices, Prospective Activity Levels of the UKCS and the Effects of Cost Savings,' *The Study Group for International Commercial Contacts, Energy Week Conference* (London).
Ministerie von Economische Zaken (1995) *Olie en Gas in Nederland, 1994* (Den Haag).
Norwegian Petroleum Directorate (1993) *Improved Oil Recovery–Norwegian Continental Shelf* (Oslo).
Odell, P.R. (1969) *Natural Gas in Western Europe; A Case Study in the Economic Geography of Energy Resources.* (Haarlem: De Erven F. Bohn NV).
—(1988) 'The West-European Gas Market: the Current Position and Alternative Prospects,' *Energy Policy,* 16:5:480-93.
—(1992) 'Prospects for Natural Gas in Western Europe,' *The Energy Journal,* 13:3.
—(1995) 'Global Economic/Energy Prospects, 1994-2020,' International Institute for Applied Systems Analysis. *International Energy Workshop* (Laxenburg).
OPAL/Energy Advice (1995) *European Energy Pricewatch* (Walton-on-Thames, UK).
Park, D. (1979) *Oil and Gas in Comecon Countries* (London: Kogan Page).
Pauwels, J-P., F. Possemiers, L. Swartenbroekx and M. Lievens (1994) *Géopolitique de L'Approvisionnement Énergétique de L'Union Européene au XXI Siecle, Vol 1* (Bruxelles: Bruylant).
Prior, M. (1994) 'The Supply of Gas to Europe,' *Energy Policy,* 22:6:447-54.
Prognos (1994) *Die Energiemärkte Deutschlands im Zusammenwachsenden Europa: Perspektiven bis zum Jahr 2020* (Basel).
Radetzki, M. (1994) 'World Demand for Natural Gas: History and Prospects,' *The Energy Journal, Special Issue on the Changing World Petroleum Market,* pp.219-36.
Royal Ministry of Industry and Energy (1995) *Fact Sheet, Norwegian Petroleum Activity* (Oslo).
Stern, J. (1990) *European Gas Markets, Challenge and Opportunities in the 1990s,* (Aldershot: Dartmouth).
—(1995) *The Russian Natural Gas 'Bubble: Consequences for European Gas Markets* (London: Royal Institute of International Affairs).
Stoppard, M. (1994) *The Resurgence of U.K. Gas Production* (Oxford: Oxford Institute for Energy Studies).
Williams, J.R. (1992) *Natural Gas Reserves and Production–the European Picture,* (London: Shell International Gas).
—(1993) *Europe: Competing for Sources of Natural Gas* (London: Shell International Gas).