Pipelines and the Exploitation of Gas Reserves in the Middle East

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and

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Summary

The Middle East is endowed with approximately 20 percent of the world's proven reserves of natural gas in the world. The cost of transporting Middle Eastern gas, however, is so high that it is difficult to exploit it commercially outside the region. The European market for gas can be supplied in the foreseeable future from North Africa, Russia, the Transcaucaus region, and the North Sea. These suppliers have a significant locational advantage that dominates any edge that Middle Eastern gas may have in the cost of production. The high cost of transporting liquefied natural gas also limits the amount of Middle Eastern gas that can be sold to the Far East.

Gas can be transported by pipeline or liquefied and then shipped by sea on special liquefied natural gas carriers. The cost of transporting 1000 cubic feet of gas 1000 miles by pipeline is approximately $.50. The cost of transporting 1000 cubic feet of LNG a distance of 1000 miles by sea is approximately $.30. However, the cost of liquefaction and regasification is approximately $1.40 per 1000 CF. Thus, for natural gas, transporting the energy equivalent of one barrel of oil a distance of 1000 miles costs $3.00 by pipeline and $10.20 if it is liquefied and transported by sea. By contrast, the cost of transporting a barrel of crude oil is approximately $.10 per thousand miles.

Natural gas and oil are not perfect substitutes. Gas has environmental advantages and natural gas is a more efficient fuel in electricity generation. However, this advantage has been reduced by new oil fired combined cycle technologies; it is unlikely that in the long run the cost per kilowatt generated with gas can deviate far from the cost per kilowatt generated with oil.

Natural gas and oil compete in the energy market. Thus Middle Eastern countries that produce oil are competing with their oil when they export gas. Selling gas reduces the market for oil. Producing LNG or producing middle level distillates at a cost of $10 to $20 a barrel does not make economic sense when the marginal cost of crude oil is under $1 a barrel. These activities can be way to avoid OPEC restrictions on crude production. Exceptions may be countries like Qatar, that have large endowments of natural gas and limited endowments of oil. It is not difficult to show that a rationalization of the OPEC cartel structure and some side payments within would lead to dominant strategies that would eliminate the export of gas from the Middle East to many markets.

Paradoxically, the difficulty of exporting natural gas outside the Middle East creates an opportunity for the economic development of the region. Abundant energy at a very low cost would provide a stimulus for economic growth if the appropriate institutional and economic infrastructure can be developed.

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1. Peterkin Professor of Political Economy, Rice University and Sir Issac Wolfson Professor of Public Finance, Hebrew University at Jerusalem. We would like to thank Sharon Hedar of McKinsey & Company, Inc. and William Laney Littlejohn for their help, suggestions and comments.

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1. Introduction

The countries in the Middle East have over 44.3 trillion cubic meters (BCM) of gas. This is the energy equivalent of almost 300 billion barrels of oil.[2] The energy content of these gas reserves is more than 35 percent of the energy content of the proven oil reserves in the region. If we include potential reserves, energy content of these gas reserves is more than 60 percent of the energy content of the proven oil reserves in the region.

World Gas Reserves

Region	cumulative production	known reserves	undiscovered resources	total gas endowment
United States	22.4	4.6	11.2	38.2
Canada	2.6	2.7	10.3	15.6
Mexico	0.8	2.0	4.4	7.2
South America	1.8	5.5	5.9	13.2
Western Europe	4.1	5.4	5.8	15.3
Russia and Ukraine	8.6	47.0	45.0	100.6
Transcaucasia and Central Asia	2.9	10.7	6.6	20.2
Middle East	2.1	44.3	31.5	77.9
Africa (including North Africa)	1.1	9.6	12.4	23.1
China	0.5	1.7	7.3	9.5
Oceania and Asia (excluding China)	2.0	8.3	13.0	23.3
Total world	48.9	141.8	153.4	344.1

In trillion cubic meters; figures adapted from *Oil & Gas Journal* and *U.S. Geological Survey.*[3]

Table 1

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[2] The countries in the Middle East have oil reserves of approximately 788 billion barrels in proven reserves.

[3] Encyclopedia Britannica On-line.

The cost of transportation, however, makes it very difficult to exploit Middle Eastern gas commercially outside of the region. Gas can be transported by pipeline or liquefied and then shipped by sea on special liquefied natural gas (LNG) carriers. The cost of transporting 1000 cubic feet of gas 1000 miles by onshore pipeline is approximately $.40 to $.85. If the gas is transported by an offshore pipeline the cost goes up to approximately $.75 to $1.35 The cost of transporting 1000 cubic feet of LNG a distance of 1000 miles by sea is approximately $.30, with a fixed cost of liquefaction and regasification of approximately $1.40 to $1.85 per 1000 cubic feet. By contrast, the cost of transporting a barrel of residual fuel oil is approximately $.10 per thousand miles. Since a barrel of residual fuel oil has the energy equivalent of 6000 cubic feet of gas, gas is more expensive to transport by almost two orders of magnitude. The economics of transportation is the key element in the export market for gas.

2. Demand for Gas

One of the most important uses of natural gas is in the generation of electricity. In that use, it is a close substitute for fuel oil. Thus, in equilibrium, the price of natural gas is linked to the price of fuel oil. Natural gas is used to produce electricity in a combined cycle plant. Historically, fuel oil has been used in a boiler-steam turbine plant. This is dominated technology. Boiler-steam turbine plants have a higher capital cost and lower efficiency than a combined cycle gas fired plant. The new technology that uses fuel in the generation of electricity is in a modified combine cycle plant that burns either residual fuel oil or crude. These plants can often also burn natural gas.

Boiler-steam turbine plants are often used as a benchmark when comparing the two fuels. However, the large advantage of natural gas, about $2.00 per thousand cubic feet, in a combined cycle plant when compared to boiler-steam turbine plants is deceptive. Gas has an advantage over fuel oil when the fuel oil is use in a modified combine cycle plant, but the advantage is considerably smaller; however, modified combine cycle plants may require nitrogen oxide reduction (NOR) which increases the required capital costs. The premiums for natural gas over oiled fired alternatives were computed by Stauffer in his study of the economics of transporting liquefied natural gas (LNG). His results are summarized in the following table:

Natural Gas Premium for Oil-Fired Alternatives[4]
Dollars per 1,000,000 BTU

	Steam Plant	combined cycle without NOR	combined cycle with NOR
capital cost	$1.07	$.08	$.20
Heat rate effect	.57	.06	.06
Maintenance	.36	.10	.24
Total Premium	$2.00	$.24	$.50

Table 2

There is a premium for gas, however, given the new combined cycle technologies for generating electricity using residual oil, the premium is not large, at most $.50 per thousand cubic feet. If we examine Table 2, it is clear that almost 50 percent of that premium can be attributed to environmental concerns.These concerns may not be very important to some of the potential consumers of energy.

3. Cost of transporting Liquefied Natural Gas

Stauffer, as well as others, have found that LNG was a very capital intensive process and one that is not subject to economies of scale above the 500 million cubic feet per day volume. Transporting LNG is a three stage chain.[5]

The first step the chain for transporting LNG is a liquefaction plant. This plant requires an investment of $1.6 to $2 billion dollars for a plant capable of handling 500 million cubic feet per day. Assuming a real rate between 10 to 12 percent, this implies a cost of $1 to $1.30 per thousand cubic feet. Most studies also report costs in that range.

The second step in the chain is the tanker. LNG must be transported at a temperature of -162 degrees centigrade and require specialize vessels. These vessels cost $230 million for a 135,000 ton tanker. This is to be compared with a cost $85 million for a 280,000 ton VLCC. The

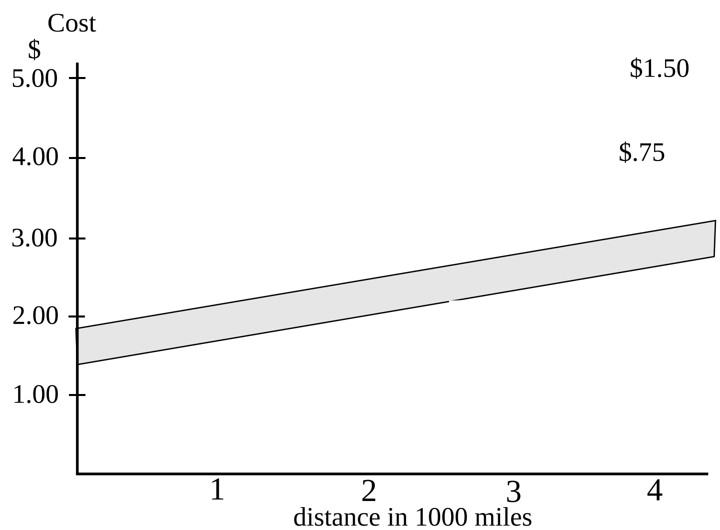
4. T. R. Stauffer, (1996) “The Diseconomics of long-haul LNG Trading,” Occasional Paper No. 26 International Research Center for Energy and Economic Development. P. 4.

5. *Ibid*

reported shipping rates are \$.20 per thousand kilometers or \$.32 per mile.[6]

The third step is regasification. Stauffer reports regasification costs of between \$.35 to \$.50 per thousand cubic feet. These numbers are very similar to those reported by Exxon. Exxon, however, reports regasification costs as high as \$1.00 per thousand cubic feet. This is due to the high cost of land in Japan.[7]

We can plot the cost of the LNG chain as a function of distance.



Cost of Transporting LNG

Figure 1

4. Derivation of the Production Function for Gas Pipelines

A simplified formula for computing the rate of flow of gas in a pipeline is given by[8]

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6. *Ibid*, citing Drewry Shipping Consultants, Ltd., *Trading in LNG and Natural Gas* (London, 1993) and International Energy Agency, Oil, *Gas and Coal: Supply Outlook*, (Paris, 1995).

7. See J. M. Temple, “Opportunities for International Investments in the Middle East,” 2nd Annual Middle East Gas Summit 1996 Abu Dhabi U.A.E.

8. See JE. W. McAllister, *Pipeline Rules of Thumb Handbook*, p. 260.

$$Q = \frac{871 D^{\frac{8}{3}} \sqrt{P_1^2 - P_2^2}}{\sqrt{L}} \qquad (1)$$

where:

D= internal diameter of pipe in inches

L= length of line in miles

P_1^2 = absolute pressure at starting point

P_2^2 = absolute pressure at ending point

The amount of power, *Z*, need compress a million cubic feet a day is given by

$$Z = \frac{R}{R + RJ}\left(\frac{5.46 + 124 Log(R)}{0.\dot{9}7 - 0.03R}\right) \qquad (2)$$

where *R* is the compression ratio, absolute discharge pressure divided by absolute suction pressure and J is supercompressibility factor which we assume to be 0.022 per 100 pounds per square inch absolute suction pressure.[9] Assuming as given discharge pressure, equation (1) can be used to solve for the necessary pressure as function of the throughput. Equation (2) can then be used to compute the amount of power necessary. We can use these values to compute the cost of transporting gas. The following tables were calculated under the assumptions that the real interest rate is.10, the cost of onshore pipeline is $40,000 per mile inch, the cost of offshore pipeline is $100,000 per mile inch, maintenance costs are assumed to be 3 percent, and the cost of gas to power the pumps is $1.50 per thousand cubic feet. The tables are calculated for a project life of fifteen and twenty-five years.

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[9].See JE. W. McAllister, *Pipeline Rules of Thumb Handbook*, p. 242.

Cost of Transporting Gas 1000 miles through Onshore Pipeline

(Fifteen Year Project Life)

Throughput (Mcf/d)	Diameter (inches)	Average Cost (dollars)	Fixed Cost/Cost
1,000	20	.84	.59
2000	30	.59	.57
3000	40	.46	.60

Table 3

Cost of Transporting Gas 1000 miles through Onshore Pipeline

(Twenty-five Year Project Life)

Throughput (Mcf/d)	Diameter (inches)	Average Cost (dollars)	Fixed Cost/Cost
1,000	20	.79	.57
2000	30	.55	.54
3000	40	.43	.57

Table 4

Cost of Transporting Gas 1000 miles through Offshore Pipeline

(Fifteen Year Project Life)

Throughput (Mcf/d)	Diameter (inches)	Average Cost (dollars)	Fixed Cost/Cost
1,000	20	1.34	.74
2000	30	.96	.74
3000	40	.80	.76

Table 5

Cost of Transporting Gas 1000 miles through Offshore Pipeline

(Twenty-five Year Project Life)

Throughput (Mcf/d)	Diameter (inches)	Average Cost (dollars)	Fixed Cost/Cost
1,000	20	1.21	.72
2000	30	.88	.71
3000	40	.73	.74

Table 6

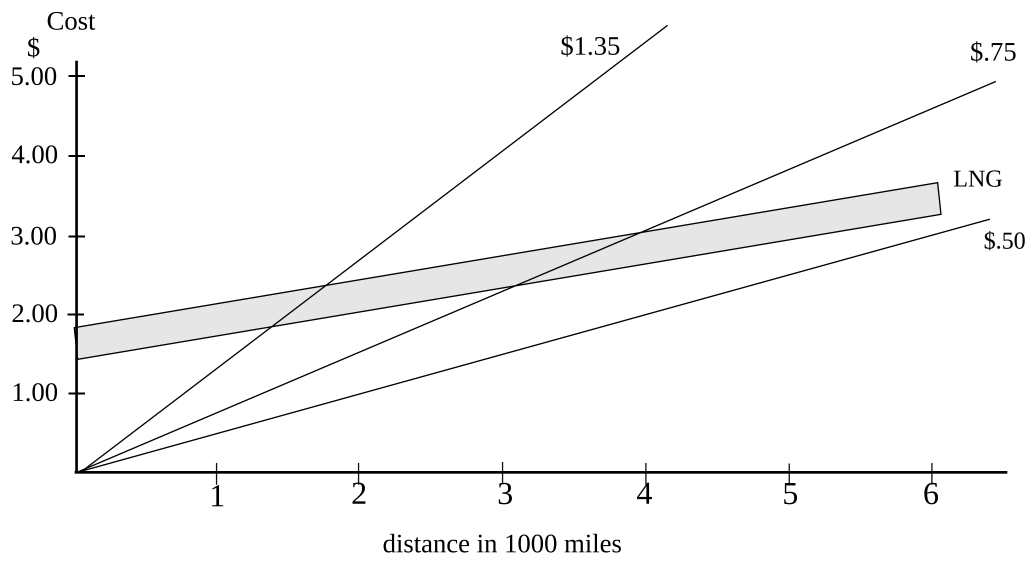
The numbers reported in the tables above are consistent with the values reported by Temple.[10] They are higher than the costs reported in the United States. This higher cost reflects our assumption of construction costs of $40,000 per mile/inch. In the United States, $20,000 per mile/inch as the cost of construction is a reasonable assumption for the cost of gas pipelines. If we use that number, the costs from our computation replicate the costs reported in the United States.[11]

It should be noted that a substantial fraction of the cost of transporting gas through pipelines can be attributed to capital investments which are fixed. Over one half the cost in onshore pipelines and as much as three quarters of the cost in offshore pipelines is due to capital. This suggests that after the pipeline is constructed, the party that owns the pipeline is in a very weak position vis-a-vis other parties in any subsequent negotiations.

10. Op. cit.

11. Discussion with industry experts led us to adopt the figure of $40,000 per mile inch as a reasonable number to use in the Middle East. The offshore number is based on reported costs in the North Sea. Costs on any specific project depend on local conditions such as terrain and infrastructure.

5. Comparison of Pipelines and LNG



Cost of Transporting LNG

Figure 2

Figure 2 compares the cost of transporting LNG and pipelines. Clearly, for relatively short distances, under 1,500 miles, pipelines dominate LNG. For longer distances, over 4,000 miles, LNG will dominate pipelines if the cost of transporting gas by pipeline is at least $.75 per thousand cubic feet. The intermediate range 1,500 to 4000 miles is likely to be project specific.Larger volumes will favor pipelines as pipelines are subject to substantial economies of scale. Local conditions, as well as politics, may favor LNG.

6. Economics of Transporting Gas by Pipeline

A barrel of residual fuel oil has 6 million BTU. The distance at which the cost of energy for oil and gas shipped by pipeline are equal as a function of the distance to the market is given by

$$p_o = 6(p_g + \alpha d - \beta) \tag{3}$$

where p_o is the market price of a barrel of oil, p_g is the price of gas per 1,000 CF at the point of origin, α is the cost per thousand miles of transporting gas, β is the premium associated with natural gas, and d is the distance in miles. If we plot this relationship we arrive at what amounts to the rent gradient for gas. For the purposes of this analysis, we will assume a cost of \$.50 for moving oil onshore, \$.75 for high volume (3000 Mcf/d) offshore and \$1.35 for low volume (500-1000 Mcf/d) offshore.

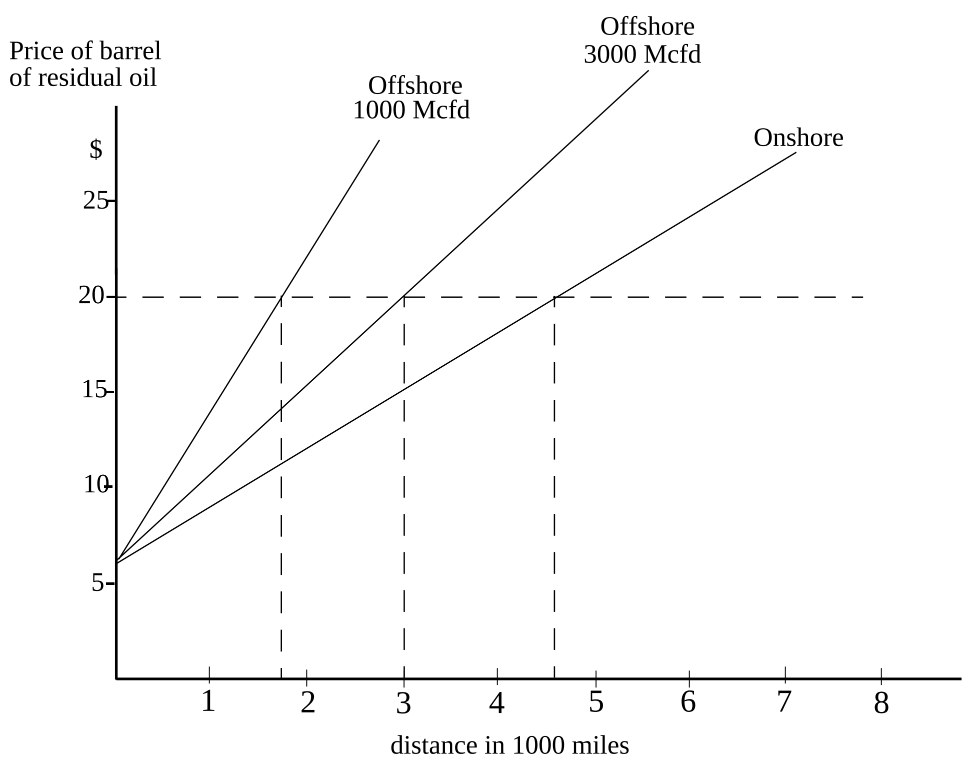


Figure 3

If we examine Figure 3, we see that natural gas priced at \$1.50 per 1000 CF at the point of origin can compete with residual fuel oil priced at $20.00 per barrel up to a distance of approximately 4,500 miles if shipped by an onshore pipeline and 2000 to 3000 miles if shipped by an offshore pipeline. Thus, gas transported by pipeline would be marginal in competition with fuel oil in the European market and competitive in India. It would yield substantial rents in the Levant. In Figure 4, we examine a similar relationship for residual fuel oil priced at $16.00 per barrel

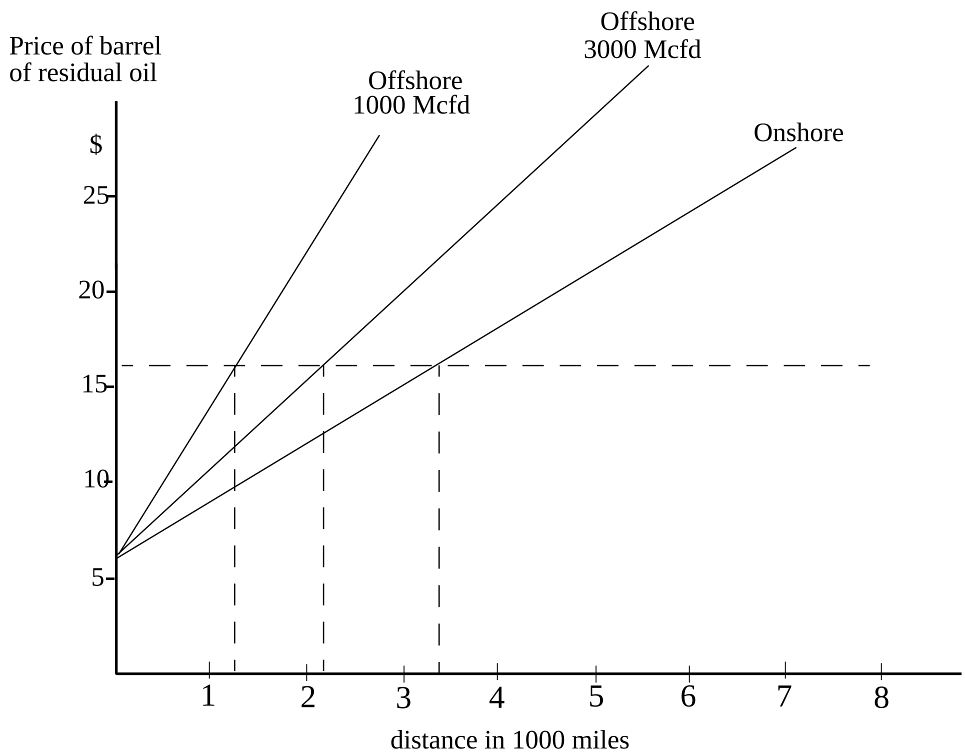


Figure 4

If we examine Figure 4, we see that natural gas priced at $1.50 per 1000 CF at the point of origin can compete with residual fuel oil priced at $16.00 per barrel up to a distance of approximately 3,500 miles if shipped by an onshore pipeline and 1,200 to 2,200 miles if shipped by an offshore pipeline. Thus, gas transported by pipeline would not be competitive with fuel oil in the European market and would be marginal in India. It would still yield substantial rents in the Levant.

These two examples illustrate how sensitive the economics of the transport of gas through pipelines are to the price of residual fuel oil. Inasmuch as pipelines are long term and fixed investments, basing the viability of such projects on optimistic forecasts for the price of residual fuel oil is risky.

It should also be noted that these calculations ignore the fact that onshore pipelines may have to cross various countries that can impose transit fees or can close the pipeline for political reasons. This would be particularly true for pipelines to serve the European market.

7. Economics of Liquefied Natural Gas

The transport of LNG can be analyzed in a similar manner. The distance at which the cost of energy for oil and LNG are equal as a function of the distance to the market is given by

$$p_o = 6(p_g + \sigma d - \beta + \gamma - \lambda) \quad (4)$$

where as before p_o is the market price of a barrel of oil, p_g is the price of gas per 1,000 CF at the point of origin, σ is the cost per thousand miles of transporting LNG by sea, β is the premium associated with natural gas, γ is the cost of liquefaction and regasification, λ is the NGL credit,[12] and d is the distance in miles. If we plot this relationship we arrive at a rent gradient for LNG. Assume that natural gas priced at \$1.50 per thousand cubic feet at the point of origin, a NGL credit of \$. 33 per thousand cubic feet and a premium of \$.50 per thousand cubic feet.

12. An important factor that has to be considered in the economics of LNG is that natural gas liquids (NGL) are a by-product of the liquefaction process. However, these liquids can also be extracted by less expensive methods. Stauffer values these by-products at between \$.30 to \$.75 per thousand cubic feet. We believe that the economic cost of producing LNG is the cost of liquefaction less the cost of producing NGL via the alternative technology. Note however, that an increase in the supply of NGL may reduce the market price.

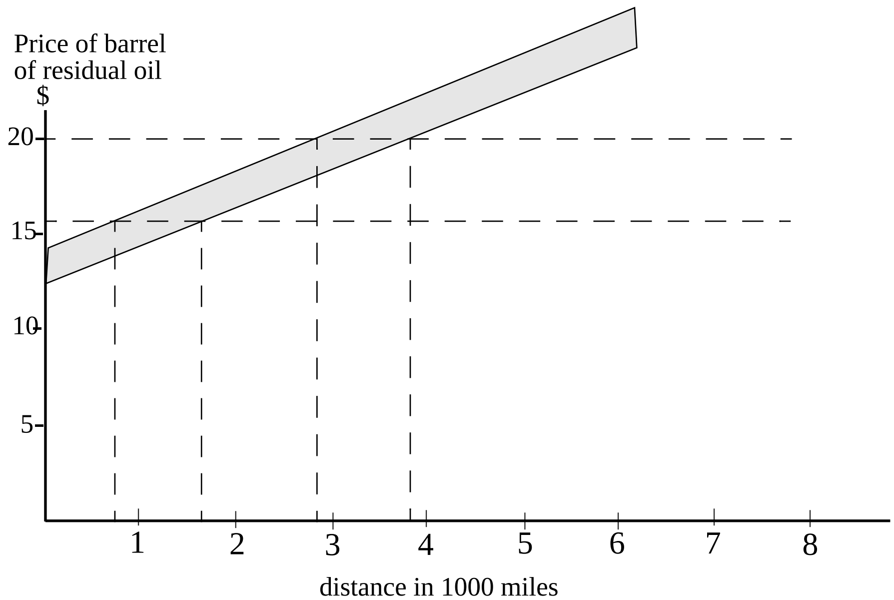


Figure 5

If we examine Figure 5, we see that under these assumptions, natural gas can compete with residual fuel oil price at $20.00 per barrel at a distance of approximately 2,800 to miles 3,800. The distance from Elat from Qatar is about 3000 miles. The project to ship LNG to Elat from Qatar is marginal when competing with fuel oil at these prices. However, if the price of residual fuel oil price drops to $16.00 per barrel, the distance at which LNG is competitive with residual fuel oil drops by about 1,000 miles. Shipping LNG to Elat from Qatar is no longer an economically viable proposition

8. Gas and Cartel Policy

Natural gas and oil compete in the energy market. Thus, Middle Eastern countries that produce oil are competing with themselves when they sell gas. Selling gas reduces the demand for oil. Producing LNG or producing middle level distillates at a cost of $10 to $20 a barrel does not make sense as an economic proposition for OPEC when the marginal cost of crude oil is under $1 a barrel. These activities make economic sense only as a way of avoiding OPEC restrictions on crude production. Exceptions may be countries like Qatar, that have large endowments of natural gas and limited endowments of oil. It is not difficult to show that a rationalization of the OPEC cartel structure and some side payments would reduce the export of gas from the Middle East if the countries involved were maximizing profits.

The proof of this argument is quite simple. Oil and gas are not perfect substitutes, but they are both inputs into the production of power through Leontief technologies of the form

$$Z = \min\left[\frac{X_i}{\alpha_i}, K_i\right] \tag{5}$$

where X_i is the fuel, K_i is the necessary investment for that fuel and α_i is a constant that gives the BTU per kilowatt hour ratio, i = gas, oil. What this technology means is that the ratio of power produce to fuel consumed is a constant for a particular fuel.[13] The marginal rates of technical substitution are very close to constant and it is possible to normalize the units so they have the same price. We can talk about the price per effective BTU. Since kilowatt hours are indistinguishable, their marginal cost should be the same. Isoquants have the form

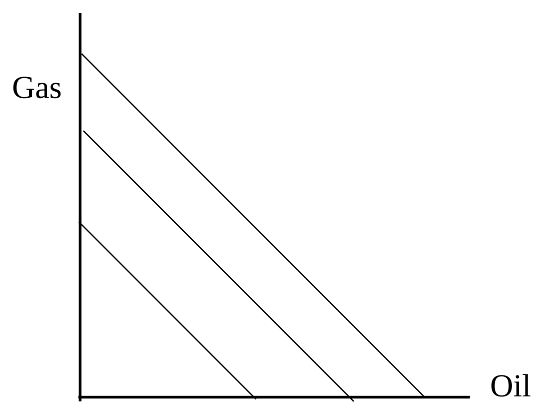


Figure 6

Figure 6 shows that to produce a given amount of electricity requires a fixed amount or either gas or fuel oil and thus the marginal technical rate of substitution is constant. This permits us to treat the market for fuel oil and gas as a single market.

There is some insight in considering the optimal choice of a monopolist that can produce

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13. See Shauffer, *op. cit.*

fuel oil or gas at different costs since a rational cartel would behave as a monopolist in deciding output.

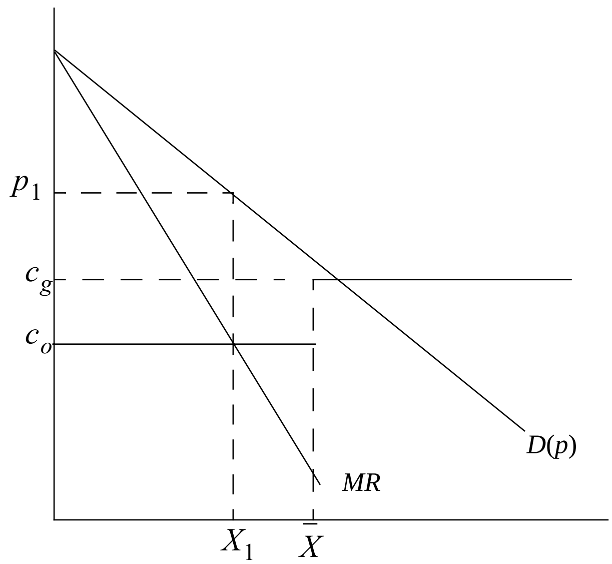

Figure 7

In Figure 7 the monopolist can produce up to X amount of oil at a marginal cost c_0 and gas at a price c_g. the MR curve is constant at c_0 until X then is discontinuous and jumps to c_g.In the example the MR curve crosses the MC curve at X_1; the profit maximizing monopolist will produce X_1 amount of energy from oil and produce no gas.The monopolist will produce gas only if it is producing X amount of oil. The monopolist will never produce gas while restricting the production of oil.

A rational cartel would behave as a monopolist. The decision making process would have two stages. In the first stage it would decide production levels so as to maximize cartel revenue, and in the second stage, production. Side payments would be used if member allocations did not reflect optimal production. The fact that gas and oil are substitutes in the production of electricity suggests that a rational cartel would define quotas in terms of BTU exported outside the cartel. The fact that transport costs makes gas very much more expensive to deliver to market means that the cartel will not export gas to markets where transport costs are a significant feature.

Side payments permit the low cost producers to buy the production shares of high cost producers, and defining the quota in terms of BTU exported outside the cartel would encourage entra-cartel trade in gas. If economics were the sole criteria, gas from Qatar would be burned in Saudi Arabia, rather than crude. It is cheaper to export the crude and use the gas locally than exporting LNG.

The argument we have made with respect to gas would also apply to high cost producers of crude. As an economic proposition, it would be optimal for the low cost producers to purchase cartel allocations from the high cost producers.

The analysis so far has been carried out under the assumption that the consumers of gas and fuel oil do not have market power. It has been suggested that some of the LNG projects are bilateral negotiations, thus it is necessary to study the implications of the technology on bargaining. Consider the case where the market for gas is characterized by a single buyer and seller. We will study the implications of the fact that gas and oil are substitutes in the production of electricity and that a substantial fraction of the cost of transporting gas involves fixed costs in renegotiations of the price of gas after the facilities are installed

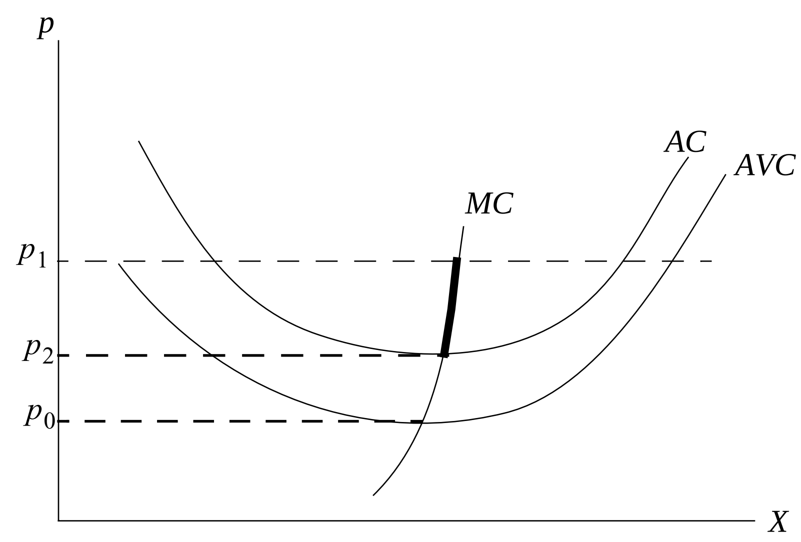

Figure 8

Figure 8 illustrates the cost curves associated with gas. the price p_1 is the price of fuel oil and is thus price at with the consumer is indifferent between using fuel oil or gas. The price p_2 is the price at which the marginal cost, MC, is equal to the average cost, AC, it is the price at which the supplier breaks even and there are no economic profits.After the facilities are installed, we know from simple economics that the gas supplier will sell gas at any price above average variable cost; *AVC*, this the price p_0 in Figure 8. The supplier will lose money but is able to recover part of the fixed costs. The supply curve is that part of the *MC* curve that is above *AVC*. That part of the supply curve that is above the *AC* curve yields locational rents which are divided by the producer and consumer. Assume initially that the producer incurs the fixed costs involved in transporting the gas. The simple Nash bargaining game implied by this model is depicted in Figure 9.

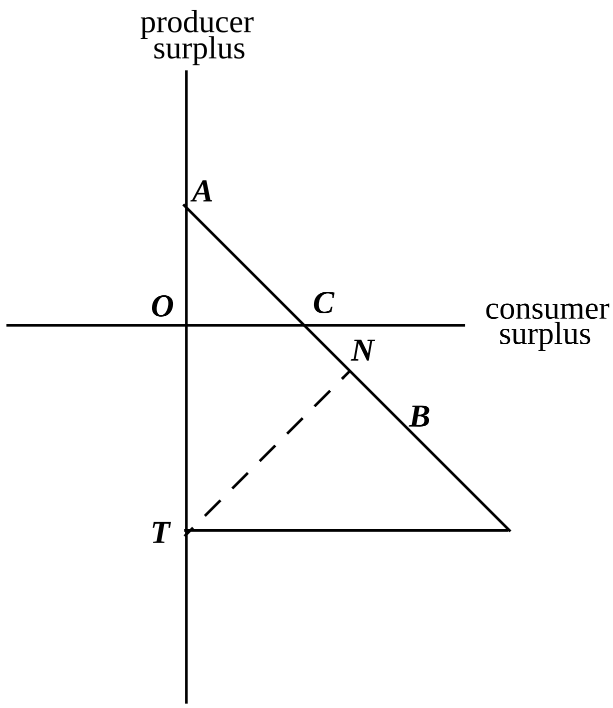

Figure 9

Producer surplus is represented on the vertical axis and consumer surplus is represented on the horizontal axis. The line ***AB*** represents possible allocations of the gains from trade. Each point on the set of allocations reflects a point on the supply curve in Figure 8. The point ***A*** is the point where the producer captures all the surplus which is implied by a price p_1. The point ***B*** is the point where the consumer captures all the surplus which is implied by a price p_0. The point ***C*** is the point where the price is equal to average cost, p_2. Thus the line segment ***AC*** denotes the locational rents that can be divided between the consumer and producer. Location rents are the difference between what it cost to bring the gas to market and the price of fuel oil. Note that as the cost of transportation (given by the length of the line segment ***OT***) increases, the amount of locational rents decrease.

At prices that imply points to the right of ***C***, the producer is losing money but recovering part of the fixed costs. At prices that imply points to the right of ***B***, the producer shuts down and goes to the threat point. The point ***T*** is the threat point, which is the reversion point if negotiations fail. It was constructed under the assumption that average fixed costs were fifty percent of average fixed costs. The Nash solution is given by the point ***N***. The Nash solution has the property of dividing the surplus equally from the threatpoint. Examining the solution to the Nash bargaining game suggested by the technology, it seems clear that if the price of gas is renegotiated after the capital facilities are constructed, the producer is in a weaker bargaining position, *ex post*. The consumer has the alternative of buying fuel oil, but the producer has no alternative use for the capital facilities.There is also a game for the case where the consumer incurs the fixed costs.

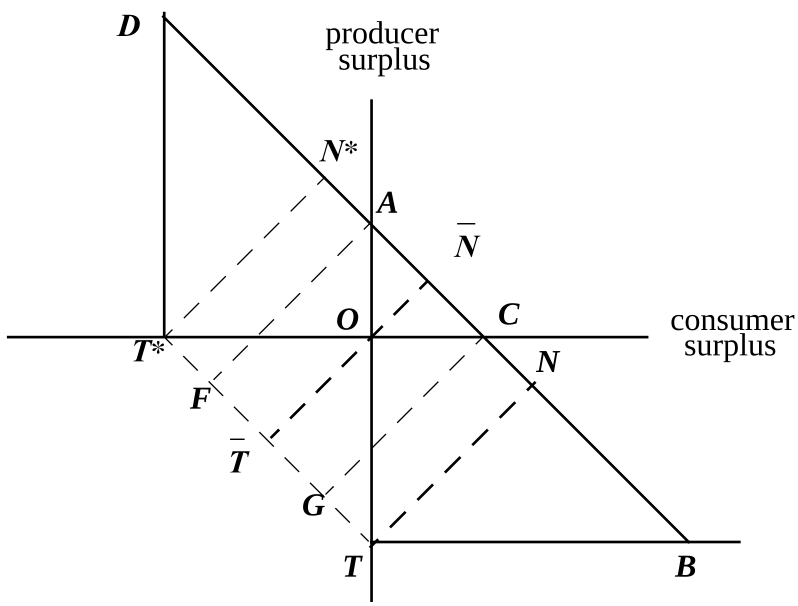

Figure 10

The two games are illustrated in Figure 10. The point ***D*** is the point where the producer captures all the surplus which is implied by producer charging a wellhead price that would force the consumer to absorb the fixed costs. The point ***A*** is the point where the wellhead price such that the price of gas is equal to price of fuel oil, p_1. Thus, the line segment ***AC*** again, denotes the locational rents that can be divided between the consumer and producer. The point ***T*** *is the threat point, which is the reversion point if negotiations fail. In this case, the consumer absorbs the fixed costs. The Nash solution associated with this threatpoint is given by the point ***N****.

The process, if viewed as a multi-stage game, is not subgame perfect. It is not surprising to learn that in many of the existing LNG projects the fixed costs are shared by both parties. Then the threatpoint, $\boldsymbol{T}$ is in the line segment $\boldsymbol{FG}$, which is dominated by points in $\boldsymbol{AC}$ for both parties. These projects have used risk sharing or other elements of the structure by which the project is financed as a precommitment mechanism. The ability to structure project financing to avoid these problems, depend on there being a surplus to share.

9. Conclusions

These rough calculations strongly suggest that, under very optimistic assumptions, the huge endowment of natural gas can be exploited economically only within 3000 miles of the point of origin if it is transported in offshore pipelines. In the European market it would not only have to compete with fuel oil, but with gas from North Africa, Russia, the Transcaucaus region, and the North sea.[14] These regions have, at present, a surplus of natural gas a well as a significant locational advantages that would likely dominate any advantage that Middle East gas may have in the cost of production. Furthermore a pipeline from the Middle East to Europe would have to transit several countries that would likely impose a transit fee.

Similarly, LNG from the Middle East would have a difficult time competing as an energy source in the European market or in the Far East. As an economic proposition, LNG cannot compete with $20.00 a barrel fuel oil as an energy source at distances beyond 4,000 miles. This creates a puzzle: why is the Japanese government restricting the importation of oil to encourage the importation of LNG from the Middle East. A possible explanation is regulatory dysfunction. A policy to diversify the sources of fuel for strategic reasons could have been implement in a fashion that led to the use of gas from the Middle East. This gas may be even more vulnerable to disruption than oil. Since a substantial fraction of the costs of transporting LNG is capital costs that are fixed.

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[14]. The gas resources of North Africa, Russia, the Transcaucaus region, and the North sea are over 140 trillion cubic meters. The Eni forecast for consumption in Europe in 2010 is between 453 to 514 billion cubic meters. The 1995 consumption of gas in Europe was 333 billion cubic meters. It is probably safe to assume that this gas can meet European demand in the foreseeable future.

The consumer can substitute fuel oil for LNG; however, the producer has no alternative uses for the invested capital. Bargaining power is very asymmetric, *ex post*, and the producer could be force to a price below the average cost, but above the average variable cost.

Natural gas and oil are not perfect substitutes. Gas has environmental advantages and natural gas is a more efficient fuel in electricity generation. However, this advantage has been reduced by new oil fired combined cycle technologies. It is unlikely that in the long run the cost per kilowatt generated with gas can deviate far from the cost per kilowatt generated with oil.

Natural gas and oil compete in the energy market. Thus, Middle Eastern countries that produce oil are competing with themselves when they sell gas. Selling gas reduces the demand for oil. Producing LNG or producing middle level distillates at a cost of $10 to $20 a barrel does not make sense as an economic proposition for the OPEC when the marginal cost of crude oil is under $1 a barrel. It is not difficult to show that a rationalization of the OPEC cartel structure and some side payments would eliminate the export of gas from the Middle East if the countries involved were maximizing profits.

Paradoxically, the steep rent gradient associated with the commercial exploitation of natural gas creates an opportunity for the economic development of this region. Most economic historians agree that the abundance for fertile land was a key element in the development of the United States. Abundant energy at a very low cost could provide a similar stimulus for regional development if the appropriate institutional and economic infrastructure can be developed.

Demand for Natural Gas in the Middle East[15]

	1995	2000	2010
Egypt	12	19	33
Syria	4	9	4
Israel	0	3	11
Jordan	0	2	8
Lebanon	0	1	3

15. The estimates for 2000 and 2010 are the high estimates of the Eni *Lavente Gas Project Report* p.12.

Turkey	8	20	30
Total	24	53	96

Billion of Cubic Meters per year.

Table 7

The Middle East has about 76 trillion cubic meters of gas in actual and potential reserves.[16] Egypt and Syria alone, have approximately one trillion cubic meters.[17] At current levels of demand, the Egyptian and Syrian gas is sufficient to meet this demand for over thirty years. If we use the Eni projections in Table 7, Egyptian and Syrian gas is sufficient to last until the year 2010.[18] Plans to use this gas as the initial source for industrial development of the region are realistic. Gulf gas could come on line well before the Egyptian and Syrian gas supplies are exhausted. Gulf gas is sufficient to supply the needs of the region for over 750 years at the projected high 2010 levels of consumption. Given technical change, it is probably foolish to predict the demand for gas more that 20 years into the future. At one time, a shortage of firewood was perceived as a problem. There was a recent report in *Science* that solar cells that cost in the neighborhood of $500 per installed kilowatt may be feasible in the near future.[19] Hoarding gas for future exploitation is not likely to be a prudent policy.

This suggests that there are several interesting economic problems associated with the development of the gas reserves in the region. The first, is what is the economic value of the gas. Technically, the question can be phrased as what is the shadow price of gas in the region. This is a complicated question that requires further study. It is our conjecture that there will be two prices for natural gas: a price internal to Saudi Arabia and the Gulf States and the price in the Levant. The reason for this dual price system is that Saudi Arabia is likely to be able to be the Stackelburg leader

16. See Table 1.

17. These regions have not be extensively explored for natural gas so there may substantial greater amounts of gas in these regions

18. Assume the growth is linear

19. *Science*, June 21,1996.

in this market due to its gas endowment and its control of any gas pipelines from the Gulf. Thus, it is optimal for it to discriminate between internal and external pricing of gas. Another question is what is the value of the Egyptian and Syrian gas, given the amount of Gulf gas that is potentially available. If the Midyan field is as large as some reports suggest, this would completely dominate the market in the foreseeable future.

A second set of issues involve Israel. First, what are the macro-economic implications for Israel, if it had access to the energy resources of the region? Second, what would be the implications for the Israeli economy if it had access to the these markets, both as a supplier and for joint ventures? Third, can this gas be used to stimulate the development of the Gaza strip and the West Bank? Finally, what is the economic cost to the parties of delay in the reaching of a settlement that would permit the exploitation of the vast energy resources of the region?