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Pipelines to Remain Dominant Force Despite Threat from LNG

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ABSTRACT

As worldwide demand for natural gas continues to grow at an increasing rate and certain countries' indigenous production is either in decline or simply unable to fill the shortfall, more attention is being given to importing gas from the few remaining major exporters. The UK has recently become a net importer of gas, and the US is expected to import as much as 5 trillion cubic feet of gas by 2020, the question that arises is what will be the primary method of delivery in the future? Can LNG alone fill any shortfalls and make interregional pipelines obsolete or will pipelines provide enough volume to stall LNG production? Although there has been a rush to build LNG facilities around the world, so have there been a number of major pipelines planned, such as the line from Russia across the Baltic Sea or the Middle East North Africa (MENA) pipeline from the Persian Gulf to Europe.

This paper looks at the threat to pipelines from LNG and other economic factors to ascertain whether interregional pipelines are set to become obsolete as a method of transporting natural gas.

Keywords - LNG, Natural Gas, Pipeline, Transport, Transmission.

1. INTRODUCTION

The importance of natural gas in the world's energy mix has been growing in recent years. That is not to say, of course that gas has not been an important resource - legislation in the US and EU prevented the burning of gas for power generation because it was "considered a premium fuel" in the late 1970s and most of the 1980s. Other countries have also acknowledged the importance of gas such as Russia, where gas comprises over 44% of its electricity generation, or India which uses compressed natural gas in its public transport sector. Gas is a cleaner hydrocarbon than oil or coal, producing fewer emissions when burned and with technological advances in the Combined Cycle Gas Turbine (CCGT) technology have made it more efficient that oil with conversion efficiency of up to 65%. According to the IEA, growth of the gas sector is set to reach 5 tcm by 2030.

Traditionally, unlike crude oil, most natural gas was pumped through pipelines, and only recently has the option of transportation by ship become available.[1] Of the 1,200,000 km of pipelines available at present, more than half is used to transport natural gas.

[1] The first test shipment was made in January 1959 from Lake Charles, Louisiana, USA to Canvey Island, England.

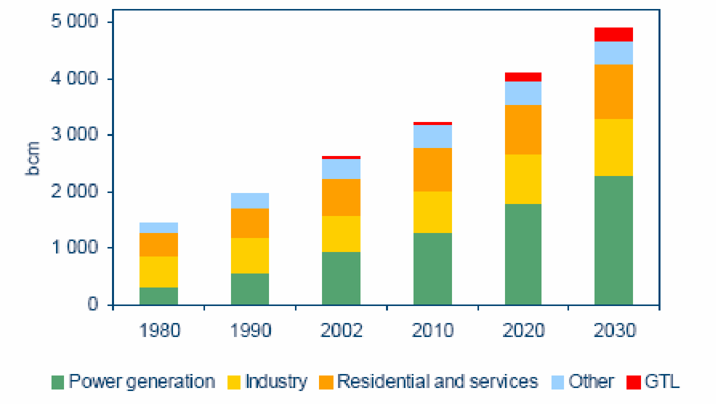

Fig. 1. Increase in primary gas demand. Source: IEA.

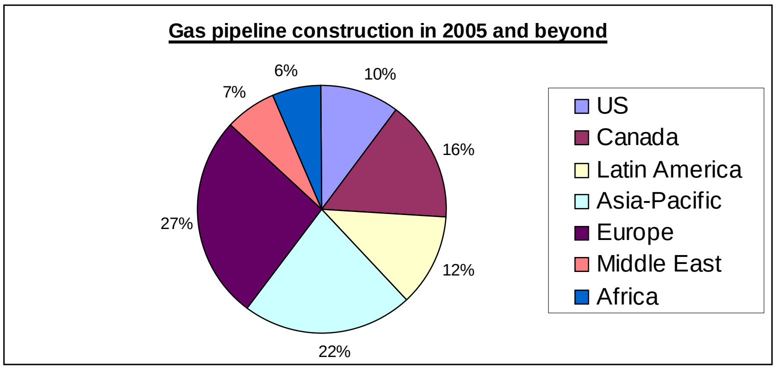

Fig. 2. Gas pipeline construction 2005 and beyond. Source: OGJ 2005.

The conversion of natural gas into liquid is called liquefaction and is achieved through refrigeration at -161 °C. Liquefaction reduces the volume by approximately 600 times, making it more economical to transport and store.

As costs associated with LNG projects fall, and the LNG tanker fleet rises (there are 150 tankers available, and another 60 under construction), the question that must be poised is what will become of the interregional supply pipelines? The strategic importance of pipelines must not be understated, and yet even with the threat to China's security of supply via naval blockade, China continues to push forward with its LNG import plans [1], [2]. The UK, who has recently become a net importer of natural gas, is building three regasification terminals, as greater competition is seen between piped gas imports and LNG imports. The ExxonMobil agreement with Qatar Petroleum could be the largest LNG deal in Europe, supplying up to 12 bcm per year for 25 years to the UK [2]. As the supply shortfall increases, and the volume of cheaper North Sea gas diminishes, new volumes will need to be acquired from more expensive sources such as Norway, Russia, Algeria and LNG. As the cost of gas rises, consumers will be looking to minimise their costs with 'just in time' contracts especially with the seasonal demand variations experienced in the UK. LNG has the ability to offer the flexibility of supply not usually found in pipeline contracts. However, the UK is looking to diversify the supply and as a result signed a flexible ten year pipeline contract with NV Gasunie Nederlands for delivery of 8 bcm per year with a 175% swing in actual quantity [2].

This paper will aim to determine whether with advances in LNG technology and falling costs of production and transport, the pipeline method of transporting natural gas may become obsolete.

Pipelines typically last about 100 years[2], and as some of them near the end of their useful life, investors must ascertain what will be the next viable method of transport for natural gas, at least in the long term. The first section of this paper will examine the threat from LNG through a series of arguments that lean to support it as the favourable method of transportation. The second section highlights arguments in favour of using pipelines for gas transport over LNG, bringing Algeria as working example. The third section will briefly describe other methods for natural gas transportation and any implications thereof. Section four presents the conclusion of this paper.

Conversion factors

Natural gas (NG) and LNG Approximate conversion factors	To convert to: billion cu m NG	billion cu ft NG	million tonnes LNG	trillion btu
From	multiply by			
1 billion cu m NG	1	35.3	0.73	36
1 billion cu ft NG	0.028	1	0.021	1.03
1 million tonnes LNG	1.38	48.7	1	52.0
1 trillion btu	0.028	0.98	0.02	1

Selected conversion factors from BP statistical review of world energy 2002.

Fig. 3. Conversion factors for gas. Source: OGJ 2004.

2. THREAT FROM LNG AND OTHER FACTORS

2.1 Falling Costs

Capital costs for LNG projects have fallen sharply in recent years. Since 1988, they have decreased three-fold, and are set to continue falling. This fall in capital cost of liquefaction facilities can even endanger current supply contracts, as switching to a new supplier maybe more economical, even when the costs associated with the breach of contract are factored in [3].

This decline in LNG capital costs is due to improvements in technology and a drive towards larger facilities where full advantage can be taken of the economies of scale associated with this type of enterprise. Also, greater competition in the construction sector has driven capital cost down even further.

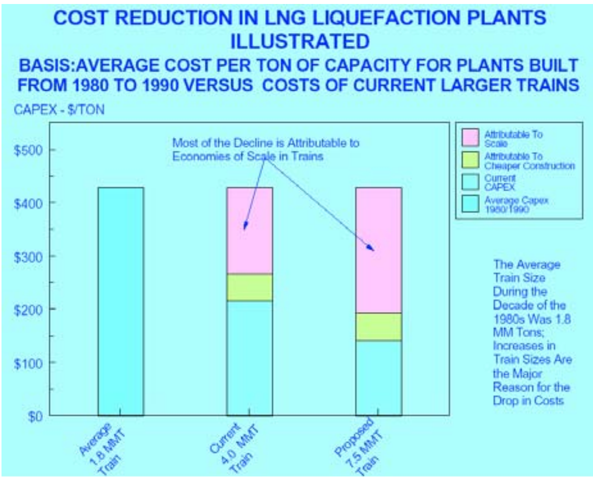

Fig. 4. Cost reduction in LNG liquefaction plants. Source: Jim Jensen Associates.

[2] The first long-distance pipeline was built in 1891 from Indiana to Chicago (120 miles), however most commercial pipes were built between 1920s-1960s. We are ignoring the hollow bamboo pipes built by the Chinese 2000 years ago to transport natural gas to the shore in order to burn the gas and evaporate the water for salt collection.

Recent figures indicate that the capital cost of a liquefaction plant has fallen to $200 per t/y, from twice that figure in the 1980s, and is set to fall to $150 per t/y [4]. This figure is set to be able to compete with pipeline gas supplies in many markets. Thus, not only has the number of terminals risen sharply, but so has the throughput capacity. The increase has been from a typical 3 million t/y per train to 8m t/y trains. By 2009, ExxonMobil and Qatar Petroleum will bring online a facility with capacity of 15.6m t/y on two trains. The cost of producing, transporting and regasifying is now estimated to be in the range of $2.80 to $3.40 / MMbtu.

2.2 Commodity Markets vs Project Markets

It is fair to say that traditionally the gas market has been strictly a project supply market with a limited number of buyers and sellers, a limited delivery system and limited use. As a result, buyers and sellers would enter into long-term contracts, typically 15 to 20 years, and we required to derive a price for the commodity based on some other tradable and competing energy source, which in most cases was oil. This type of arrangement was perfect for pipeline delivered gas. However, as the market moves towards a more commodity supplied market, LNG becomes a preferred method of delivery. This is because a commodity supply market is characterized by a large number of buyers and sellers, a defined delivery grid, transparent price mechanism and a degree of competition. In this scenario, buyers and sellers can enter into short-term agreements and may avoid being tied into one delivery location and/or one buyer/seller. Evidence of this type of shift manifests itself in the growing number of regasification terminals and liquefaction facilities. There already exists spot and short-term trading for LNG and accounts for over 9% of total world trade, according to 'Petrostrategies'.

2.3 Monopoly Power of Pipeline Operators

Pipelines have often been considered a natural monopoly [5]. A monopoly is an industry that produces a good or service for which no close substitute exists and in which there is one supplier that is protected from competition by a barrier preventing the entry of new firms [6]. Natural barriers to entry commonly result from economies of scale, which are characteristic of pipeline economics. When the long run average cost curve is negatively sloped over a large range of output, big firms have significantly lower average total costs than small firms. Natural barriers to entry give rise to natural monopoly, which occurs when, given the industry's current technology, the demand conditions allow no more than one firm to cover its costs while producing at the minimum point of its long run cost curve. In such a natural monopoly, there is no price at which two firms can sell enough to cover their total costs [7]. A number of reports have found subadditivity in natural gas transportation. Subadditivity plays an important role in establishing the existence of a natural monopoly. Subadditivity is realised if no combination of multiple firms can collectively produce an output at a lower cost than the monopolist [8]. A number of authors have found that subadditivity is present in natural gas transmission such as Mansell and Church (1995) [9] and Gordon, Gunsch and Pawluk (2003) [10]. Nevertheless the US gas pipeline market is not saturated as may be expected. A fairly low Herfindahl Index of 0.03787 (379) of 90% of all pipeline miles shows there is competition in the market. However, due to the heavy segmentation of the market, each pipeline operator serving a specific route, local segment monopolies exist.

Given that a monopoly is a market failure, and governments must intervene, the common solution is for a government to assume ownership of a single firm, and create a nationalized industry. Another solution, employed first in the US and subsequently in other countries, is to intervene via regulation of the monopoly by an independent body.

In many cases, ownership of the gas and ownership of the pipeline belong to unconnected entities, the communication between which can often be cumbersome and ineffective. In order to transport gas from Turkmenistan to the Ukraine, EuralTransGas (ETG) had to use a pipeline network belonging to Gazprom of Russia. This transit was not only costly for ETG, but the contract was fragile and the passage of gas to the Ukrainian consumer was left at the hands of a volatile Gazprom management. In this particular example, no other method of transportation was available, nor was it possible to avoid using the Gazprom network; however it serves to show the difficulties encountered by private companies in dealing with the monopoly power of the pipeline operator.

2.4 Atomization

In some cases, the pipeline operators have been a part of a longer value chain that owned the gas it was transporting. The quasi-monopoly Gazprom is an example of this. It used to own all the gas found on the territory of the FSU as well as the pipeline network. Now it owns just over half of the proven reserves in Russia, as well as controlling the pipeline network, export market, many distribution networks, and most major gas processing plants. Standard Oil was also a pipeline owner (for oil) that took control of both upstream and downstream operations. The problem may arise when vertically integrated companies try to restrict access to third party users to reduce competition [11]. This type of behaviour is usually hard to counteract, typically due to ex-post litigation having a delayed effect and also due to the lack of transparency in some markets – if the regulator is unable to have clear and timely access to pipeline capacity and bookings, its powers to regulate are significantly reduced.

The trend, however, seems to be away from vertical integration. The petroleum industry appears to be breaking up, or atomizing, into specific niches in order to gain some competitive advantage. Most of the industry's growth has been captured, in recent years, by highly skilled, 'vertically specialized' petropreneurs[3]. Perhaps due to the collapse of the official oil price in the 1980's and the expansion of the liquid spot markets, as well as the deregulation of natural gas markets, the value of vertical integration has been eroded away [12]. Once there was transparency in the market, and the spot market began to develop, new companies were able to enter and exploit the smaller reserves rather than be forced out of the market by the IOCs and their long-term contracts. The petropreneurs did not have to engage in marginal sections of the value chain such as refining but were able to slim-line the business and manage efficiency to gain a competitive advantage over the IOCs.

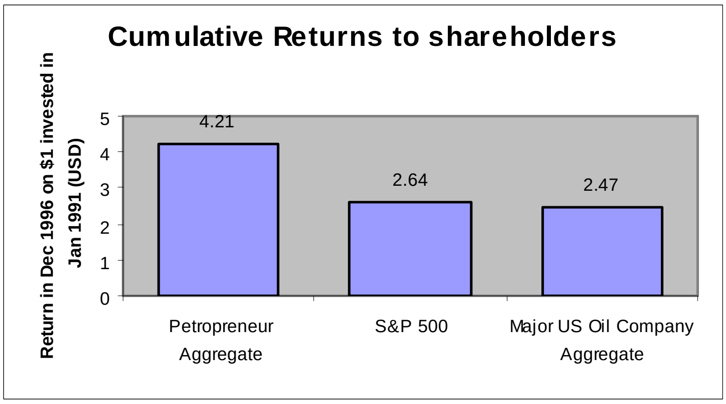

Fig. 5. Cumulative returns to shareholders by stock type. Source: Compustat.

If the trend continues, the vertically integrated pipeline owners may disintegrate themselves from the pipeline business. In the US, after 1984 the pipelines gradually moved from owing the gas to simply providing a transport service. It must be remembered that the best way to ensure optimal throughput of a pipeline is to own both sides of the value chain. If atomization does take place in this sector, there may be less incentive for pipeline owners to operate the pipelines.

[3] Enron, Toscos etc

2.5 Legal Issues

A number of legal issues arise from cross-border and transit pipelines. The obvious problem stems from differing jurisdictions and legal systems. There is no easy way to regulate the activities of the involved states, save for perhaps international arbitration. Even then, these decisions may not be overturned by the courts or maybe discarded by the sovereign state to which the decision may apply. This predicament is also encountered in dispute resolution.

Supply may be stopped in cross-border agreements due to factors arising out of political hostility or disagreement, and perhaps due to economic reasons driven by the monopoly power of the supplier.[4] In the latter case, an additional obstacle may be created from non-compatible markets - if one is a project supply market and the other a commodity supply market, the risk in the two markets will differ.

In the case of transit pipelines, the transit state is in a position to demand higher transit fees or lower cost of off-take. Needless to say, the bargaining position of the transit state is stronger for oil pipelines; it nevertheless exists for gas pipelines also. To build an alternative route would more than double the average cost of the pipeline.

For many years, Ukraine failed to pay debts due to Russia for gas imports, using its position as a transit state as the bargaining chip. Another example is the failed attempts to deliver gas from Iran to India. The plans for the pipeline cannot be approved until the long-standing dispute between India and Pakistan is settled. The Turkmenistan-Afghanistan-Pakistan (TAP) pipeline has been in the negotiating stage for years, yet Pakistan is not willing to take on the risk of the politically unstable Afghanistan as a transit state. Pakistan also demands that the gas reserves in Turkmenistan be independently certified before it commits to the TAP pipeline.

2.6 Outage Costs

It is important to remember that gas pipelines are different from oil pipelines. Not only are gas pipelines more expensive than their oil counterparts, but also the outage costs associated with gas pipelines require more consideration. If a supply is lost, the reconnection for gas pipelines is not at all an easy process - there are dangers that air has entered the pipeline which can cause an explosion and linepack (an operating volume in the pipe) must be maintained. Although not in the scope of this paper, it might be worth mentioning that for low pressure distribution networks a danger exists that certain gas burning appliances have not been turned off, optimally requiring a gas engineer to be present at every burner tip. This burner tip obstacle means that it is difficult to re-establish supply quickly. A study conducted in the 1980's in the UK concluded that it would take 3 years to re-establish a gas supply to Birmingham, if it was ever disrupted.

2.7 Market Failure

When a market economy fails to achieve an efficient allocation of resources, it is termed market failure. One of the market failures associated with pipelines, monopoly, was discussed in paragraph 2.3. The other type of market failure is externalities. This is a cost or benefit of production or consumption that affects people other than those involved in deciding the scale of the activity. In the case of a pipeline, parties other than the main participants in the transaction are affected. The environmental damage caused by the construction of the pipeline, and the damage to privately owned property[5] through which the pipeline runs is a major external cost. Also, the potential damage from a leak in the

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[4] The monopsony power of the buyer may create the opposite effect and prevent access to the market.

[5] In most cases, landowners are reimbursed for this damage. However, differences in Purchasing Power Parity can make this figure inadequate. A farmer in Azerbaijan was paid USD$500 for allowing the BTC pipeline through his land. At today's prices, the pipeline will pump USD$ 40 million worth of oil everyday.

pipeline is considered an externality. Leaks of natural gas can cause an explosion but also add to the greenhouse effect if released into the atmosphere. It must be noted however, that due to the compressed gas carried in LNG tankers, the possibility of a large explosion cannot be ruled out. But the tankers do most of their travelling in the high seas, whereas pipelines often run through residentially occupied land. Another type of externality that can be identified is the pecuniary network externality. This describes the decreased benefit that is experienced by market participants who require access to the pipeline as the number of such participants increase. Because of increase demand for the pipeline, tariffs increase thereby generating benefit for the operator [13]. In cases where the tariffs are regulated, a direct negative network externality exists. This is because no benefit is gained by the pipeline operator.

2.8 Gas Field Location

Pipelines are static features. Once a pipeline has been built, it cannot be moved. It can be extended, or rerouted (as in the case of the Russian pipeline rerouted through Dagestan to avoid Chechnya) but the costs of the original pipeline have been sunk. With gas fields moving away from traditional areas due to field exhaustion, certain pipelines are becoming obsolete. The US gas reserves stand at 5.3 tcm but domestic production is unable to meet the growing consumption, and as this gap widens, it can really be opposed by increased domestic production of unconventional gas[6], new supplies from Alaska and LNG imports.

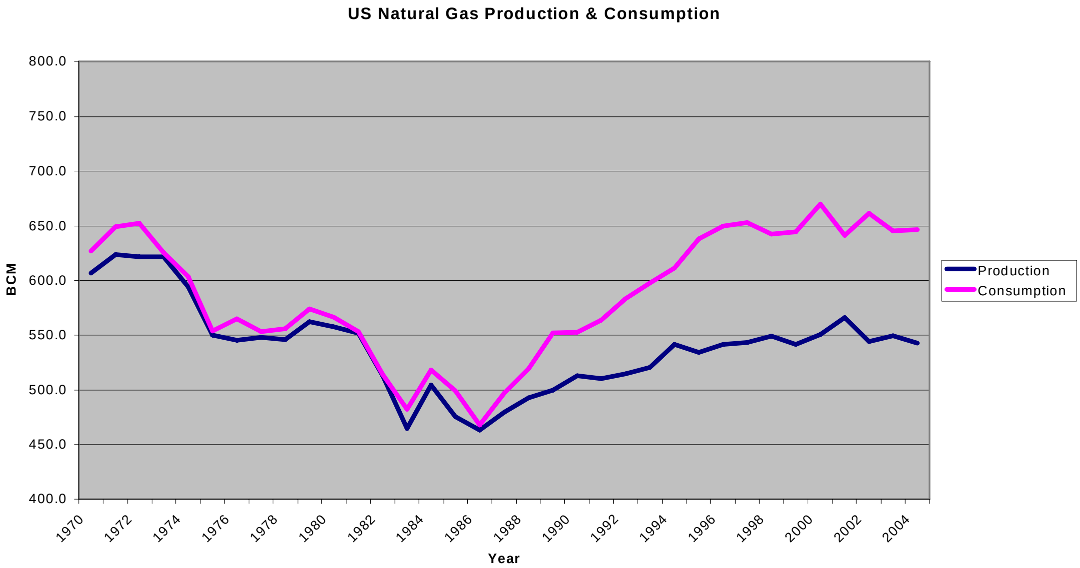

Fig. 6. US natural gas production and consumption. Source: BP Statistical Review 2005.

There are currently five existing regasification terminals in the US, with 14 more approved by FERC and US Coast Guard, and 20 more proposed terminals.[7] By comparison, US Gas pipeline construction in 2005 and beyond totalled just 3000 miles [14]. It is worth remembering that for a pipeline project to be economically viable, the reserves of a field must exceed 2 trillion cubic feet (tcf). Many areas, for which pipelines were built, are running out of these reserves, and many more fields are in decline surely rendering those pipelines useless.

[6] Unconventional gas includes tight sand gas, coal bed methane gas, Devonian shale and gas hydrates.
[7] According to FERC

3. THE CASE FOR PIPELINES

3.1 Security of Supply

Although there are problems associated with security of supply issues discussed in paragraph 2.6, pipelines can guarantee supply to a specific point. Once a pipeline is built between point A and point B, the hydrocarbon can only travel from the seller to the buyer. There is a guarantee that the hydrocarbon will not end up with a different buyer, which can be a danger with LNG deliveries.

For a country such as China whose demand for gas is set to double every 7 to 10 years, a gas pipeline such as the Kovytke pipeline proposed from Russia, or one from Turkmenistan, will guarantee a delivery of gas and avoid the strategic implications associated with delivery by tanker. China is the world's second largest importer of oil, after the US, and 80% of its imports must travel through the Strait of Malacca, a 600 mile long waterway between Malaysia and Indonesia with the narrowest point being only 1.5 miles long. With 50,000 ships travelling through the straight every year, and some 11mbd of crude, it is clear to see why this is a clear choke point in Asia [15]. This raises serious questions regarding security of supply for China and other Asian importers of oil and gas. Firstly, there is a threat from pirates who operate in this region, with more than half of the world's pirate activity taking place in the Strait. Secondly, there is a danger that terrorists may wish to sabotage this route, or even an accident or oil spill may put the passage out of actions for a considerable period of time. Some commentators have perhaps overestimated the importance of the Strait, since a blockage would not cause serious problems as long as the importer can delay receipt by a week and cover the additional shipping cost that would be incurred if the Straits had to be circumvented. In light of some complicated international relations in recent years, however, the region is strategically important and some commentators have expressed the view that China is concerned about the possibility of a naval blockade by the US, however it seems that although China is aware of this possibility, it do not see it as a likely eventuality, continuing to import oil by tanker and making final preparations to take first delivery of LNG. As China's dependence on Middle East oil imports grows, and perhaps with a greater demand for LNG to be met by imports from the Middle East or Africa, American intervention via a naval blockade of this region would be an effective way to take action against China [16].

It is worth noting however, that supply may be turned off at one end of the pipeline. This causes implications for security of supply and as was recently experienced by Ukraine. At midnight on December 31st 2004, Ukraine's gas supply from Turkmenistan was terminated. After renegotiating the delivery contract, and accepting the price increase from \$44 to \$58 per thousand cubic meters, Ukraine began to take delivery of the gas on the 5th of January. In the interim, almost half of Ukraine was left without domestic heating. However, considering the time it takes for a tanker to arrive to its destination, reconnecting a supply via a pipeline was much more efficient.

The construction of the West-to-East (internal) pipeline, and the possible constructions of pipelines from Kazakhstan and Turkmenistan, suggests that China is willing to pay a high premium for security of supply.

3.2 Cost Structure of Pipelines

The pipeline cost structure is capital intensive, and requires large upfront investments. Typically, the consortium of owners provides only 25% towards the cost of the pipeline, and as result the profitability is often dependent on interest rates. Costs of pipelines do vary, and depend on a number of factors. For example, a pipeline running through a dense urban area will cost up to 5 times that of a pipeline running through a rural area [17]. Comparing prices between 1989, 2000 and 2005 the costs have risen steadily but not significantly.

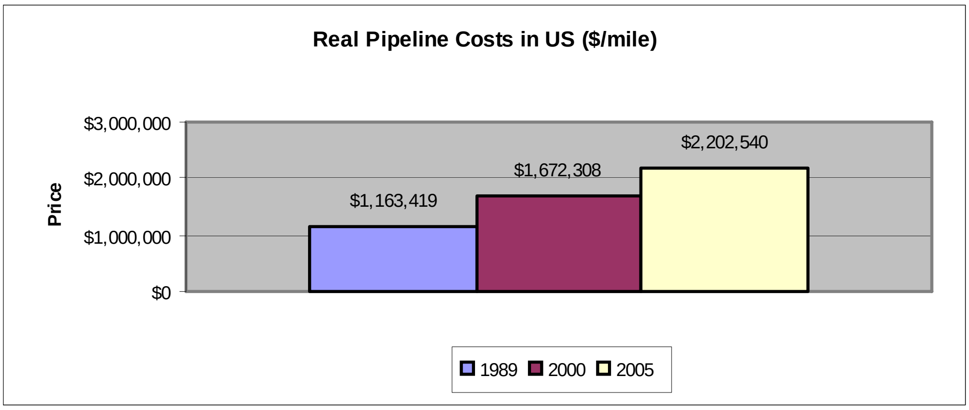

Fig. 7. Real pipeline costs. Source: Oil & Gas Journal.

The pipeline construction costs can really be split into four categories of cost: Labour, Materials, Right of Way (ROW)[8] and Miscellaneous. The two largest components for on onshore pipelines have traditionally been labour and materials, comprising over 70% of total costs. Labour usually takes up the biggest percentage of costs ranging from 35 to 45% depending on the costs of the materials which can be quite volatile. The remainder is split between ROW and miscellaneous, with ROW being the smallest component, usually taking up between 5 to 10% of total costs. Offshore pipelines, because these tend to be shorter yet more technically challenging, have about half of their costs allocated to labour, with materials taking up about 15 to 20% and the remainder being made up by the miscellaneous costs. ROW component in offshore pipelines is usually negligible [18].

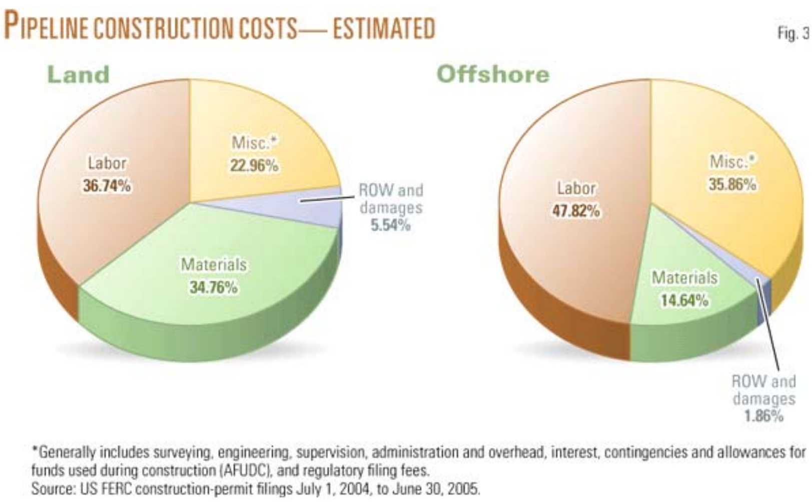

Fig. 8. Pipeline construction costs. Source: OGJ 2005.

Although these figures are true for most Western countries, they may differ in other states. Those countries where labour is cheap, can expect to see a smaller labour component of costs, although it should be remembered that because of the complex nature of the industry, many specialists must be recruited from Western countries to oversee or train local labour. Other countries, which may have a

[8] ROW costs include obtaining permission to use land, compensation and damages.

cheaper supply of the building materials e.g. Russia or Ukraine, may see a smaller materials component. ROW may not be a cost component at all in some countries, such as China for example. 2004 to 05 was a specifically expensive year for US pipeline manufacturers because of the high world steel prices, with material cost per mile jumping to $765,633/mile from $315,815 / mile for the same period a year earlier [19].

There are currently 190,000 miles of interstate gas pipelines in the US [18] and the cost per mile of a pipeline, or even the actual cost ratios are very hard to predict. The more difficult the terrain, the higher will be the labour cost with mountainous or marshy areas as well as built up areas and river/road/ channel crossings provide additional difficulties and are very costly. Even so, laying rates of 3km per day have been achieved in the past. Obviously the more densely populated the area is, the higher will be the cost of ROW. For example, two similar 42- inch pipelines in New Jersey had right of way costs that differed by a factor of 2, or for two 36- inch Pennsylvania pipes where one cost of ROW was 2.75 times higher than the other [18].

Actual average costs may range from a cost $150,000 per mile to over $6 million per mile. However, an average cost of $2m is commonly accepted as the norm. Generally however, it can be said that the longer the pipeline, for a given diameter, the lower the cost per mile for construction; this can be attributed to increasing economies of scale and scope. The higher pressure designs allow for a greater distance between compressors and a decrease in compressor horsepower, translating into lower compression costs. Further costs may be saved be employing a high strength steel line pipe which allow for cost saving over long distance gas transportation [20].

High fixed costs and low variable costs are also characteristic of pipeline economics. Depreciation and financing costs are considered fixed costs. The operating costs of the pipeline, which are comparatively low, are considered variable costs, although this is not entirely true. This is because personnel can only be dismissed if the pipeline is not operating at all for an extended period of time. The actual throughput of the line is rarely responsible for these expenses. The number of personnel required to operate a pipeline is not commonly large, for example only 150 people operate the Lavéra-Karlsruhe line running from Marseilles in Southern France to Germany, through 770km.

However an element of the costs does rely on throughput. Energy, which accounts for 30% of operating costs, depends on the number of pumping or compressor stations.

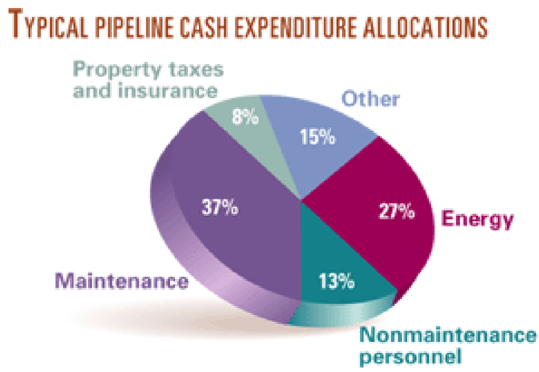

Fig. 9. Pipeline operating costs. Source: OGJ 2004.

The compressors that keep the gas in the pipeline flowing through the system require energy and are usually fuelled by natural gas from the pipeline.[9] However, for very long distances, the amount of this fuel may be substantial: a proposed pipeline from Yamal in Siberia to Frankfurt in Germany will have a production at Yamal of 83bcm per year whilst 10bcm/y will be used as compressor fuel [21].

[9] Some compressors can be electric driven, such as those installed at Peterstow and Lockerly in the UK.

The number of compressor stations are in effect a function of the pipe diameter - the biggest loss in piped gas comes from friction, specifically wall friction, and this loss is a decreasing function of the pipe diameter, there is a set off between the pipe diameter and the number and/or power of the compressor stations - in essence, the greater the diameter of the pipe, the less the compressor-capacity that needs to be installed to move a specific quantity of gas across a specific distance [21]. However, this relationship breaks down after a certain point.

The average construction cost of compressors is about $1500 per horsepower of output, with the more powerful engines having a shaft power of up to 36,000 hp. As can be expected the majority of the costs are associated with the equipment and materials, taking up between 40 to 50% of the total costs. Labour usually comprises between 20 to 30% of the total cost with miscellaneous[10] also being between 20 to 30%. The remaining costs can be attributed to the land value [18].

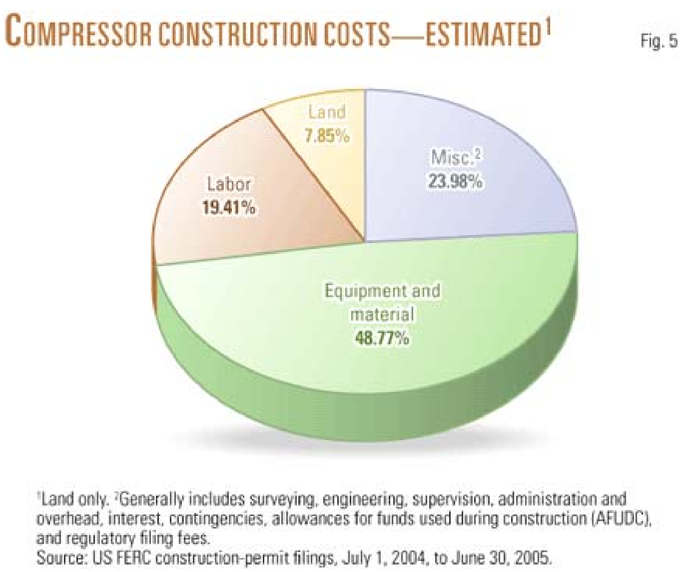

Fig. 10. Compressor construction costs. Source: OGJ 2005.

Maintenance is the biggest aspect of the pipeline's variable cost and with greater automation (which drives down the operating cost) comes increased maintenance cost [22].

The cost of construction of sub-marine pipelines has fallen in recent years, due to construction of new high-pressure pipelines, yet they still cost over three times that of their onshore counterparts. This drop in capex has in turn driven down the transit fees (tariffs) of these pipelines.

Also, because the capacity of the pipeline is a function of the square of its radius whilst the cost is a function of the surface area, and there is an exponential relationship between the two, there is a technical economy of scale. Due to this fact, as capacity increases, average fixed cost falls sharply; in order to take advantage of this economy of scale, throughput must be maximized. If capacity is not maximized, fixed costs are spread around a lower throughput and therefore rise. There are two ways to raise the throughput of a pipeline – one is to increase the compressor capacity (by increasing number of stations or increasing horsepower of the existing stations), the second being via 'looping' or adding another pipeline to run parallel to the current one. An interesting economic discussion about when either method becomes more suitable can be found in Chenery (1952) [23]. One way to ensure maximum capacity utilization is possible is to own the upstream and the downstream, which is discussed in paragraph 2.4.

[10] Miscellaneous generally includes surveying, engineering, supervision, administration, overheads, interest, contingencies, regulatory filling fees and the like.

The nature of these costs means that the “bygones rule” is strongly applicable. This states that even if the operation is making a loss, so long as the variable costs are covered, and some contribution is made to fixed costs, the operation should continue. Thus, pipeline owners will often operate the pipeline if there is any revenue to be gained at all.

Furthermore, a pipeline investment is considered a sunk cost. This is because once a pipeline is built there is little that can be done with it. It would make little economic sense to disassemble the pipeline and sell it for scrap. One option would be to use the pipeline for other purposes, such as the recent proposal by Petrobras to convert a disused natural gas pipeline into an LPG carrying pipeline.

It thus appears very difficult to put a pipeline out of operation economically.

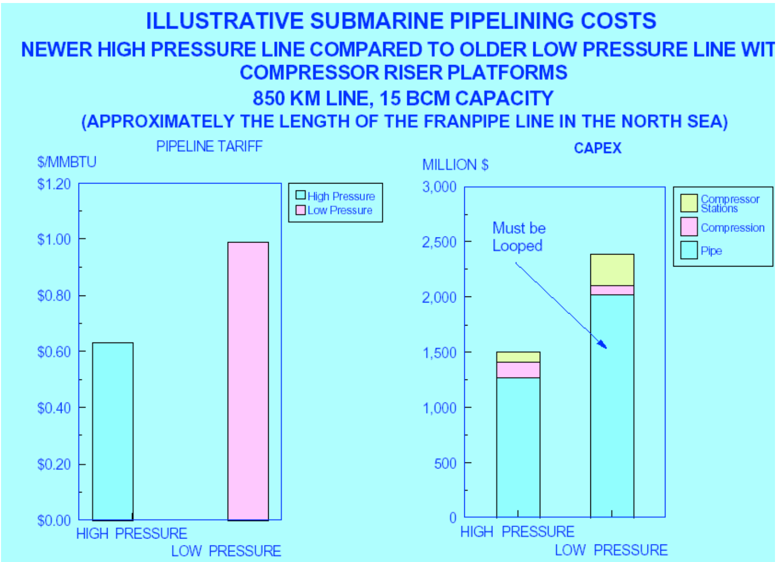

Fig. 11. Submarine pipeline costs. Source: Jim Jensen Associates.

3.3 Comparative Costs

With the recent reductions in costs associated with LNG technology, pipelines are still a cheaper option for transport over distances less than 1500 km. (Between the range of 1500 km and 3000 km), pipelines and LNG begin to compete with each other. For longer distances, LNG becomes a more economical way to transport gas.

For local and regional markets, pipelines are undoubtedly the method of choice. Due to the large number or local and regional markets that must be served, pipelines remain the only viable option.

However, as costs for LNG facilities continue to fall, the abovementioned figures are liable to change.

A study carried out by ILF Consulting Engineers compared the cost of moving natural gas from Turkmenistan to China via two options: pipeline only and a hybrid option of a combination of a shorter pipeline and then LNG via ship. Because Turkmenistan is a land-locked state but high in gas reserves (as explained below), one option is to build a 1,400 km pipeline from Dauletabad (a giant gas reserve in the south of the country on the Iranian border) through Afghanistan to the Pakistani coast where the gas will be liquefied and sent to China as LNG traveling 5,125 nautical miles (9,500 km). The other option is to build a pipeline direct to Shanghai through 6,300 km. The economic analysis shows that it would be considerably cheaper to send the gas via the direct pipeline:

The total specific transportation cost shows that the cheapest method via the hybrid model is more expensive than the most expensive direct pipeline option.

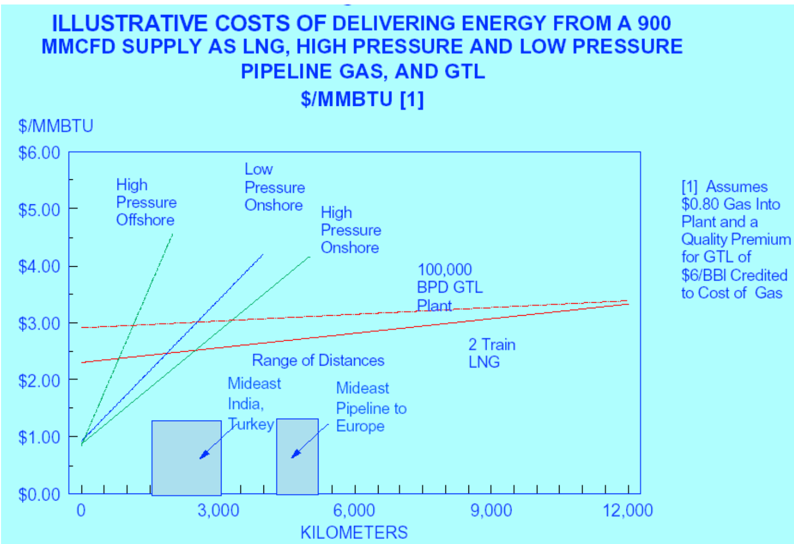

Fig. 12. Comparative costs of gas delivery. Source: Jim Jensen Associates.

INPUT DATA, RESULTS OF COMPARISON Table 5

Natural gas transport	Unit billion std. cu m/year	Annual throughput 10	20	30	40
Option 1:					
Landbased pipeline Dauletabad-Shanghai:					
Length	km	6,300	6,300	6,300	6,300
Total specific	$US/MMbtu	2.30	1.69	1.43	1.28
transportation cost	$US/1,000 std. cu m	82.8	60.8	51.5	46.1
Option 2:					
Land-based pipeline Dauletabad-Karachi:					
Length	km	1,400	1,400	1,400	1,400
Specific transportation cost	$US/MMbtu	0.51	0.37	0.31	0.28
LNG-chain Karachi-Shanghai:					
Length	km	9,492	9,492	9,492	9,492
LNG throughput	million tpy	3.3	14.6	21.9	29.2
Specific transportation cost	$US/MMbtu	2.45	2.28	2.12	2.04
Total specific	$US/MMbtu	2.96	2.65	2.43	2.31
transportation cost	$US/1,000 std. cu m	106.6	95.3	87.6	83.3

Fig. 13. Turkmenistan to China gas transport costs. Source: OGJ 2004.

3.4 Land Locked States

A number of states that require gas imports or even those that wish to export their natural gas, are landlocked. Turkmenistan, with reserves of about 3 trillion cubic meters[11], is principally land locked.[12] There are plans underway to construct a gas pipeline from Turkmenistan to Iran, and since they share a border, this method of delivery would be more desirable than others. Thus it is fair to say that only pipelines will be able to service these regions. Yet what is not commonly known is that Turkmenistan

[11] There has been no official reserve estimation but informed sources such as BP and Gazprom put the reserves at around 3tcm. However, Turkmenbashi Saparmurat Niyazov claims that the reserves are closer to 23tcm.
[12] Turkmenistan has access to the Caspian Sea, however for our purposes this is ignored as export of LNG via the Caspian is not viable.

does produce LNG and exports it to Afghanistan and Iran, hoping that China will come on board as the main buyer of the liquefied gas. It transports the LNG via rail in specialised containers and hopes to reach output of 1 mt/y. It is fascinating to see how in the absence of a pipeline, this landlocked state exports natural gas via LNG in rail containers.

3.5 Existing Contracts

There at present exist a number of long-term contracts for the supply of gas via pipeline. For an array of reasons, despite what Wardlaw and Alai say, it is unlikely that these contracts would be broken in favour of an LNG supply. Reasons may include damage clauses, political alliances, status quo, security of supply, other contractual obligations, barter agreements and the like.

3.6 Size of Gas Reserves

Simple financial analysis shows that for an LNG project to be economically viable there must be at least 5 tcf of recoverable reserves. By contrast, a pipeline project requires only 2 tcf of recoverable reserves. This fact may play a role in the decision making process when deciding which of the two projects to undertake. Needless to say, not all fields or regions hold reserves of 5 tcf but may well contain only 3 tcf. In such a case, a pipeline project must be selected.

3.7 The Algerian Example

The situation in Algeria is a perfect example where pipelines compete directly with LNG. Initially, an LNG project was setup to export gas across the Mediterranean, but encountered problems over prices and delivery terms. It was also grossly over budget. But the technology to lay pipelines across the sea was not available, and LNG remained as the only option.

But a study was undertaken in 1970 and the TransMed line was finally completed in 1981; delivery of gas began in 1983. In 2001, the TransMed pipeline delivered 21.85 billion cubic meters to Italy and 1.2 billion cubic meters to Tunisia [11].

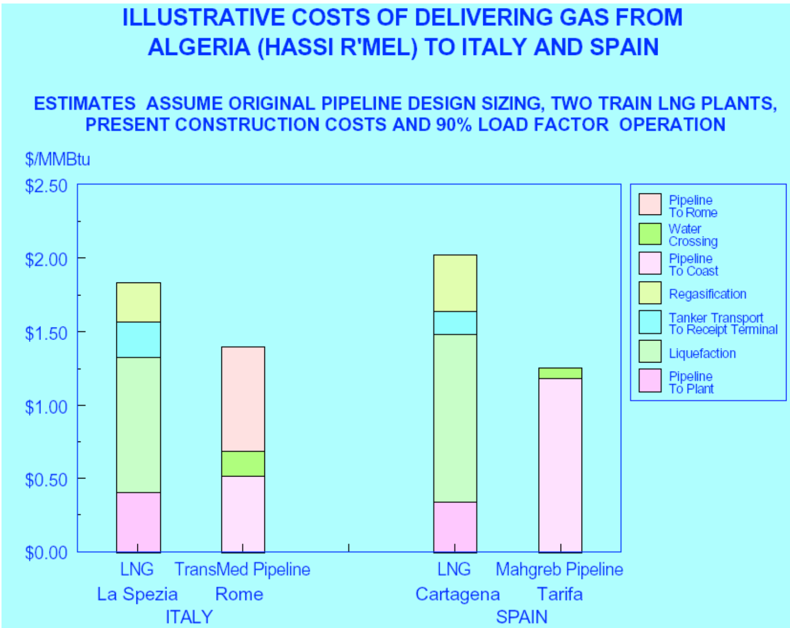

Fig. 14. Gas delivery costs from Algeria to Europe. Source: Jim Jensen Associates.

The chart below shows the comparative cost of delivering gas from Algeria to Italy via the TransMed, and to Spain via the Mahgreb. These figures illustrate that over these short distances,[13] the pipeline is a cheaper option than LNG.

Algeria is also planning to add a second pipeline to Spain to run across the Mediterranean. This pipeline, to be commissioned in 2010 will be known as the Medgaz pipeline, and will deliver 16 bcm /year of Algerian gas via two 24 inch subsea pipelines to Almería, Spain. The pipelines will run for 200km underwater, reaching a maximum depth of 2,155 meters. Compared to all other available sources of gas for Spain (such as Mahgreb, Algerian LNG, Netherlands, Egypt LNG, Libya LNG etc), the Medgaz is considerably the cheapest option [24].

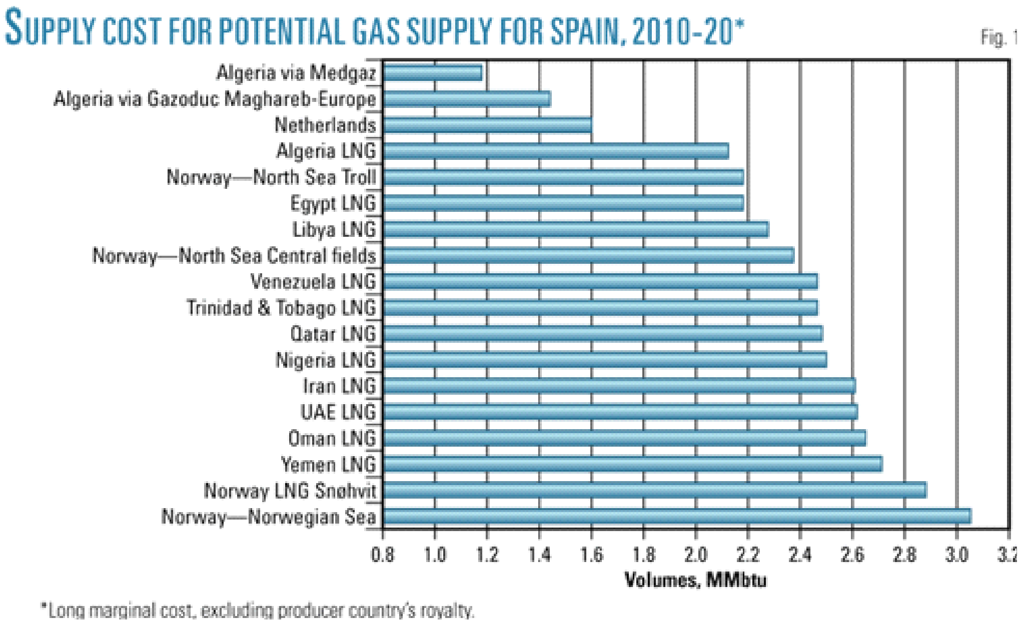

Fig. 15. Gas supply cost for Algerian gas to Europe. Source: OGJ 2005.

4. ALTERNATIVE MEANS

4.1 Gas-by-Wire

Innovation and improvements in superconductors can increase the use of Gas-by-Wire technology. Essentially, CCGT technology can be used generate electricity on location, and send it as the export product by wire cables. There is great optimism that this type of technology can be used to utilize fields where reserves are not large enough to justify a pipeline or LNG project. Since the end use of gas is often electricity generation, it may be wise to send the electricity direct, but only if the loses associated with the wire transfer are truly minimized.

4.2 GTL

Gas-to-liquids technology[14], which produces a sulphur and aromatic free diesel, is only a competitor to LNG over longer distances. For shorter distances, GTL cannot compete with pipelines. It may,

[13] The length of the line from Hassi R' Mel to La Spezia is reported as 2,500km.
[14] GTL technology was first introduced in Nazi Germany, and the Fischer-Tropsch (F-T) technology is used to this day.

however, be a solution for landlocked states that wish to export to markets unreachable by pipeline, or to utilize stranded gas where lack of infrastructure of inability to access available infrastructure may prohibit the development of that field. Nigeria is one example where the majority of discovered gas is flared because of no infrastructure to utilize the gas. LNG projects in Nigeria will be especially important because of this.

5. CONCLUSION

Before LNG technology became available, there was no other means to transport large quantities of gaseous hydrocarbons but pipelines. Now however, due to the number of reasons discussed above, LNG can compete with pipelines over distances of 1500km. Nevertheless, we can see from the Algerian example that even for sub-marine transport, with the advances in high-pressure pipeline technology, pipelines can compete with LNG over distances of 2500km.

Due to the nature of the business, each new project will have to be weighed on its own merit to decide the most economical and strategic method of gas transport. It is fair to say that many pipelines will continue to serve domestic or neighbouring markets, however some distant markets that are unable to keep the production high enough to satisfy the growth in demand, may need to look to LNG to fill the gap. Many commentators fear that LNG alone will not be sufficient to fill the US growing shortfall, and as Canadian reserves become depleted, new pipelines will need to be built to access the reserves of offshore hydrates and other restricted fields. Obviously we can expect even greater cost reduction in LNG delivered gas, especially as the credit is amortized over time for older facilities and technological advances drive down the cost of new facilities. Clearly some pipelines will cease to have any use, as the resources become depleted, but new pipelines may be built to attract other fields or imports. LNG can globalise any gas reserve, despite local political or technological constraints. Yet the fact that projects such as Medgaz are still very competitive with LNG is a sign that LNG has not overtaken pipelines as the method of choice for transport. Pipelines continue to be a profitable venture with natural gas pipeline operators in the US posted earnings of over $3.5 billion in 2004. It is unlikely that the pipeline operators will forfeit this profit easily. Despite the growing threat from LNG and other economic factors, it seems likely that pipelines will play a growing role in satisfying demand increment, not in competition but in compliment to LNG.

As demand for gas increases, and reserves become more localised, it is likely that both methods will play an active role in satisfying world gas hunger in the near, mid and long term. The two methods will work together deliver natural gas to both new and mature markets. LNG will help supply distant markets or help producers with inadequate infrastructure to successfully market their gas. Pipelines will work to serve local and mature markets where LNG is not required or less economical.

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