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In The Name of God, Architect of the Earth and Creator of the Oceans

To my Family

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Abstract

This thesis looks at the natural gas market to France, Italy and Spain by proposing an econometric model for the consumption of gas in the residential and industrial sectors of these countries and a discreet choice model for the decision making of investment in import infrastructure and partner choice. Results from the above work is integrated in an object-oriented model aiming to generate benchmarks on trade flows to France, Italy and Spain.

The thesis also looks at the prospects for the LNG market and critically discusses the problematic of security of supply with liberalisation of markets against the background of changes within the Mediterranean market.

Primary information and analysis is an initial contribution of the thesis. The thesis also contributes in terms of the results in the consumption modelling, including the effect of weather on residential gas consumption. Also, the discreet choice model shows a clear pattern in decision making pre-gas liberalisation in Europe and shows, numerically, the drive towards diversification of partners. Finally, the object-oriented model shows scenario driven benchmarks for the choices of partners, suggesting, *inter-alia*, an even supply for France, an over-supply for Italy and an under-supply for Spain.

1. Introduction

Energy markets are going through a tremendous amount of change: Oil prices appear to have undergone a structural change; China and India are emerging as large and growing sources of consumption and are henceforth becoming price drivers. As environmental awareness is more established and as the Kyoto protocol comes into force, the debate about the usage of nuclear power generation is at the forefront of many national energy policies and unprecedently high amounts of investment are going into research and development of renewable technologies. As electricity consumption is also growing at high rates, natural gas and coal are in fierce competition.

The world security paradigm, particularly in OECD countries, has also shifted. As an increasingly higher share of their consumption comes from imports, security of supply is also at the height of energy policies, from a logistical perspective and from a geopolitical one.

The change, however, that natural gas and LNG are witnessing is even more spectacular as current world trade capacity is expected to double within the next five to ten years, with an uncertain international market structure. Indeed, as deregulation is implemented in many consuming markets, triggered by the US and the UK and followed by the EU, Japan and Korea, profound changes are poised to reshape the natural gas industry, very certainly with an effect on security of supply.

One of the issues of consideration is the trade-off between security of supply and market liberalization. As markets are free and competitive, and there is an increase in market players, investment in infrastructure is not necessarily inline with consumption as the decision making process shifts from the *macro* (government and monopoly utility) to the *micro* (firm and independent regulator) level. Markets are likely at times to be over-supplied or under-supplied and definitely more cyclical, as competitive industries that are constrained infrastructurally, like shipping, tend to be. More importantly, as incumbent utilities do not enjoy their status of legal monopolies, profit maximization will constrain reinvestment in infrastructure, especially at times of low prices, with all the potential security of supply concerns that this may entail.

The Mediterranean –or the south European market and some North African suppliers- is a very particular and interesting region to study– particularly as it is an area where academic interest in natural gas remains limited. The largest natural gas markets in this area (France, Italy and Spain) have many interesting particularities: they have low-reserves and low-production in gas; they have booming natural gas consumption; they are undergoing industry changes through market liberalization with a reasonably similar timing; and they maintain a mix of pipeline/LNG imports with an increasingly well diversified portfolio of suppliers. These suppliers range from the usual pipeline exporters: Algeria, Norway, the Netherlands and Russia to new LNG entrants like Trinidad & Tobago, Egypt, Qatar, Nigeria and others.

This thesis will look at the past patterns of natural gas consumption in the markets above and look into potential forecast scenarios. Further it will also look at past decision making patterns in term of partner diversification and infrastructure investment under the previous industry status (legal monopolies) and proposes a model for capacity building and long term contracts based on the decision making processes of the buyers above. This thesis does *not* aim to offer capacity forecasts, rather it aims to offer a platform of comparison between current market developments and how they *should have* been, if natural monopolies and macro-level decision making are assumed to be optimal for capacity investment and partner choice.

The contribution of the present thesis is threefold. On the substance, the research included primary information collection, including formal interview and less structured discussions with market players, governments, inter-governmental organizations, consulting firms and think-tanks. Data in regards to different infrastructure outlets and long -term contracts was also gradually collected from different sources. On methodology, the research introduces a simple, user-friendly, easy-to-construct, object oriented simulation tool with scenarios capability. On results, the thesis offers insightful answers to current industry questions, in relation, for instance, to elasticities of consumption and over/under-supply in some markets. In effect, this research is one of few pioneers in LNG trade modelling in the region and globally.

Chapter 2 of this thesis starts off by offering some basic facts about natural gas and LNG and will move on to discussing supply/demand factors and international trade patterns. This chapter demonstrates the unique properties of natural gas and will offer some initial grounds why it should not be treated in the same context as other commodities. Chapter 3 will have a deeper focus into the area of interest, looking at the current and expected import/export infrastructure in France, Italy and Spain and their respective suppliers. It will also address supply and demand patterns and will discuss in more detail the EU market liberalization.

Chapter 4 offers a comprehensive consumption analysis for natural gas in the markets, from different angles. This chapter investigates the importance of macro-economic variables on the consumption and looks forward into how this consumption is likely to evolve. This chapter will look at natural gas consumption with less emphasis on power generation demand whose estimation is more appropriately addressed using a lengthy bottom-up (plant-by-plant analysis) approach, already available in the literature at the EU scale.

The fifth chapter looks into the decision-making determinants in terms of infrastructure investment and "partner choice". Putting consumption and decision making patterns together, the sixth chapter proposes the Dynamic Object Oriented System, which simulates new terminals and new contracts in the market –allowing for scenarios- based on consumption forecasts and decision making. The thesis ends by offering results, conclusions and potential for future work.

2. Overview of the Natural Gas and LNG Industry

This chapter will provide an overview about various aspects of natural gas and natural gas trade as well as critically discuss potential future trends in LNG markets.

Natural gas is a fossil fuel source of primary energy. It has been the fastest growing energy source for the past thirty years taking market share from oil and coal. It now represents around a quarter of the world's primary energy consumption. This growth is associated with its safety (reduced flammable range), its environmental friendliness, its potential cost efficiency (ongoing with technological advances in extraction, transportation and distribution) and its relative abundance at proximity to markets and more uniform distribution of reserves than oil.

Natural gas is colourless, odourless and lighter than air. The primary component of natural gas is methane (CH_4) which usually accounts for 90% of NG. Other components are ethane, propane, butanes and pentanes and in less proportions CO_2, Helium, Hydrogen Sulphide and Nitrogen. Natural gas is not to be confused with "town gas" which was artificially produced from the carbonization of coal.

The most "natural" way for transporting NG is through pipelines. However, this cannot be feasible for long hauls. Figure 2-1, below, shows the competitiveness of transporting gas by pipeline versus LNG carriers depending on capacities of pipelines (width in inches) and LNG carrier capacity.

Under a temperature of -161°C, NG liquefies and becomes LNG (Liquefied Natural Gas). LNG takes $1/600^{th}$ of the volume of Natural Gas and is less than half the weight of water, for the same volume. It is non-corrosive and non-toxic and it does not explode in an unconfined environment. LNG is thus preferred in many instances for transportation and storage purposes.

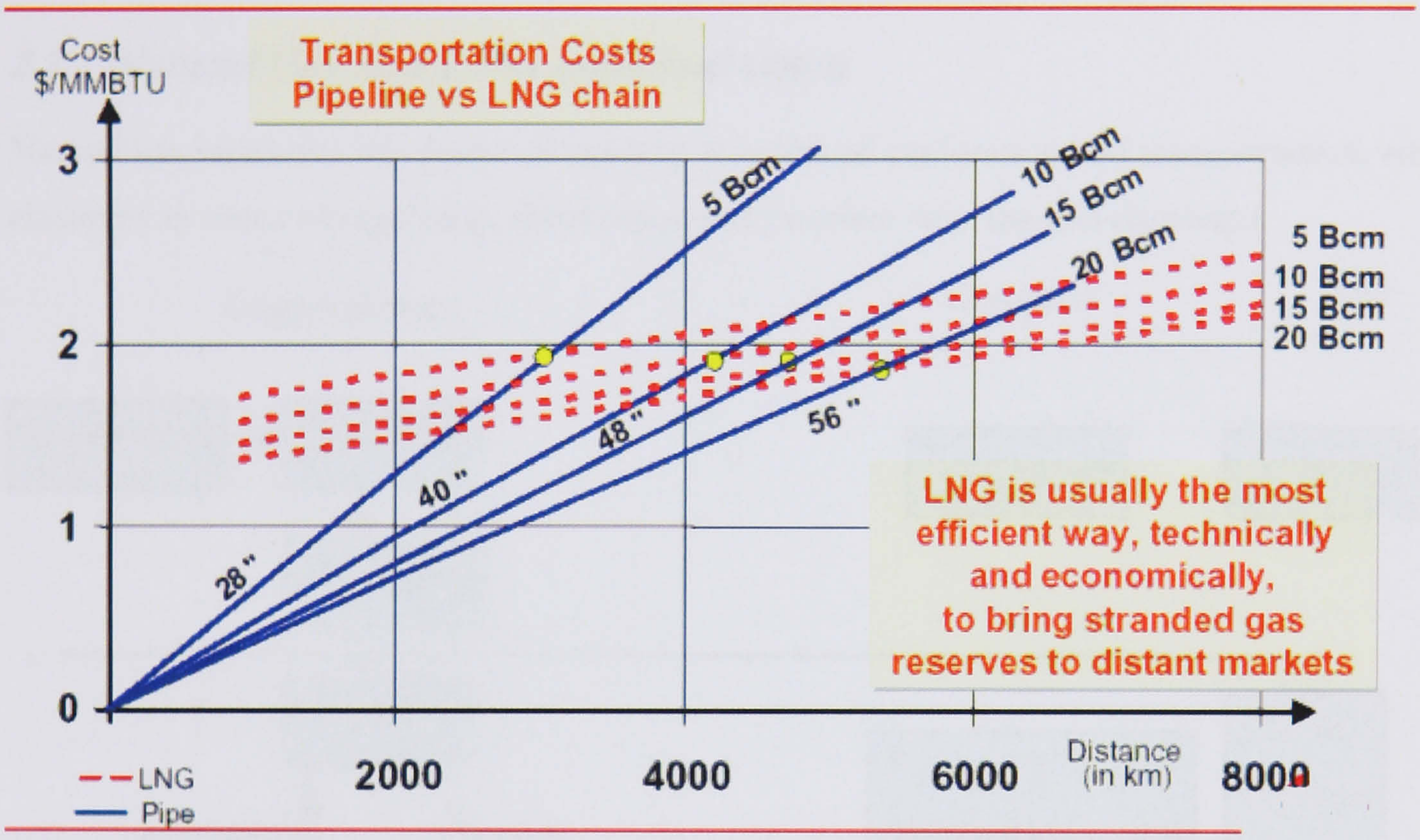


Figure 2-1 Comparison of the Unit Cost of Natural Gas (pipeline) and LNG[1]

Natural gas originates in the same way as oil does through chemical reactions occurring on organic matter during hundreds of thousands of years underground. It is believed, according to Banks (1987), that Natural gas is one step further from oil in the reaction of organic matter. This explains why areas abundant in oil reserves are more likely to be also abundant in natural gas resources. Furthermore, it is noteworthy to classify natural gas in two types:
Associated natural gas is that which is extracted as a side product of crude oil exploration. It is also called wet-gas. This gas can either be flared (burnt into the atmosphere), reinjected into the well to create a "natural" pressure for oil extraction, or marketed. It is important, with regard to economics, to note that the supply function in relation to gas price is flat since

[1] Total, Presentation in the 2nd Energy Risk Management Seminar, 2004

the production is not controllable and is only subject to the oil extraction with which it is associated. Non-associated gas, or dry-gas, is that which is extracted from dedicated gas fields

2.1 Natural Gas and LNG logistical chain

Natural gas resembles the crude oil industry in terms of exploration and transportation, and electricity in terms of regulation, distribution and interface with the end consumer.

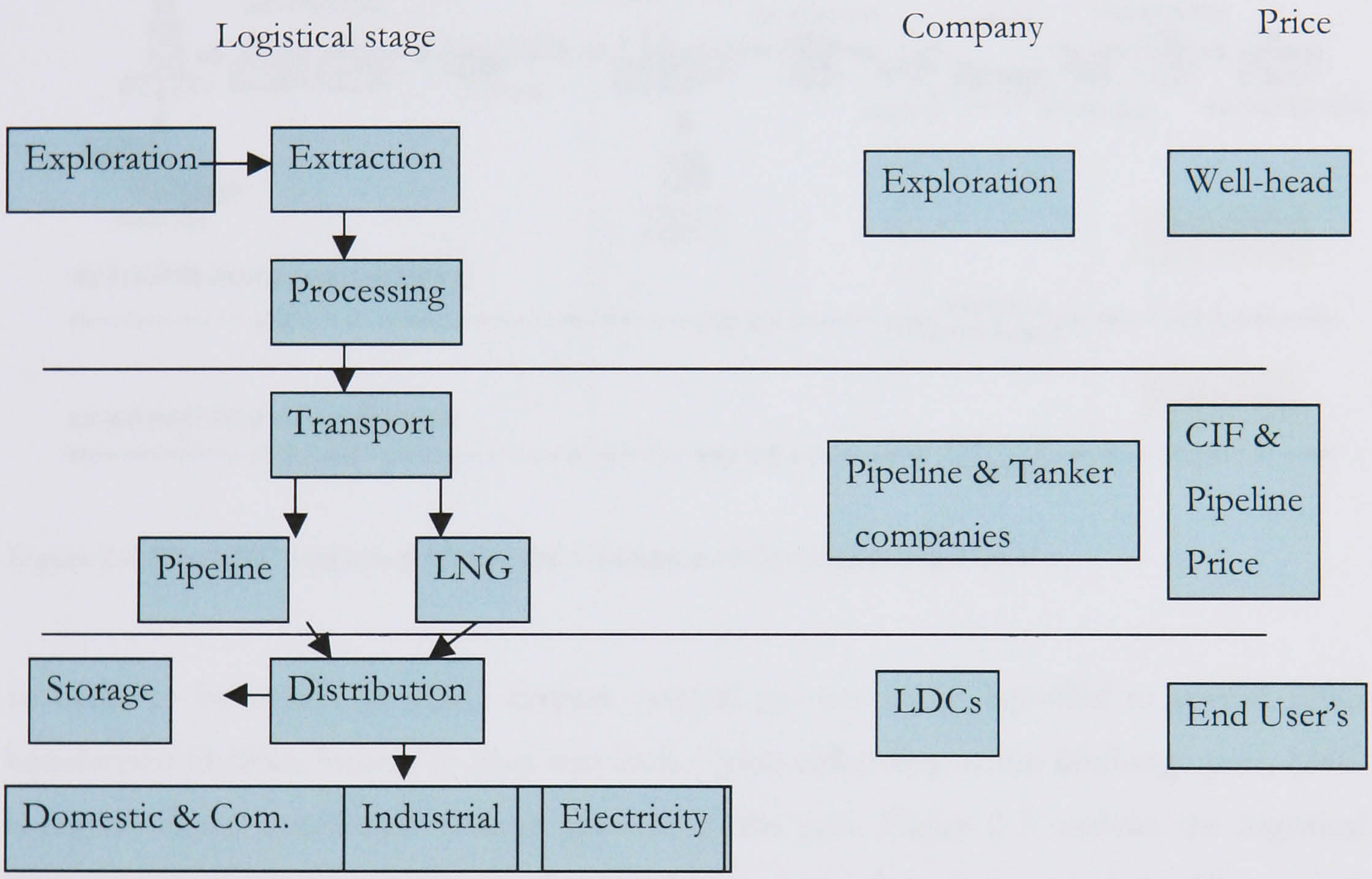


Figure 2-2 Use, Prices and Vertical Structure of the Natural Gas Value Chain[2]

Figure 2-2 shows the logistical chain for natural gas including prices. Throughout the past twenty years, vertical integration of the natural gas market was witnessed, whereby the same

[2] EIA (2004)

companies or alliances (utilities companies) undertake all stages of production and distribution of natural gas. Also, there is a move from oil majors to be involved in the natural gas exploration and trade (EIA 2004).

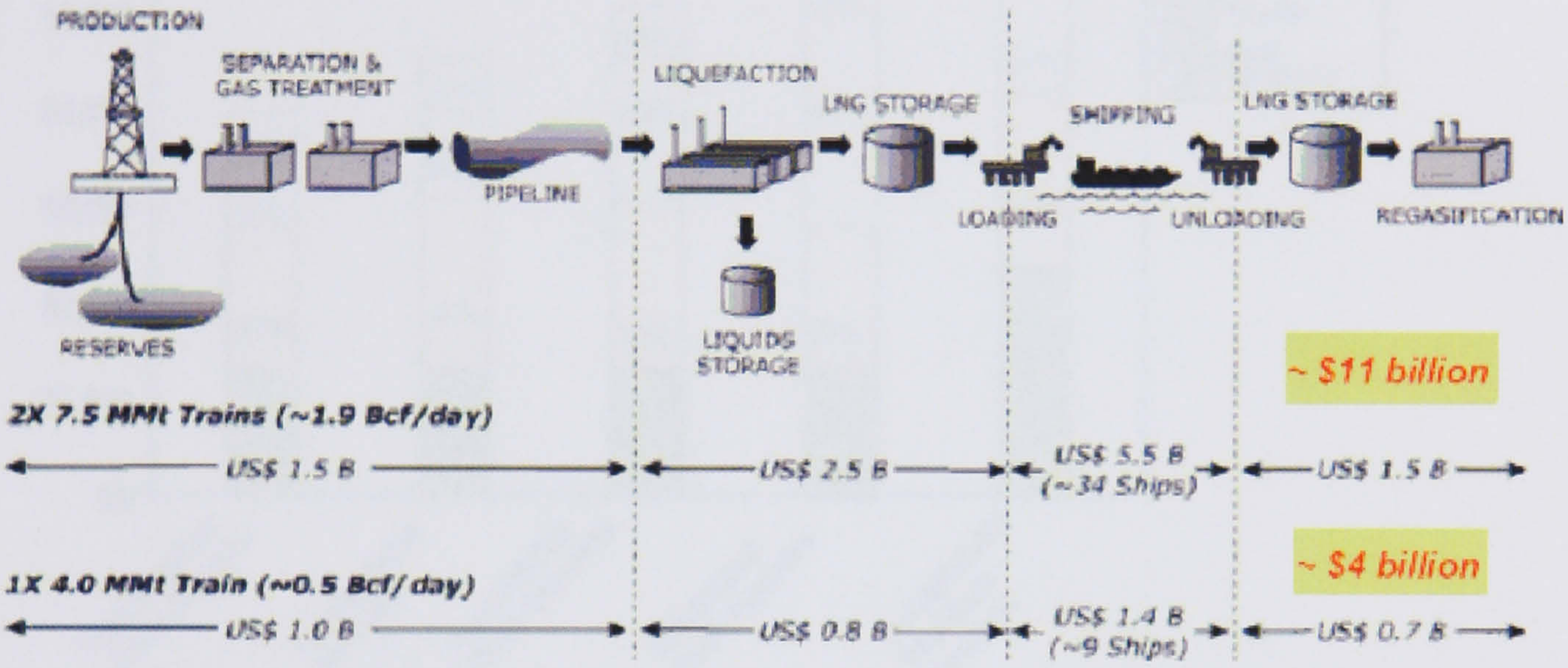


Figure 2-3 The LNG Logistical Chain and Examples of Corresponding Costs[3]

In order to be traded by LNG carriers, natural gas has to be liquefied in special LNG liquefaction facilities located in port terminals. Upon offloading at the discharge port, LNG is regasified and distributed through pipeline to the grid. Figure 2-3 outlines the logistical chain and the typical capital costs of the different parts of the logistical chain. These costs vary from project to project. Figure 2-4, below, shows the cost distribution for the LNG chain.

[3] Total, Presentation in the 2nd Energy Risk Management Seminar, 2004

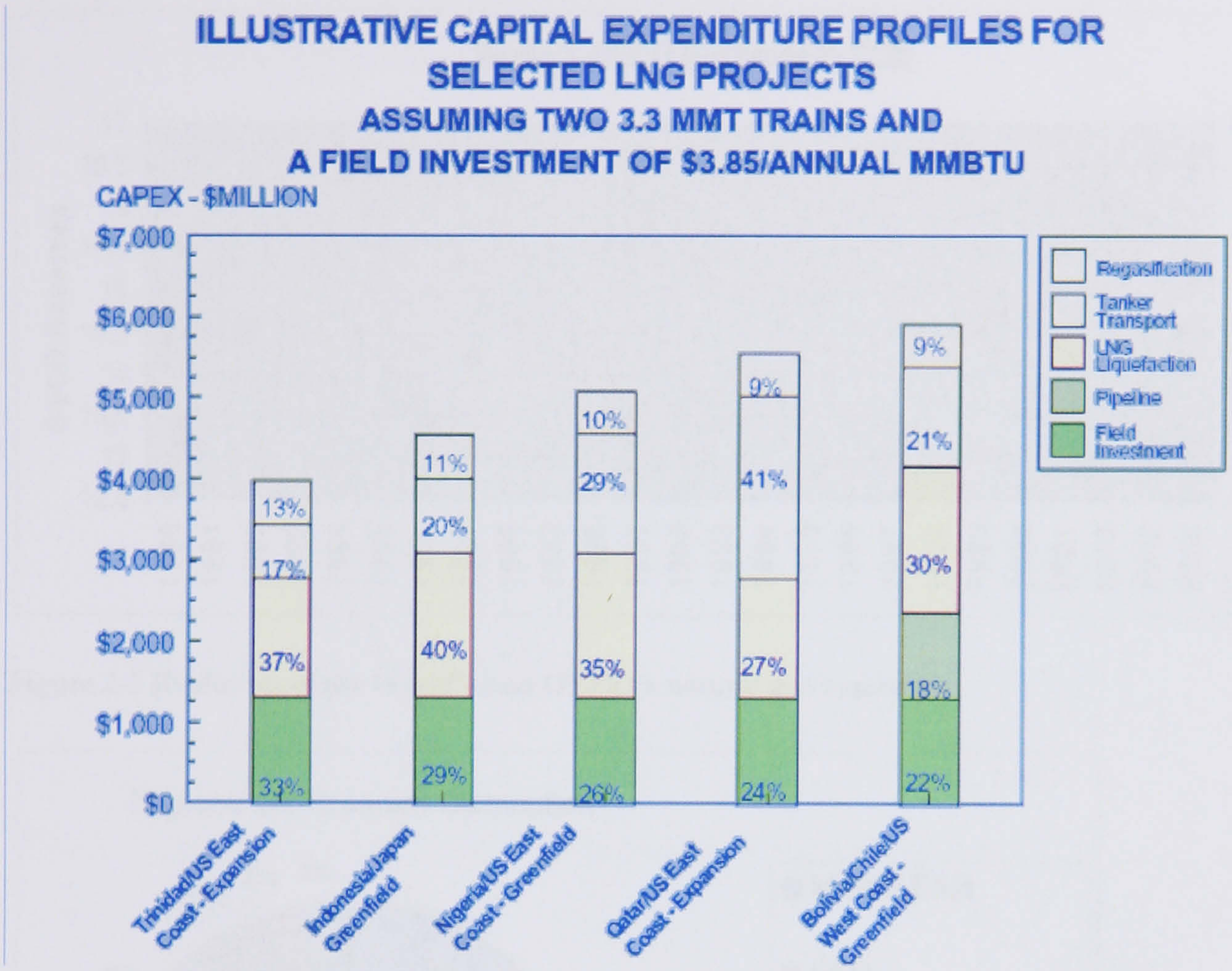


Figure 2-4 Cost Distribution of Different LNG Projects, Jensen (2004)

2.2 Upstream

2.2.1 Reserves

The world proved reserves of natural gas have amounted, at the end of 2004, to 180 trillion cubic meters, translating to an estimated world R/P ratio[4] of 67 years. It is important to note that this ratio is not constant as both the world's production and proved reserves have been increasing at a steady rate since the mid-seventies (Figure 2-5).

[4] R/P stands for Reserves over yearly Production. It is used to quantify the number of years available for a depletable commodity, should production remain constant and reserves and no new reserves or technologies are discovered

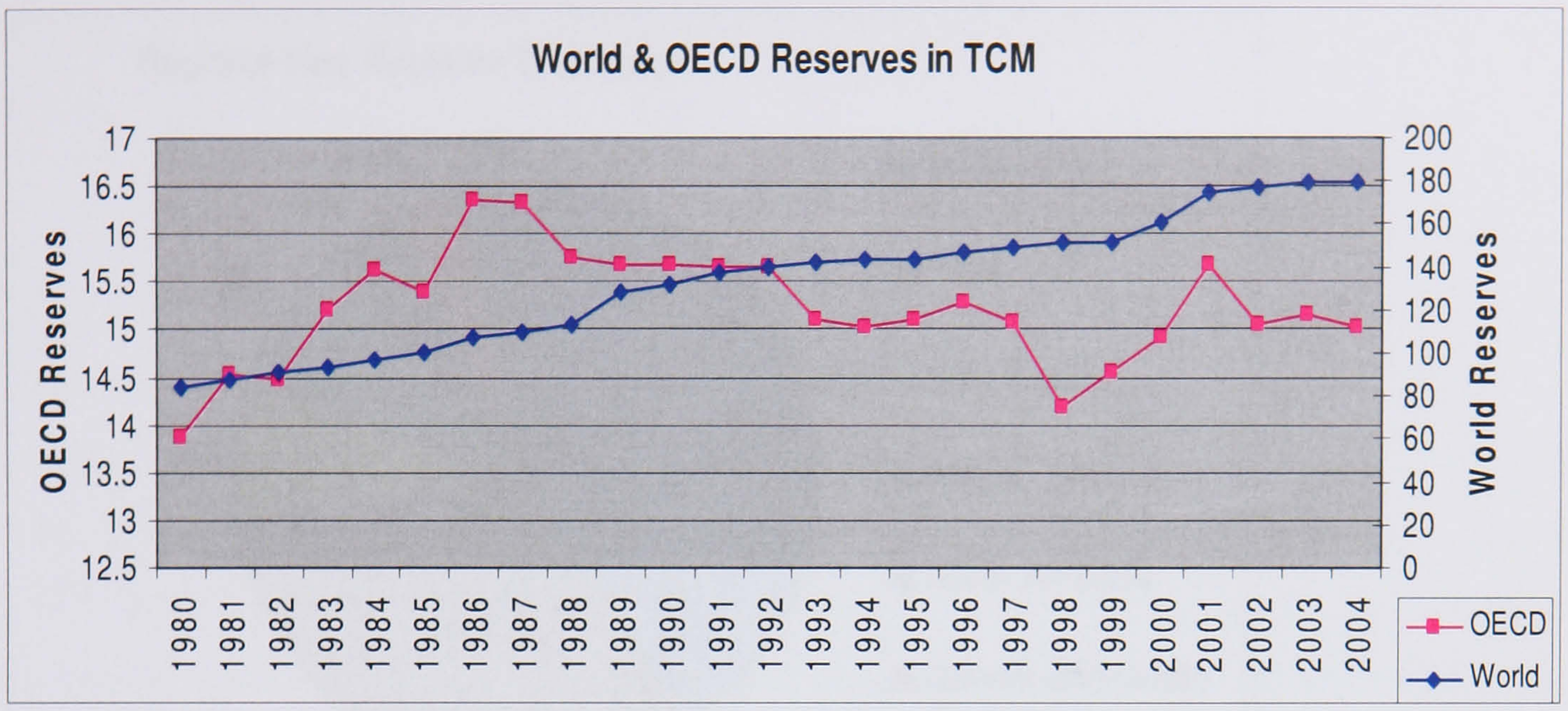
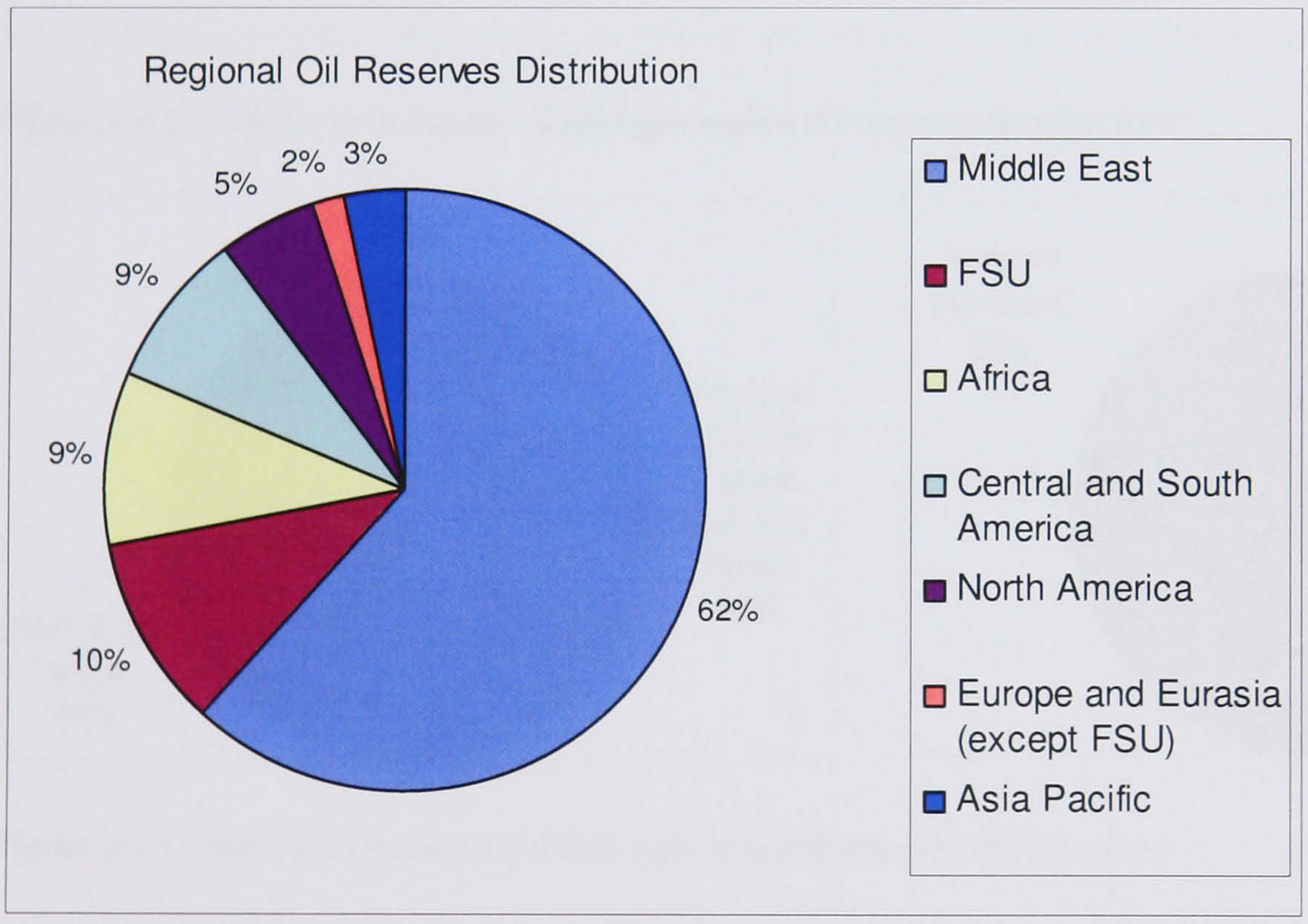


Figure 2-5 Evolution of the World's and OECD's natural gas reserves[5]



[5] BP Statistical Review of World Energy 2005

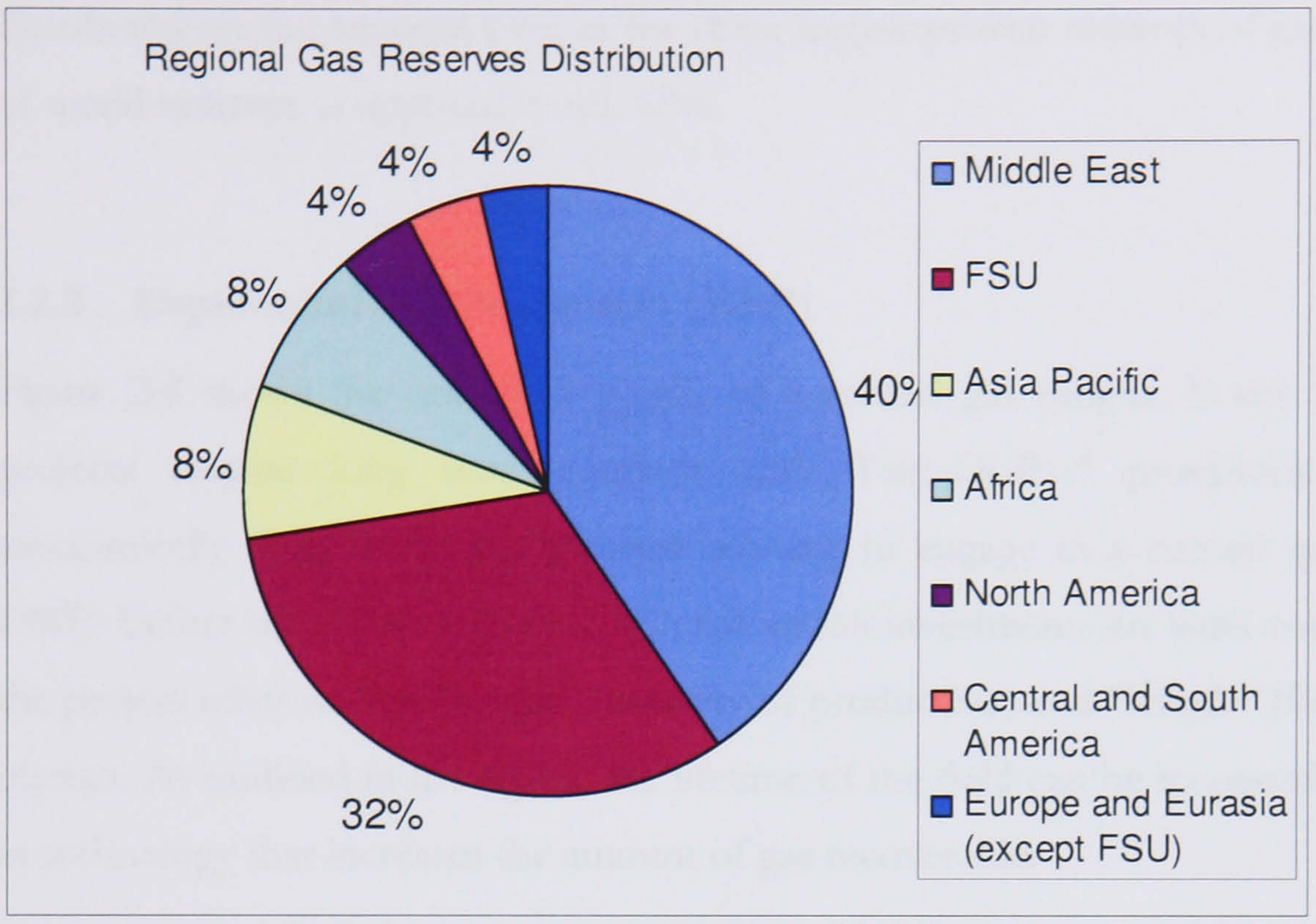
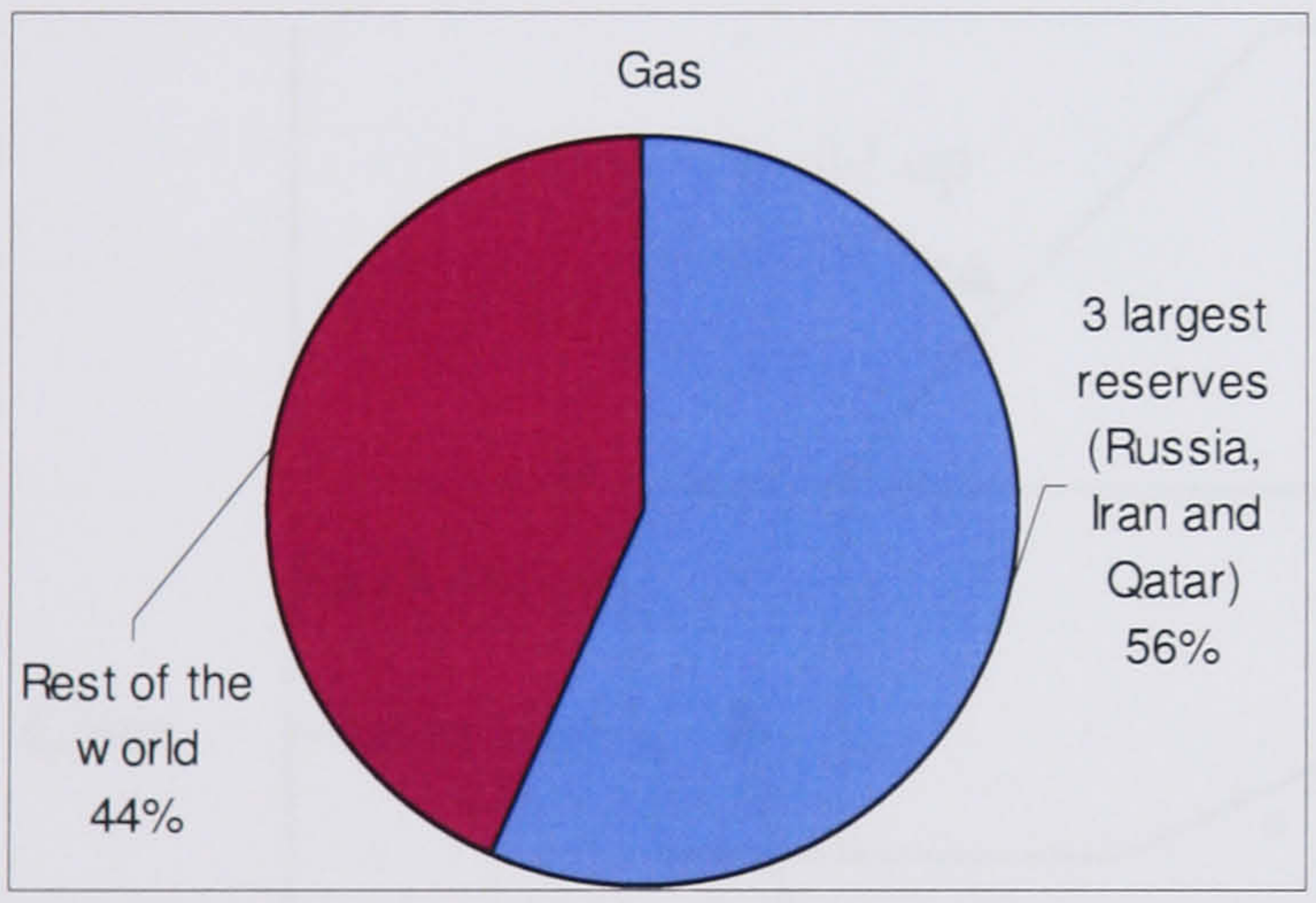


Figure 2-6 Comparison between oil and gas regional reserves distributions[6]



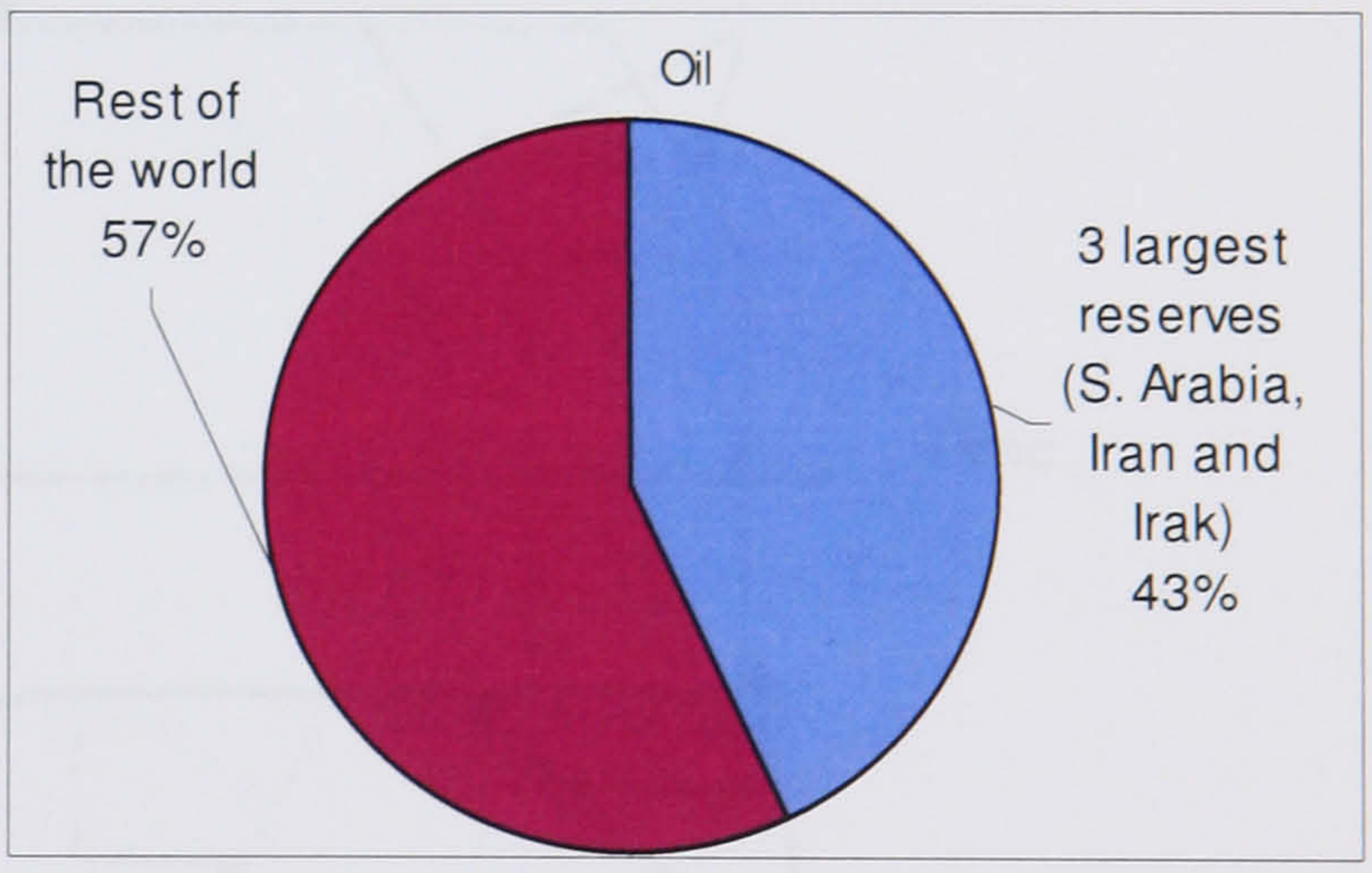


Figure 2-7 Comparison between oil and gas national reserves distribution[7]

An interesting fact about reserves distribution in gas, if compared with oil, is that it is more evenly distributed regionally, as shown by Figure 2-6.Figure 2-7, but it is much less evenly

[6] BP Statistical Review of World Energy (2005)

[7] BP Statistical Review of World Energy (2005)

distributed on the national level as the three largest proven reserves of gas account for 56% of world reserves as apposed to oil, 43%.

2.2.2 Exploration and Production (E&P)

Figure 2-8 shows the cash flow profile of a natural gas project. It can be seen that such projects require long term contract with Take-Or-Pay[8] provisions to make them economically feasible for the investor wishing to engage in a natural gas project (Banks, 1987). Before the investment time, all exploration investments are sunk costs. The success of the project relies on the "height" (capacity of production) and "length" (field lifetime) of the plateau. As outlined in the figure, the lifetime of the field can be increased given investment in technology that increases the amount of gas recoverable.

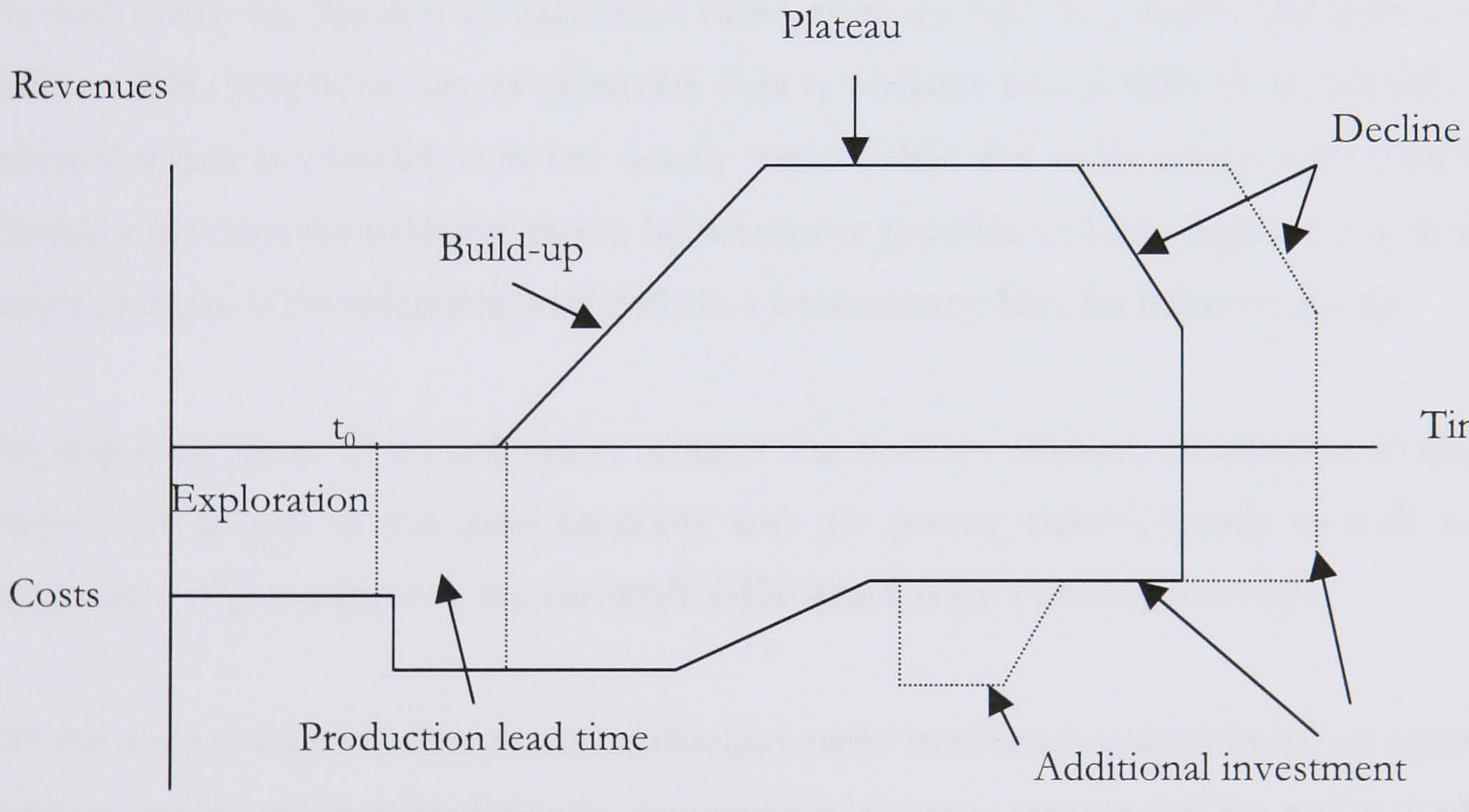


Figure 2-8 Cash flow profile of a natural gas upstream project[9]

[8] ToP provisions require the off-taker of the long term contract to buy a pre-specified percentage of the contract nominal quantity, say 80%, or else to pay for it

[9] Bank (1987)

2.2.3 Elements differentiating suppliers

Due to many logistical, financial and strategic issues, competitiveness in natural gas is different than in oil. This competition is impeded by a number of factors. An important issue to consider is the cost of transportation, especially over long hauls (refer to figure 2-1), as LNG liquefaction terminals are highly capital intensive. Compared to crude oil, LNG carriers are 8 times more expensive to build than crude oil carriers carrying the same amount of energy[10]. This makes CIF[11] prices of LNG highly sensitive to transportation and henceforth to distance. Because of this, the global natural gas market is a quasi-detached one with (Atlantic and Pacific markets are separate).

As with crude oil, the cost of extraction varies from country to country, and indeed from field to field. Very little cost of extraction data is available as it is difficult to quantify and, when this data is available, it is not usually made public due to its competitive sensitivity. Distance between the field and export infrastructure (pipeline or LNG liquefaction) is also a major element of consideration, especially in a large country like, for instance, Russia.

An important issue of consideration remains the reserves amount, production levels, the importance of gas to the local economy and the pricing thereof locally as well as the importance of gas exports to the country's GDP and foreign currency revenues.

On the micro-economic dimension, production varies between countries based on upstream policies and the relationship between the regulator, the government and the national oil/gas company –if such company exists. This factor is further amplified by the creditability of the national oil/gas company and indeed the credit worthiness of the country itself[12].

[10] Source: The US Department of Energy Energy Information Administration

[11] Cost, Insurance and Freight – the cost of gas just before regasification

[12] Boussena (1994)

2.2.4 Main producers

The US is the world's second largest producer with 543 Billion Cubic Meters (BCM) in 2004, amounting to 20% of the world's production, against less than 3% in reserves. The R/P ratio of the US is one of the lowest in the world: 10 years. Canada who produces 183 BCM has an R/P ratio of 9 years.

Russia is the largest producer with 584 BCM in 2004, with the noticeable difference that it has over 80 years of R/P ratio. Other large producers of the Former Soviet Union are Uzbekistan with 56 and Turkmenistan with 55 BCM in 2004.

The EU has a 13 year R/P ratio as it produced 215 BCM in 2004. The European Gas production is dominated by the UK with a 45% share, the Netherlands and Norway with 32% and 37% share, respectively. African production, 145 BCM in 2005, is dominated by Algeria that has a 56% share. Egypt, Nigeria and Libya now have 18%, 14% and 5%.of African production, respectively.

The Middle-East, which is the largest regional single producer of oil, only produces 10% of the world's gas and therefore has an R/P of 264 years. Iran and Qatar, the two main producers of the region, sitting on the world's second and third largest reserves produced over 85 BCM and 39 BCM, respectively, in 2004.

While Asia-Pacific produced 323 BCM in 2004, to which Indonesia contributed 64 BCM, South America has only produced 129 BCM, to which Argentina and Venezuela contributed 37 and 27 BCM.

2.2.5 Main exporters

2.2.5.1 By Pipeline

Due to the more even distribution of reserves of gas if compared to oil, on a regional level, a small proportion only of natural gas is traded, most of which through pipelines, as Figure 2-9 shows.

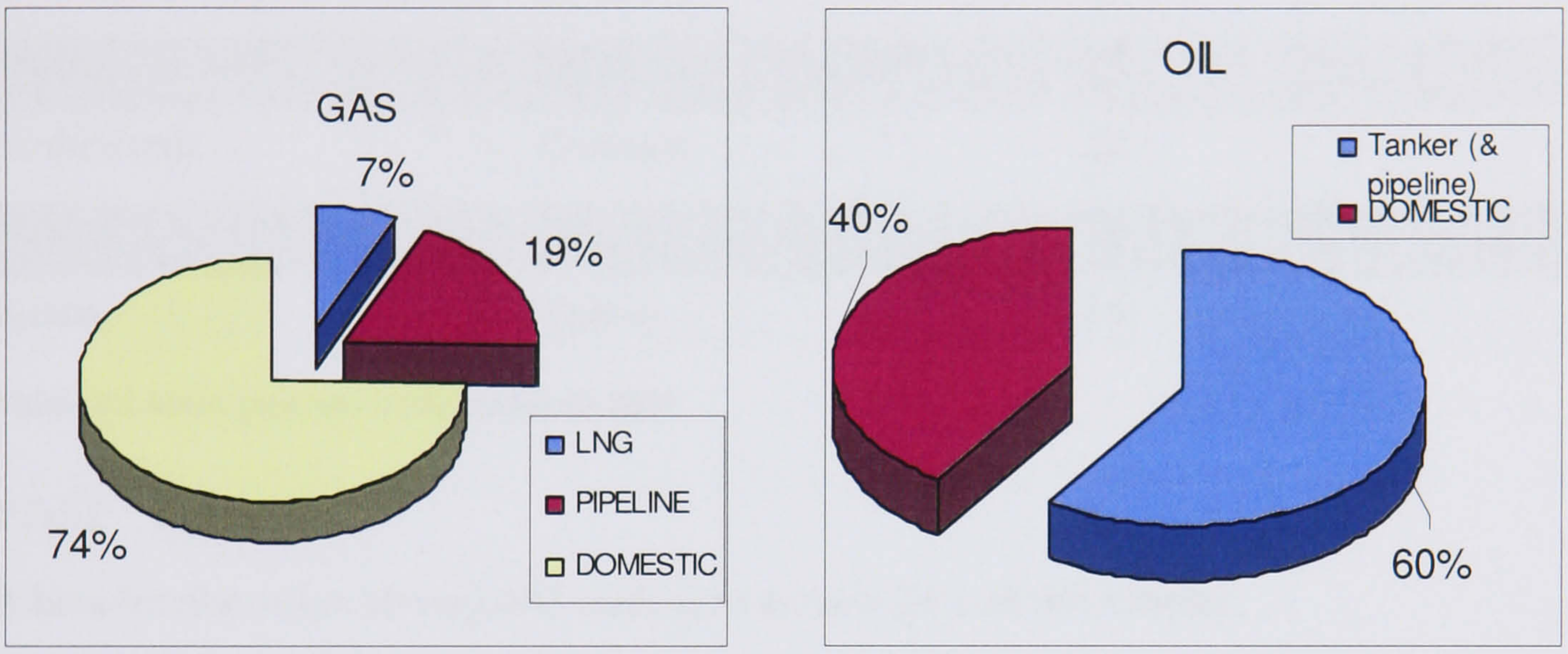


Figure 2-9 Comparison of proportion of gas and oil traded vs. produced

With exports of over 148 BCM in 2004 to most West-European countries (principally France, Germany and Italy), Russia is the world's largest exporter of Natural Gas by pipeline.

Canada is the world's second largest exporter of natural gas by pipeline as it exported over 102 BCM in 2004 to the US. Canada is advantaged as it is the only country with high enough production rates and economically feasible distances from the US, the world's largest market. It is worthwhile noting that Canada also imported 1.78 BCM from the US in 2004.

In Europe, Norway and the Netherlands head the list by supplying, respectively, 49 and 75 BCM of natural gas by pipeline in 2004. Algeria is the world's 5th largest supplier of Natural Gas by pipeline with 35 BCM exported in 2005 principally to Italy and Spain through the

Pedro Durran Farrell and the Enrico Mattei pipelines. Table 2-1 shows the most important pipeline trade routes in 2004.

From	To	Amount (2004, in BCM)
Canada	US	102
Russia	Germany	38
Norway	Germany	26
Algeria	Italy	24
Netherlands	Germany	22
Russia	Italy	21
Russia	Turkey	14

Table 2-1 Main pipeline trade routes in 2004

2.2.5.2 By LNG

A broader discussion about LNG trade is in section 2.6.1 of this chapter.

2.3 Demand side

2.3.1 Use of natural gas, determinants and substitutes

2.3.1.1 Residential use

The operating costs of residential equipment using natural gas are usually lower than those using other primary energy sources. Consequently, natural gas is used in different applications at home, amongst them, cooking and heating.

Residential consumption of Natural Gas is largely affected by weather. In cold weather, consumption of Natural Gas increases for heating uses. In hot weather, demand for natural gas increases through the increase of demand in electricity for cooling (air conditioning). This illustrates the seasonal nature of natural gas demand. Other commercial and residential applications of natural gas and electricity are usually dependant on income and population. It is expected that a so-called "summer peak" will form in gas pricing, as a result of increased usage of gas either directly, or through electricity consumption, driven the usage or air conditioning equipment, particularly in hotter countries.

Natural gas is usually substituted for electricity for both heating and cooking. Refined crude oil (fuel oil) is also used for heating and, in some countries, coal and wood are still used for domestic energy consumption.

An important issue for consideration for a geography-bound infrastructurally-constrained industry like natural gas is the differentiation between demand and consumption. In an infrastructure poor area, there could be demand that does not materialize into consumption. There is therefore econometric evidence suggesting a granger-causality relationship between new capacity and consumption[13].

2.3.1.2 Commercial

Natural gas is also used in the hotel, office building and healthcare industries for cooling and heating. The determinants of such demand are similar to those mentioned in the previous section of residential uses.

2.3.1.3 Industrial

"Natural gas is used as an input to manufacture pulp and paper, metals, chemicals, stone, clay, glass, and to process certain foods. Gas is also used to treat waste materials, for incineration, drying, dehumidification, heating and cooling, and cogeneration."[14] The demand for natural gas also increases with the demand of end products (pulp, paper, metals...etc), in which NG enters as an input.

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[13] Hallouche & Tamvakis, Presentation at the Second Energy Risk Management Seminar (2004)

[14] Source: UNCTAD

2.3.1.4 Power generation

An increasing number of electric utilities use natural gas as it enables them to have (i) a lower cost of capital, (ii) faster set up, (iii) a more efficient production and (vi) less pollution in emissions. Increase for demand in Electricity, usually provoked by higher economic welfare or higher industrial activity, increases demand for natural gas. Power generation consumption is characterised by step-changes due to the entry in operation of gas-powered generators. Chapter 4 in this thesis shall discuss this further.

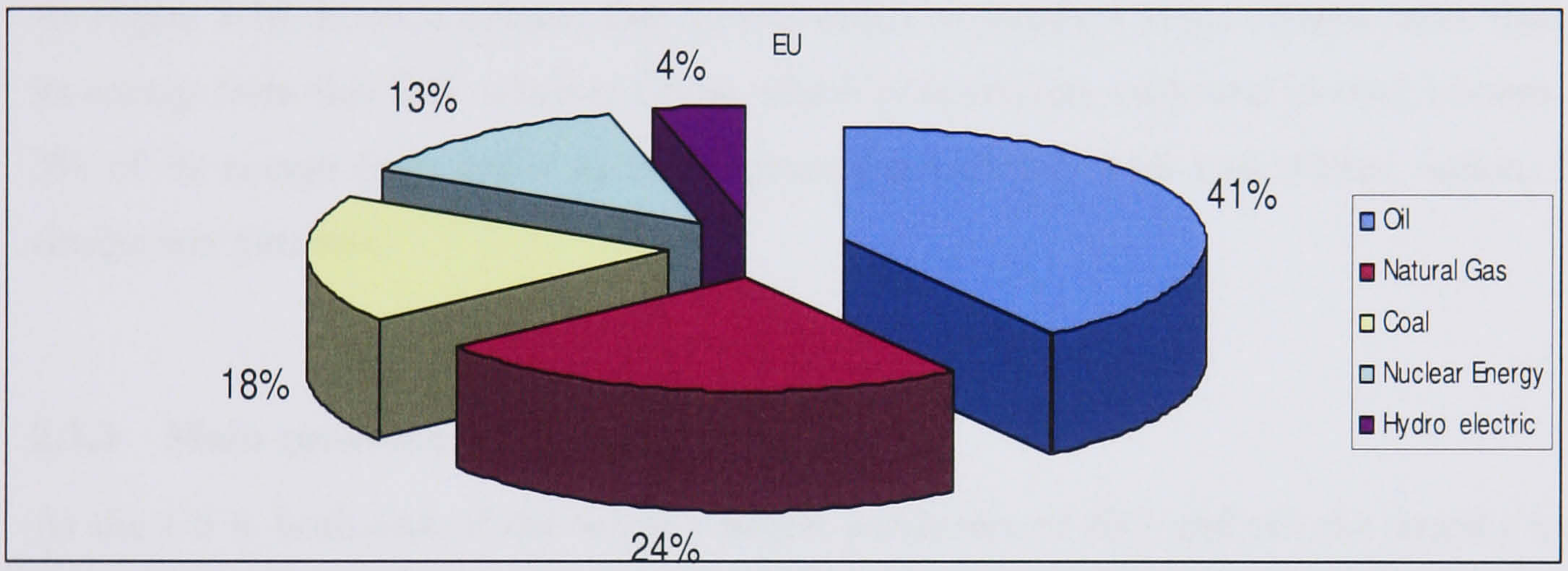
Natural gas competes with coal and nuclear energy in the power generation sector. The former has been constrained due to its polluting nature but with the emergence of new clean coal power generation technologies, it is deemed to continue to play an important role in the power generation sector. In the face of security of supply, reduced cost and environmental friendliness, nuclear is being more actively considered by policy makers, but is facing political hostility in some countries, due to the potentially hazardous and dangerous fuel, production and wastes disposal processes.

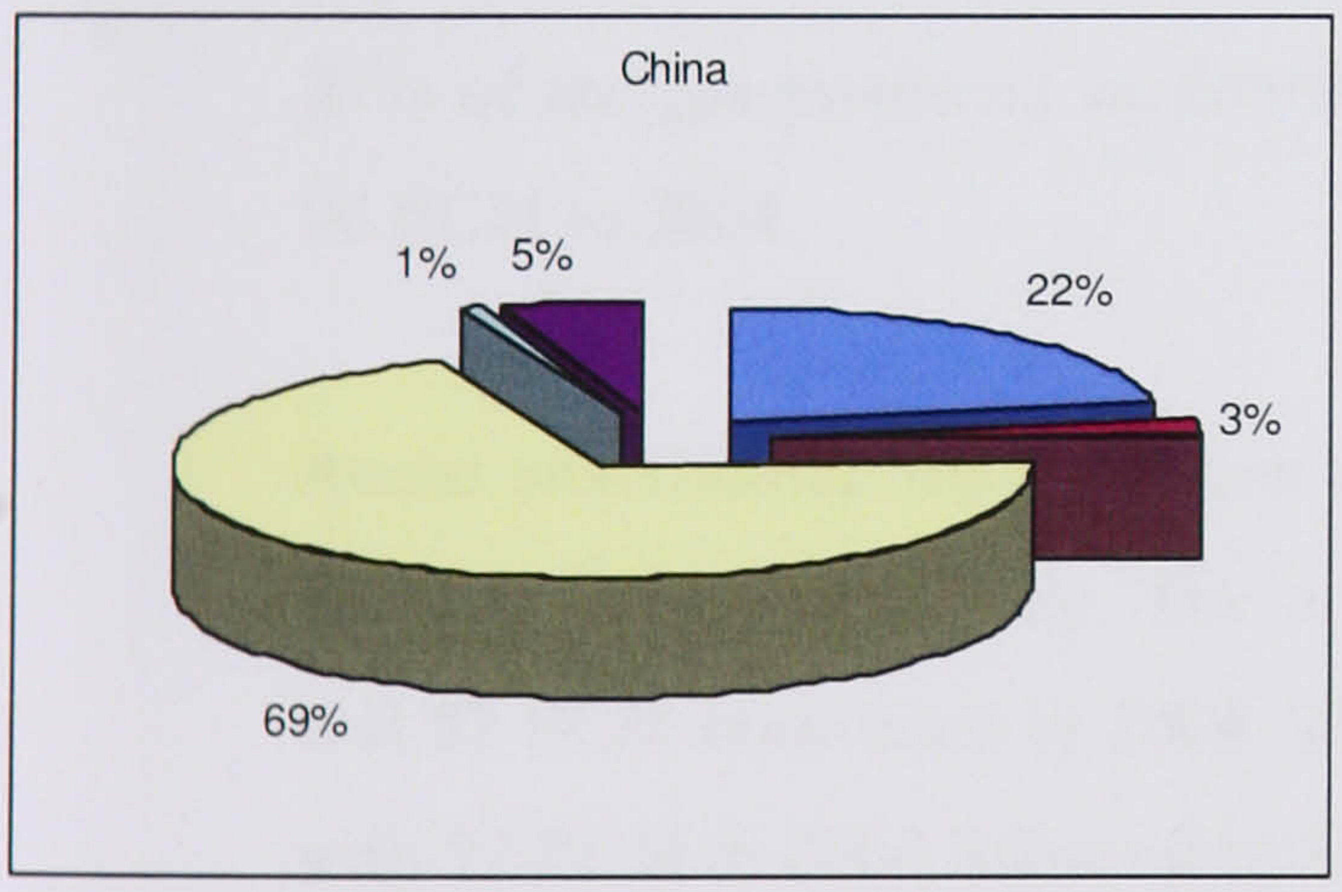
2.3.1.5 Transportation

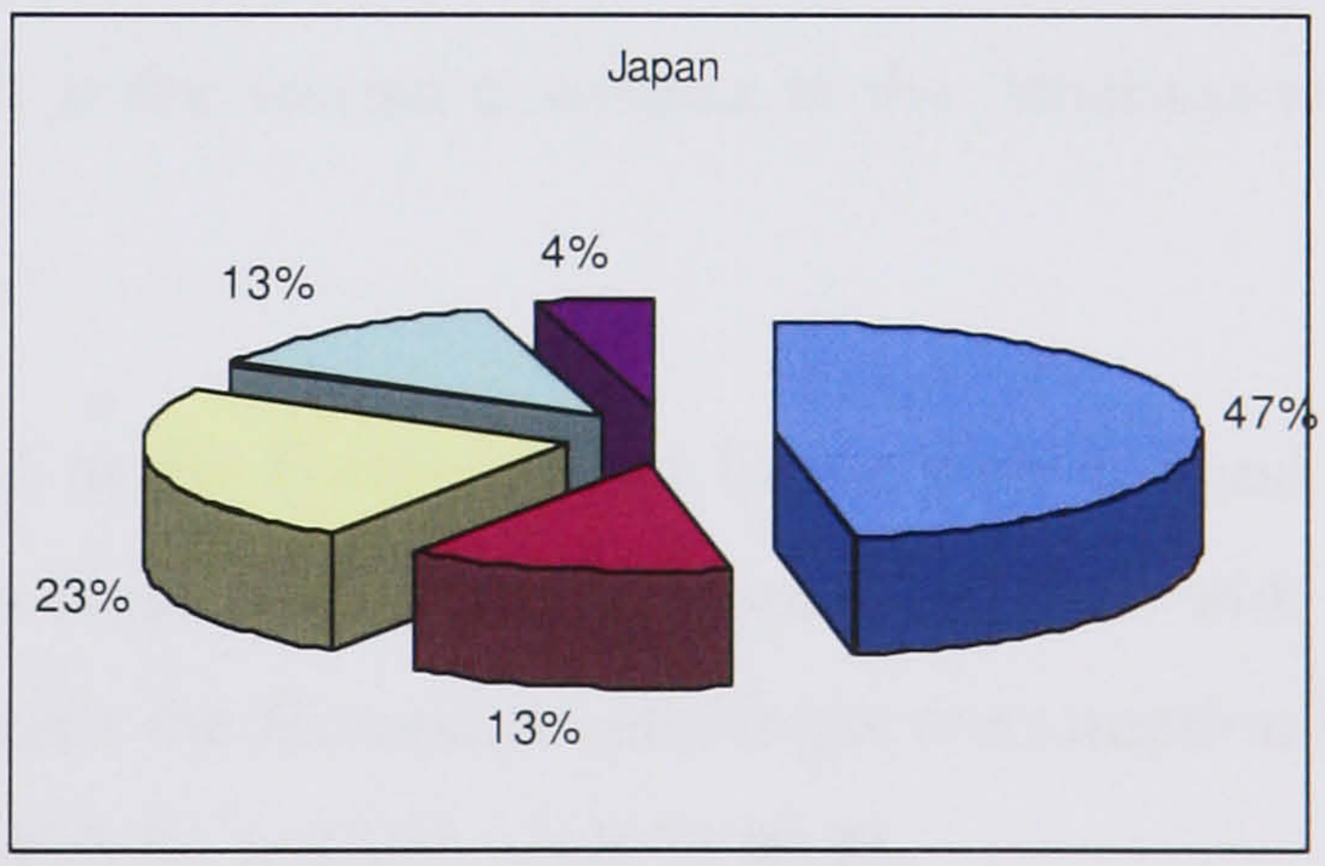
The usage of natural gas for transportation only represents a minute proportion as oil accounts for almost the totality of primary energy consumed in this sector. However there are available technologies. According to the International Natural Gas Vehicles (NGV) Association, the world's fleet for Natural Gas Vehicles accounts for half a million cars and increasing. This is due to the rising environmental concerns and the efficiency of natural gas as a fuel. Natural gas is also used as input for Gas-to-Liquid which has similar properties to refined crude oil products. There has been strong interest for GTL in some producing countries like Qatar and Algeria.

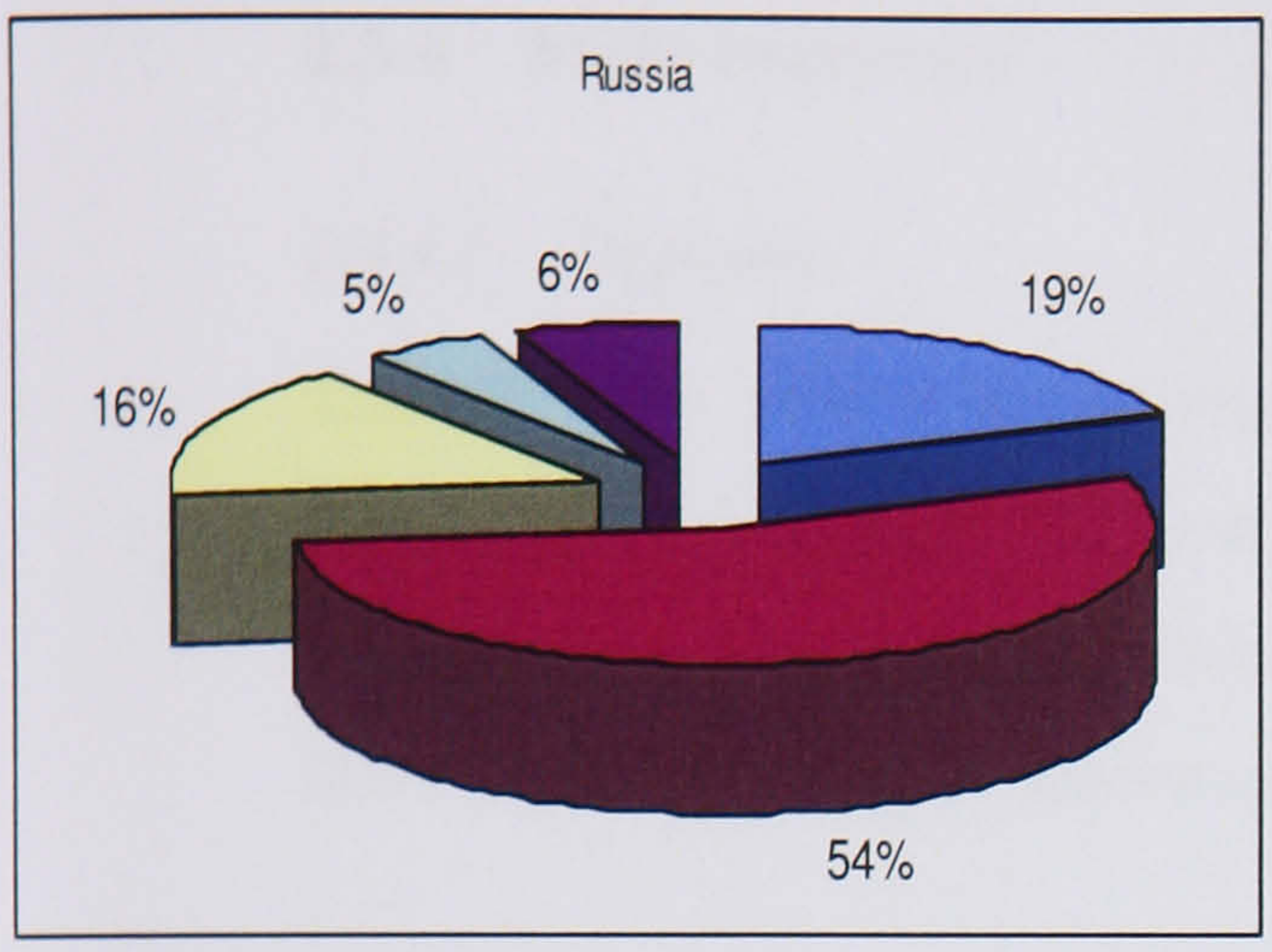
2.3.2 Tastes and Primary Energy Consumption Mixes

Different countries have different tastes in terms of their primary energy mix. The mix largely depends on their national resources endowment and their ability to import fuels from neighboring countries, which proxies the cost. It also reflects their national policy in terms of environment and market liberalization. Further, oil consumption is usually higher with high usage of transportation which is usually an attribute of countries with low population density (more transportation needed).









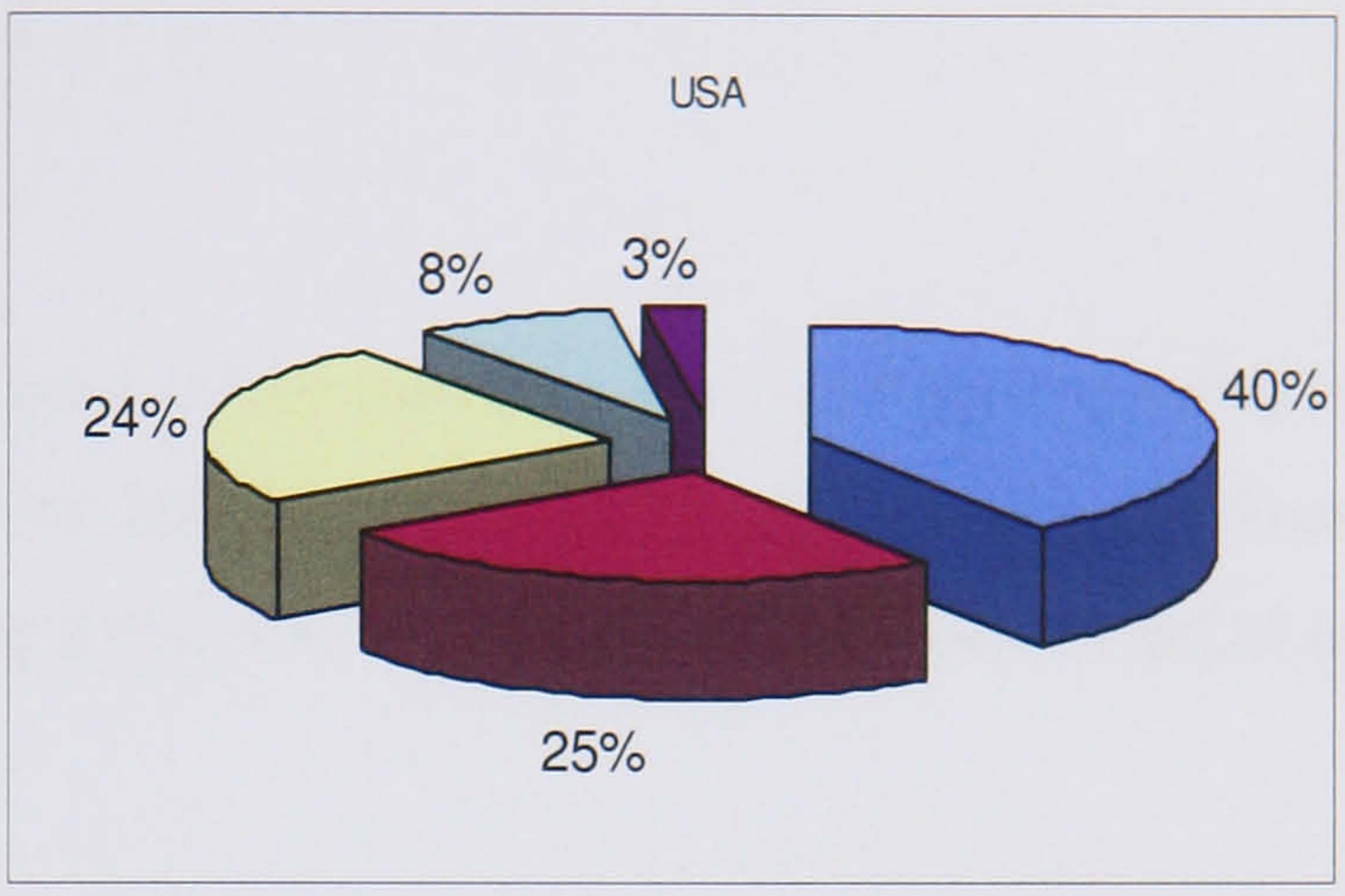


Figure 2-10 Primary Energy Mix for the EU, Russia, China, Japan and the US -2004[15]

As Figure 2-10 shows, a country like Russia, which is abundant in gas obtains more than half its energy from this fuel, whereas China, which is favourably endowed in coal, obtains only 3% of its energy from gas – as it competes quasi-directly with coal. Other regions have similar mix patterns.

2.3.3 Main consumers

As the US is both one of the world's largest producers of NG and yet the world's largest importer, it is therefore the world's largest consumer. Indeed, the US consumes more than 27% of the gas produced worldwide. Canada is the second consumer in the Americas with 90 BCM in 2004.

Russia and Ukraine are the largest consumers in the Former Soviet Union with 402 and 71 BCM in 2004, respectively. The other Asian major consumers are Japan and Iran with 72 and 87 BCM consumed in 2004. The UK heads the European natural gas consumption list with 92 BCM in 2004 followed by Germany with 86 and Italy with 73 BCM.

[15] BP Statistical Review of World Energy (2004)

2.3.4 Main importers

2.3.4.1 By pipeline

The US is the world's largest importer of natural gas by pipeline. Their principal supplier in this category is Canada. Germany imported in 2004 92 BCM by pipeline principally from Russia, Norway and the Netherlands. The third importer by pipeline is Italy with 61 BCM in 2004 supplied mainly by Russia and Algeria.

2.3.4.2 By LNG

A broader discussion about LNG trade is in section 2.6 of this chapter.

2.4 Industry and Regulation

2.4.1 Policy

2.4.1.1 Deregulation

Being considered as a strategic commodity, the natural gas industry –as indeed many other energy commodities- has always been controlled by the state and not by market forces. There have been trends in the past years, both by developed and developing countries, for a move towards market liberalisation of the natural gas industry.

In effect, the Natural Gas Policy Act of 1978 in the US has totally deregulated the market in that country. Further, in 1992, The Federal Energy Regulatory Commission required pipeline companies to unbundle their transportation, sales and storage services[16].

[16] EIA (2004)

The EU on the other hand is still behind the US in terms of deregulation. The first and second gas directives are in the process of being implemented (more details on the regulatory framework of the European Union in chapter 3). Deregulation and market liberalization are also gradually being implemented in Korea and Japan, who are major LNG importers.

2.4.1.2 *Security of supply*

As mentioned above, security of supply's importance in energy policy has been growing particularly in the EU with the publication of the so-called Green Paper on Energy by the EU Commission and the Natural Gas Security of Supply Directive which calls upon Member States to have contingency plans for their natural gas procurements through the usage of storage and the diversification of partners. For example, it is a legal requirement in Spain that no single supplier can account for more than 60% of the Spanish market.

2.4.1.3 *Environment*

Natural gas is always favoured as a means of diversifying energy resources because of its cleaner emissions. Several regional or international agreements and organizations try to promote this. The Kyoto protocol, which has just come into force, provides that signatories reduce their carbon emissions so as to reach an agreed-upon level. These changes are implemented on the micro-level as companies are now able to purchase allowances for carbon and trade them on the EU Emission Trading Scheme. The Energy Charter and the Energy Services treatment with the WTO are also some other important international energy related treaties.

2.4.2 Downstream industry structure

As discussed above, currently, there is a trend to moving from a monopolistic natural gas market towards the deregulation of it. Natural gas exploration, transport and distribution suffer, at their infant stage, high marginal costs due to high capital expenditure and technical risk. However, as projects progress towards maturity, capital outlays are depreciated and technical risks are lower. The IEA (2004) has identified the following steps of market deregulation:

2.4.2.1 Pipeline-to-pipeline competition

That is the environment emerging from the competition between two or more pipeline companies for the local market. Although supplies are usually organized in long term contracts, the threat of the construction of a new pipeline will impose competitive pressures on the current suppliers and would naturally regulate the prices.

2.4.2.2 Wholesale or bulk market competition

In this step of deregulation, non-discriminatory third party access to the high-pressure transmission system is mandatory and transportation services are unbundled.

2.4.2.3 Full retail competition

Mandatory third-party access is expanded to cover distribution networks and high-pressure transmission system. All gas price controls are removed.

2.5 Markets

2.5.1 Pricing

The lack of uniformity in the world's natural gas pricing is due to the presence of several sub-markets, segmented regionally and nationally. Also it is due to the regulatory framework imposed both on natural gas exploration, transport and distribution. The lack of transparency resulting therefrom, and to the long-term nature of natural gas contracts, both at the exploration and distribution levels are also factors affecting the pricing of natural gas. Logistically, it is also due to the fact that NG is difficult to transport and store, which reduces significantly the scope for arbitrage between sub-markets.

In the US, a fairly liberalized gas market, the end-user price of natural gas (i.e. the price to the end consumer) was broken down as in Figure 2-11. It can be seen that the price depends more on distribution expenses, then on the well-head price and finally on transportation prices. Figure 2-12 shows the differences between prices charged for different needs (e.g. commercial, industrial, domestic or power generation).

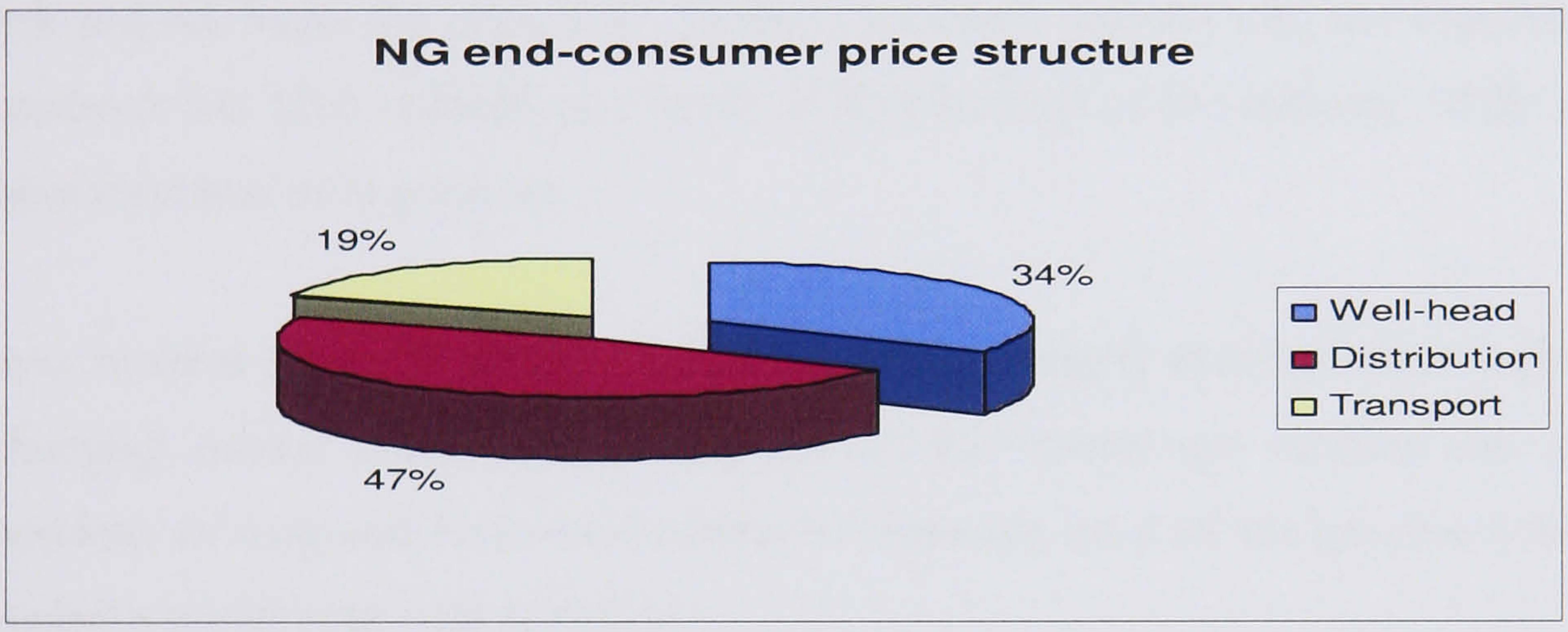


Figure 2-11 End user price decomposition in the US in 2004[17]

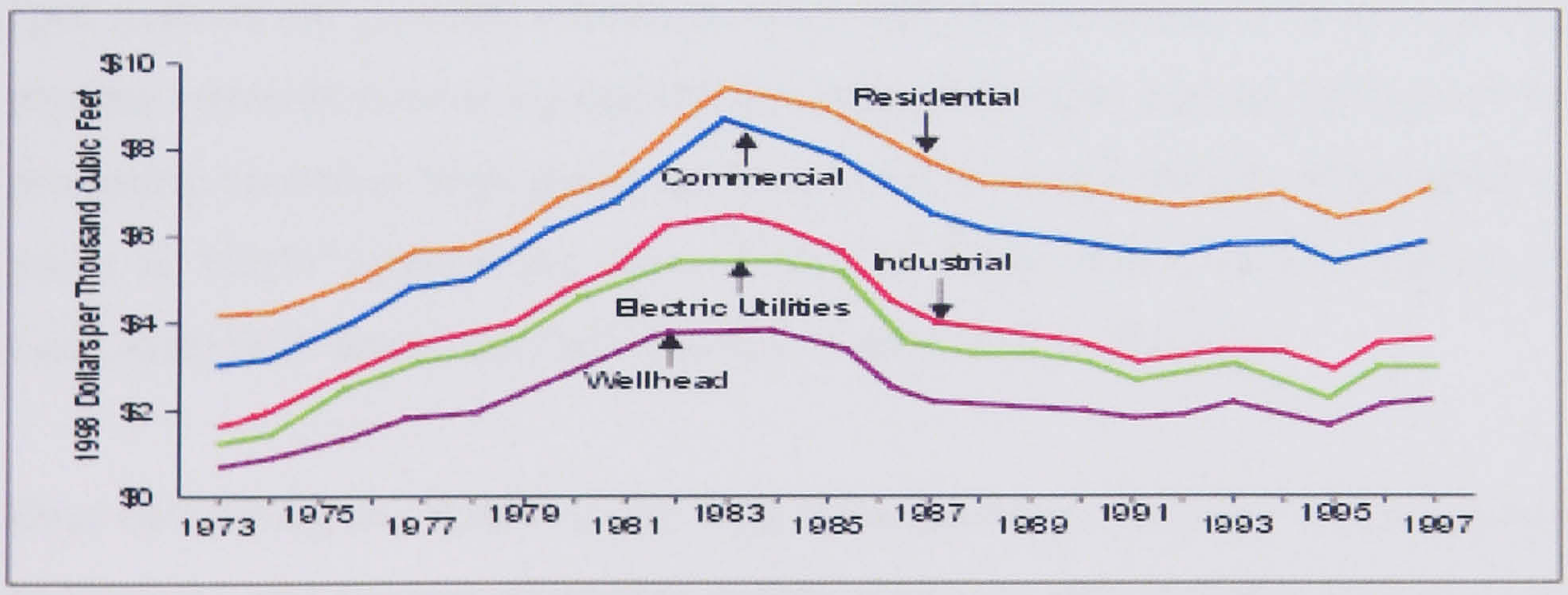


Figure 2-12 Gas price movements in different consuming sectors in the US[18]

[17] EIA (2004)

A more specific discussion on natural gas pricing on the international trade level is available in chapter 3 with special focus on the studied markets.

2.5.2 Contracts & Spot trade

Traditionally, natural gas contracts were long-term contracts between integrated natural gas companies and users, with fixed prices, reduced supply and price risks and little flexibility. The principle around which contracts were agreed was that "the supplier takes the volume risk and the buyer the price risk". In the US, Canada and the UK, the importance of these contracts has been reduced as a result of liberalization of the industry, while spot markets have increased their presence.

Spot markets allow for greater flexibility to balance supply and demand in order to react to changing market conditions. Participants in the natural gas markets can then form a portfolio of long and short-term contracts. However, most of the gas that is internationally traded is under long-term contracts.

Spot markets are generally created in areas with concentration of buyers and sellers such as pipeline interconnections located close to large consuming regions, or major terminals of gas producing countries. Spot prices are then set at various locations. Main references for spot prices in North America are: New York City Gate, Henry Hub Louisiana, Chicago City Gate, Katy Hub Texas, So. Calif. Border or AECO Hub (Canada).

Data concerning the terms of the long terms contracts between countries, quantities sold and prices –and pricing structures- agreed upon are almost impossible to obtain officially,

[18] EIA (2004)

due to confidentiality. More details on the European Natural Gas Long Term Contacts can be found in chapter 3.

2.5.3 Derivative or paper markets

When there is an actively traded spot market, price volatility, a mature pipeline infrastructure and possibilities for storage, there emerges the potential for a derivatives market. Below are examples of derivatives natural gas markets.

- Henry Hub (in Nymex): Nymex launched the world's first natural gas futures contract in April 1990. Options on natural gas futures were launched in October 1992.
- IPE (now renamed ICE) Gas Contract is traded in the London International Petroleum Exchange, for delivery to the National Balancing Point (NBP)
- The Inter-continental exchange: The Intercontinental Exchange is an Internet-based marketplace for the trading of over-the-counter energy. It represents the partnership of world leading financial institutions with some of the world's largest diversified energy and natural resource firms.
- The natural gas exchange: NGX, located in Calgary, Canada, provides electronic trading and clearing services to natural gas buyers and sellers in Alberta, one of the largest and most significant production areas of natural gas in North America. Since its inception in 1995, NGX has grown to serve over 120 customers with trading activity averaging 200 BCF (211 000 TJ) per month
- Altra Market place: Formerly known as Altrade™, it offers real-time online electronic trading for energy commodities where traders actively view and exchange bids and offers quickly and anonymously. It is accessible 24 hours a day, seven days a week.
- Kansas City Board of trade Gas Contract

The rationale behind Long Term Contracts, as illustrated by Neuhoff & von Hirchhausen (2005), outlines three schools of thoughts: The institutional economics literature interprets them as a tool to avoid opportunistic risk taking in high sunk cost investment industries, advocated by Klein et al (1987), Williamson (1985) and others; The industrial organisation theory, which looks at the strategic value of long term contracts, advocated by Parsons (1989) and others; The infrastructure investment literature, advocated by Oren (2003), which looks at the risk sharing along the logistical chain and how this risk balance can be disturbed under a scenario of supply chain desaggregation.

2.6 Discussion around the World's LNG market

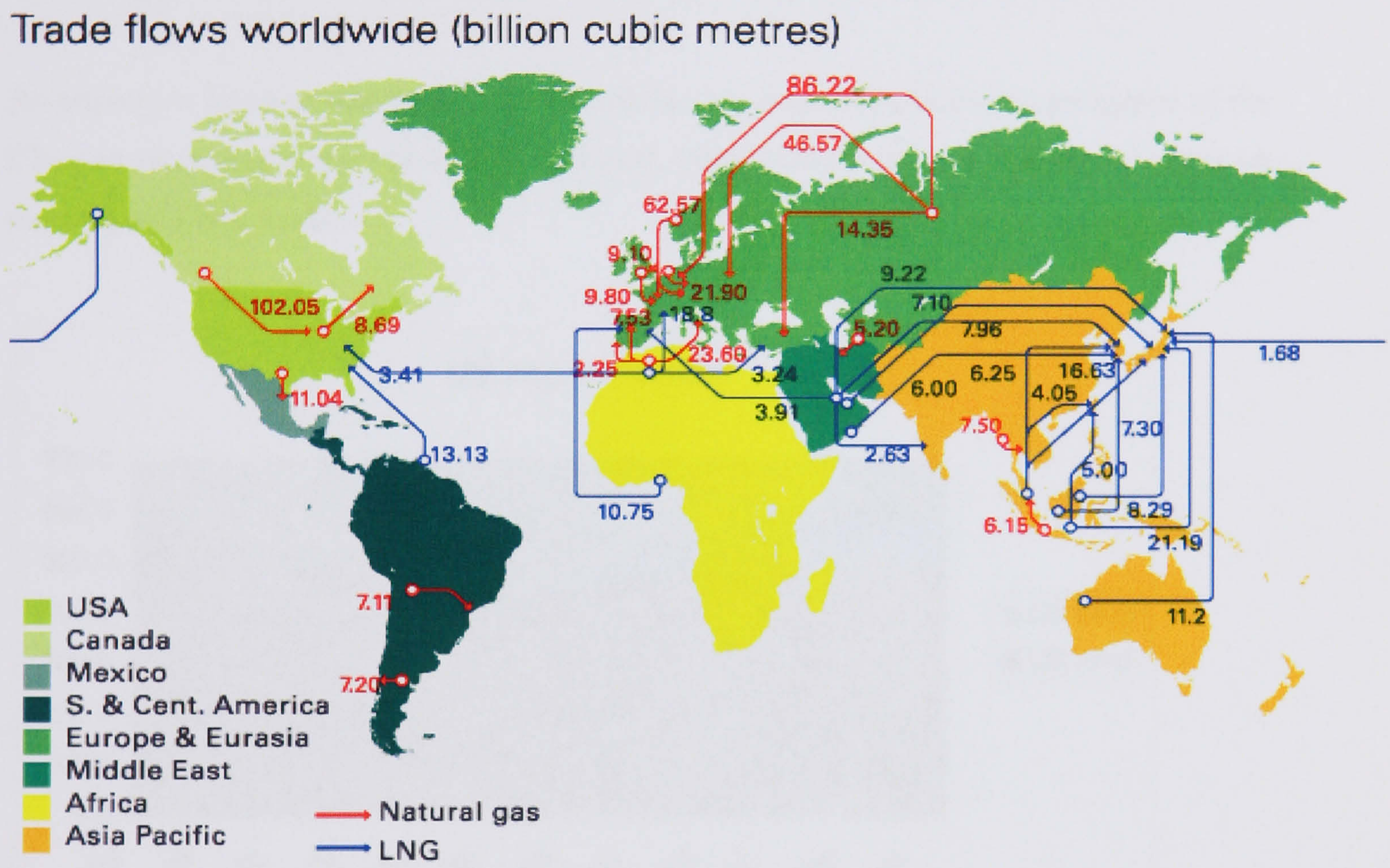


Figure 2-13 Snapshot of natural gas and LNG trade flows around the world – 2004[19]

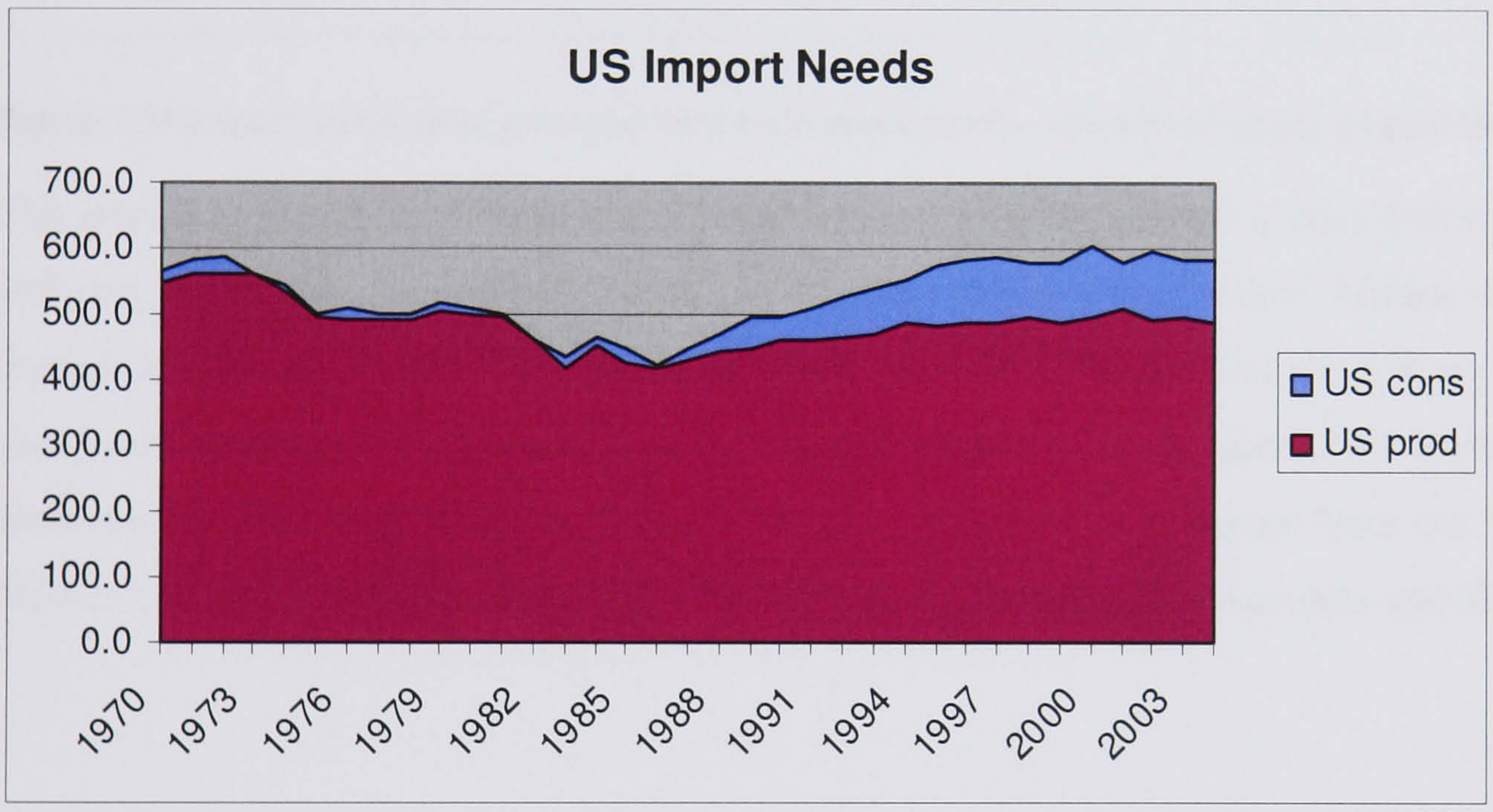
As mentioned before, only a small proportion of natural gas is traded, and only a small proportion of that is traded as LNG. As consumption has been growing, domestic production in consuming markets declining, and pipeline opportunities are limited, LNG trade has been growing fast.

[19] Source: BP Statistical Review of World Energy

Pictures of LNG export and import terminals are available in Appendix 2.

Figure 2-13 shows that the pipeline market is local and the LNG market sub-regional. Two almost distinct markets, the Atlantic and the Pacific, can be distinguished. As mentioned above (Figure 2-9) due to its cost implications, natural gas is not as actively traded as oil.

An important development in the Atlantic market has been the continued emergence of the US as an increasingly important LNG importer, which is likely to have a profound effect on the Atlantic LNG market.



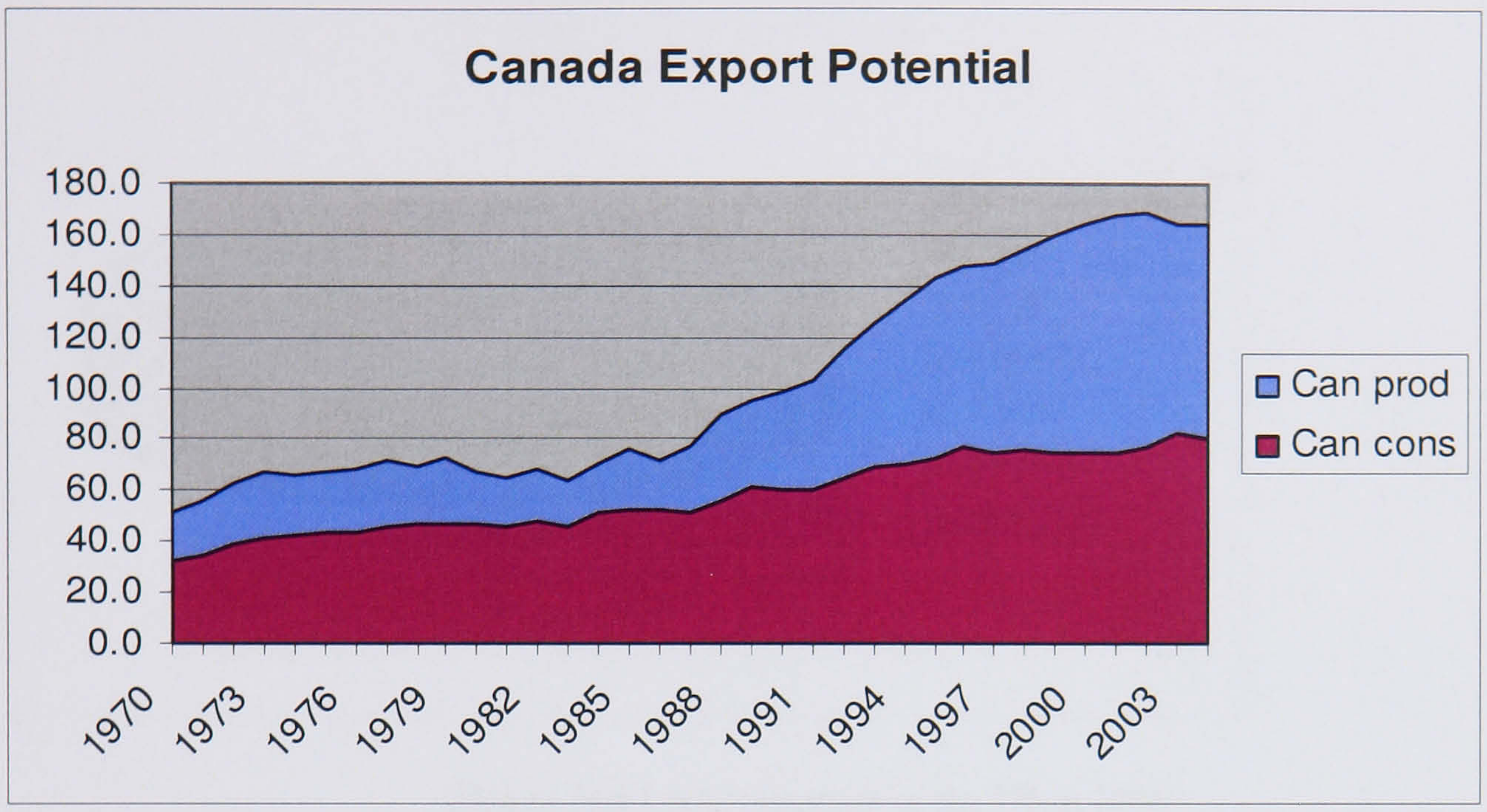


Figure 2-14 Import and Export potential for the US and Canada - the widening gap (figured in BCM)[20]

The graphs in Figure 2-14 show that US production is stabilising and consumption growing and that the export potential of Canada by pipeline is becoming limited. Unless there is a decline in consumption or an increase in production, LNG imports to the US are likely to rise. In the meantime, the US has been the strongest driver of short-term LNG trade in 2004 from the suppliers highlighted in Figure 2-15. Although most of them are from the "Atlantic Market", some of them are also players from the pacific market (like Australia and Malaysia).

[20] BP Statistical Review of World Energy (2004)

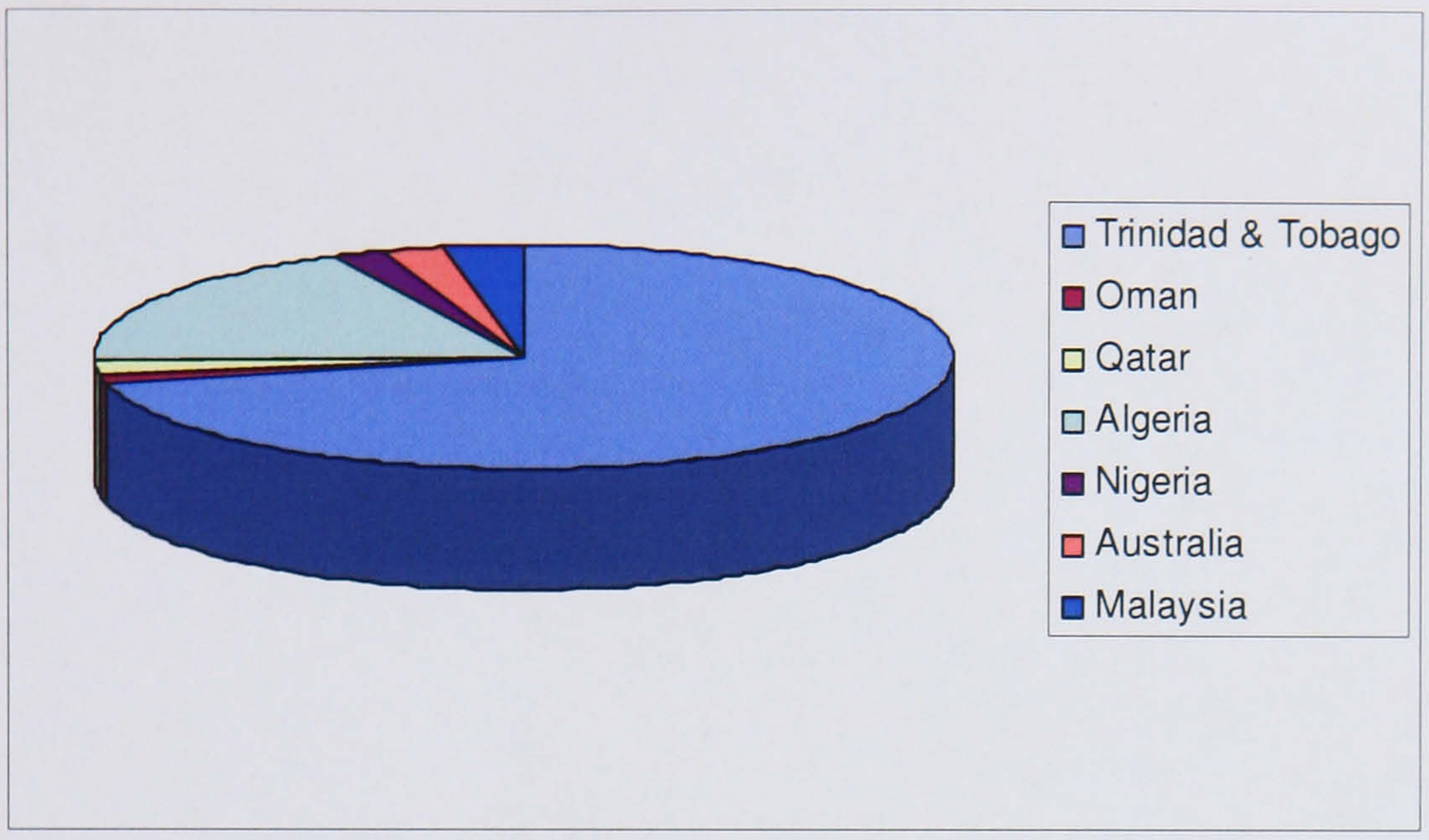


Figure 2-15 LNG exporters to the US in 2004[21]

The US has one export terminal in Alaska that supplies Japan. It also has 4 LNG import terminals. Due to institutional changes in the 1980s, these terminals were shut down as LNG lost its competitiveness[22]. The new emergence of the US market has made LNG attractive again and as figure 2-18 shows, there is a number of LNG regasification plants proposed, planned or under construction in both the East Coast (Atlantic market) and the west coast (Pacific market). Not all of them will eventually be built, but the US is nonetheless expected to become an important LNG market player. It is worth noting that the LNG terminal construction has faced fierce opposition by local groups amid fears of safety. The so-called NIMBY (Not In My BackYard) attitude is representing an important impediment to regasification terminals procedures.

[21] BP Statistical Review of World Energy (2004)

[22] Ali Hached, Vice President of Sonatrach discussion, Port of Spain, 2005

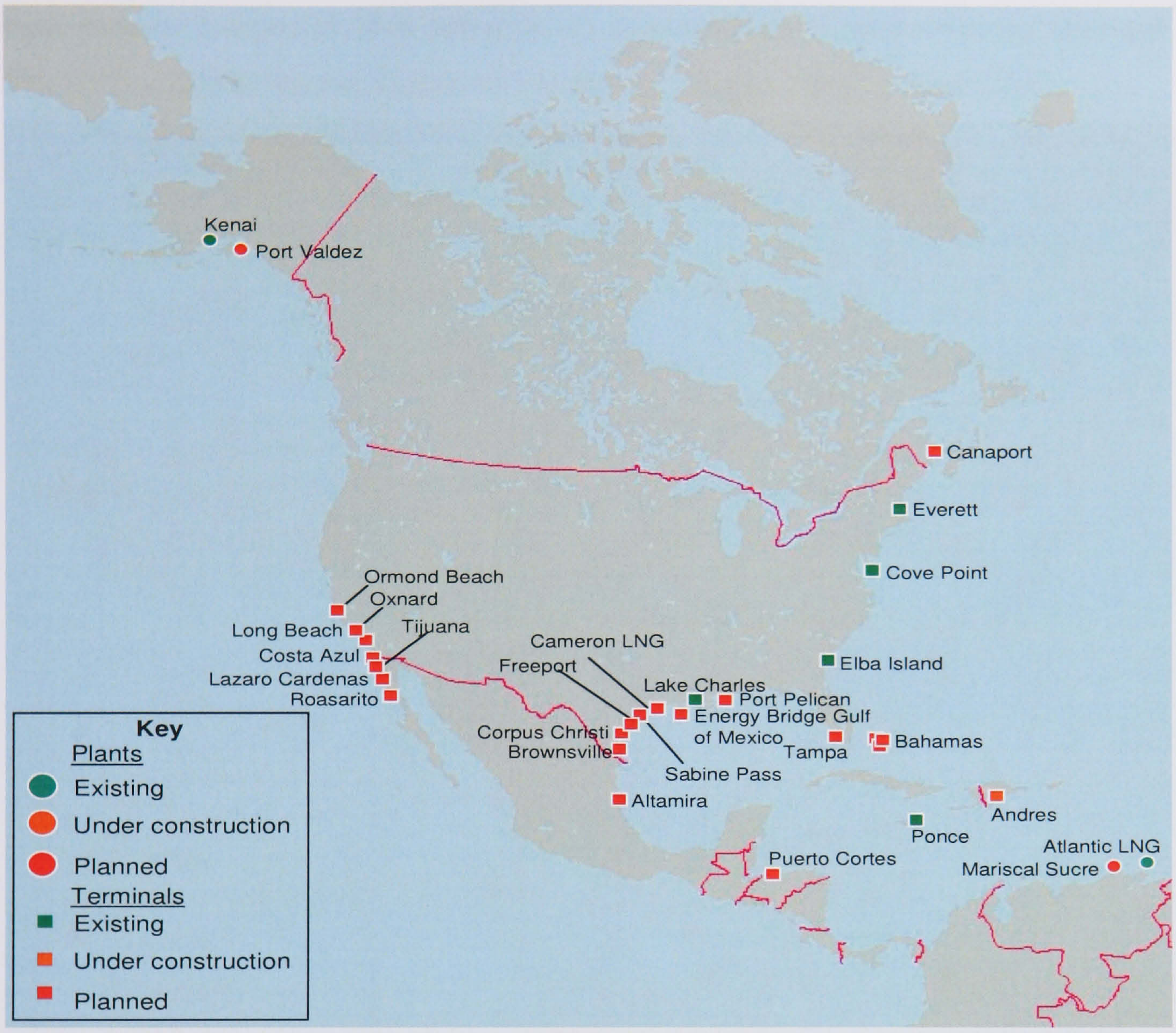


Figure 2-16 LNG projects in North America – 2005[23]

There are also talks of off-shore regasification terminals as well as the so-called "regasification sub-contracting" that involves buying pipeline gas from other countries who buy LNG (potential examples are Mexico, Puerto Rico and Jamaica).

There is also a large amount of new capacity in Africa. After the explosion of the Skikda terminal in Algeria in January 2004, fresh investment in that terminal are being made and

[23] Gas Strategies Online (2005)

more capacity is expected. New terminals are expected both in Egypt (who has delivered its first LNG in 2005), Nigeria, Equatorial Guinea and Angola. Refer to Figure 2-17.

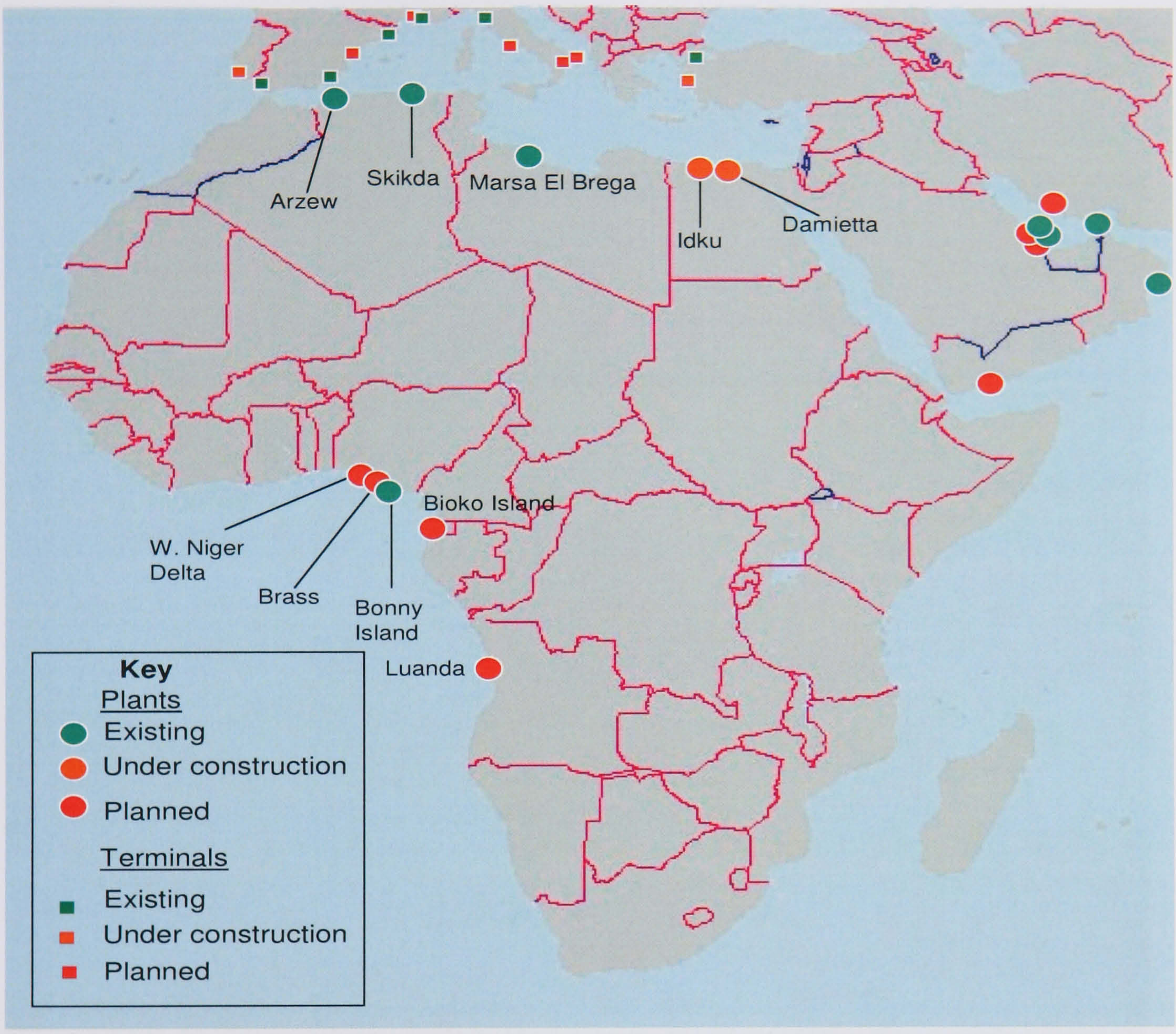


Figure 2-17 LNG Projects in Africa[24]

Spain has also been a major driver of LNG trade. France is one of the largest LNG importers in Europe and Italy has been proactive in building terminals and concluding LNG long-term contracts[25]. The UK has received its first LNG delivery for 40 years in 2005 in the new Isle of Grain terminal and Belgium, Portugal, Greece and Turkey continue to be buyers

[24] Gas Strategies Online (2005)

[25] More information about France, Italy and Spain LNG in chapter 3

in the LNG market (Figure 2-18). Europe will also see its first liquefaction terminal in Norway which is due to operate in 2007.

Figure 2-18 LNG Projects in Europe[26]

The Middle East is home to one of the world's largest single reservoirs of natural gas (the North Field in Qatar of the South Pars Field in Iran). A large amount of investment is going to liquefaction, and by-products, infrastructure in Qatar, the UAE and Oman who are taking market share in the European market and also the Pacific market.

[26] Gas Strategies Online (2005)

The Pacific Market is different from the Atlantic one in that there is very little pipeline trade. Most of the gas traded is in LNG, most of it in Long Term Contracts and most of it indexed to a cocktail of Crude Oil blends (Japanese Crude Cocktail).

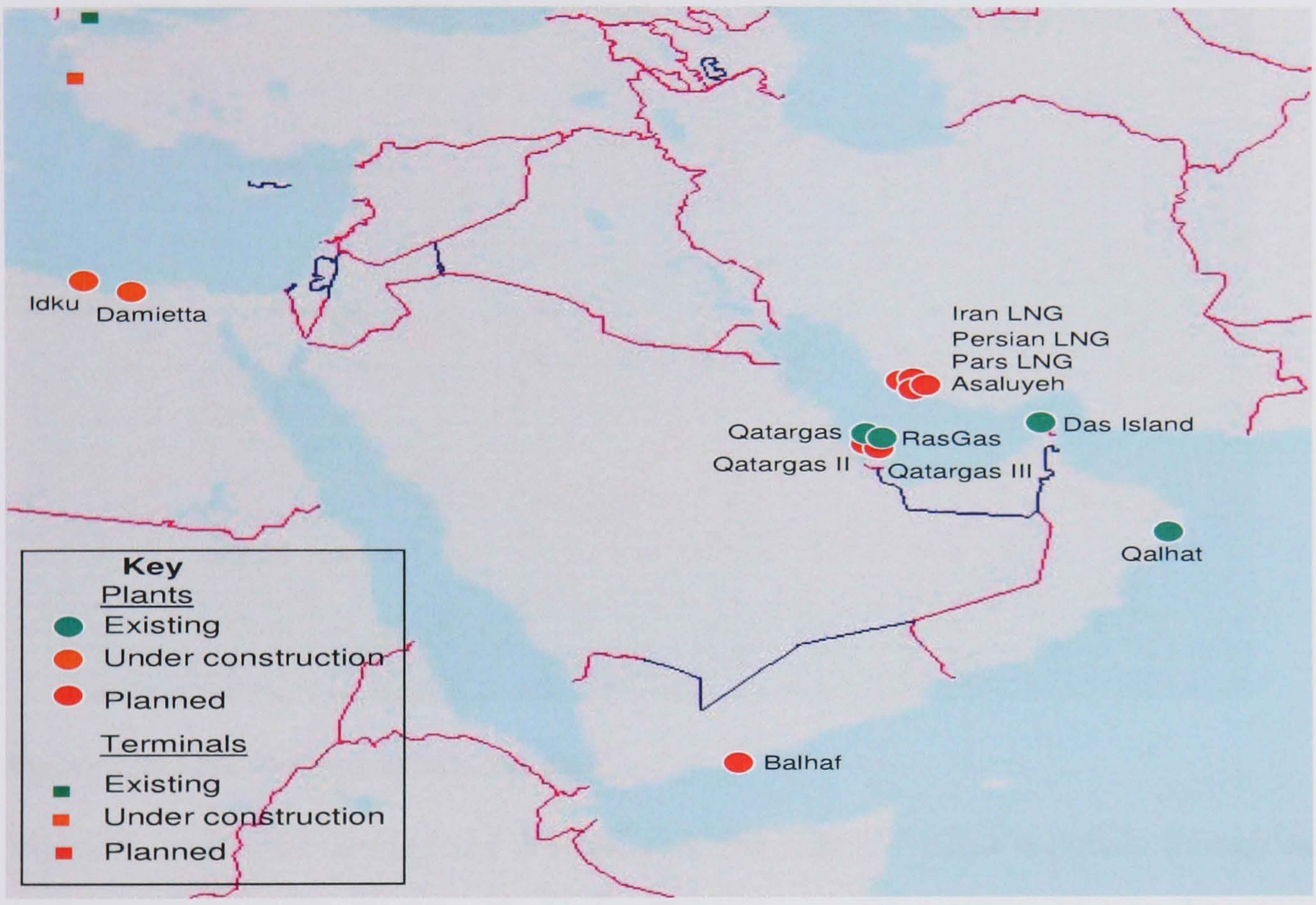


Figure 2-19 LNG Projects in the Middle East[27]

[27] Gas Strategies Online (2005)

Figure 2-20 LNG Projects in Asia-Pacific[28]

Malaysia, Indonesia, Brunei and Australia are the region's major suppliers though new ones, such as Peru and Russia (the Shakhalin Project), are expected to start trading soon. Japan and Korea are the most important buyers with the latter being the world's largest importer of LNG in the world.

[28] Gas Strategies Online (2005)

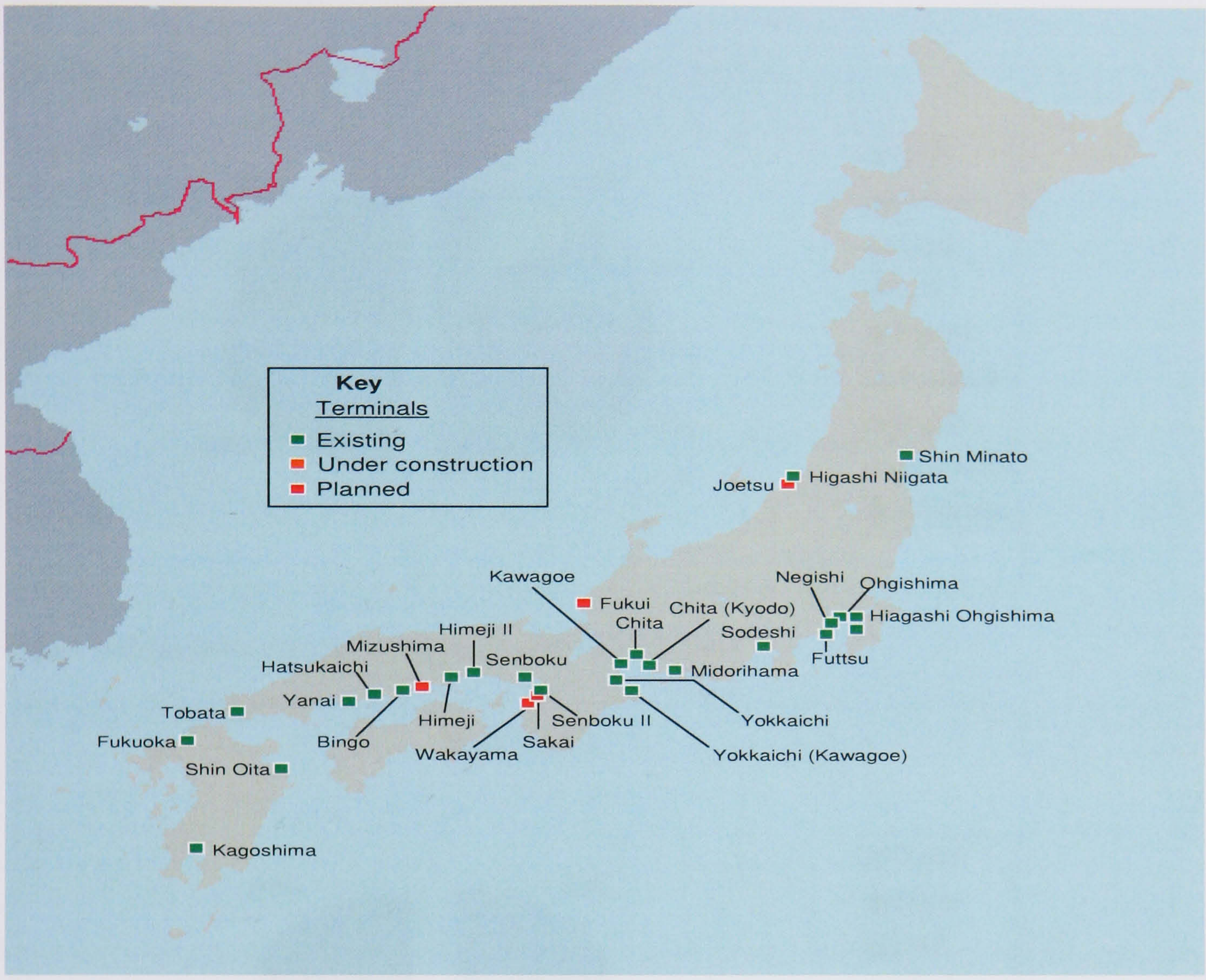


Figure 2-21 LNG Projects in Japan[29]

Due to its seismic attributes, Japan cannot have a complex internal pipeline structure; its utilities have therefore invested in a number of regasification terminals (the largest one in the world) in its major consumption hubs.

[29] Gas Strategies Online (2005)

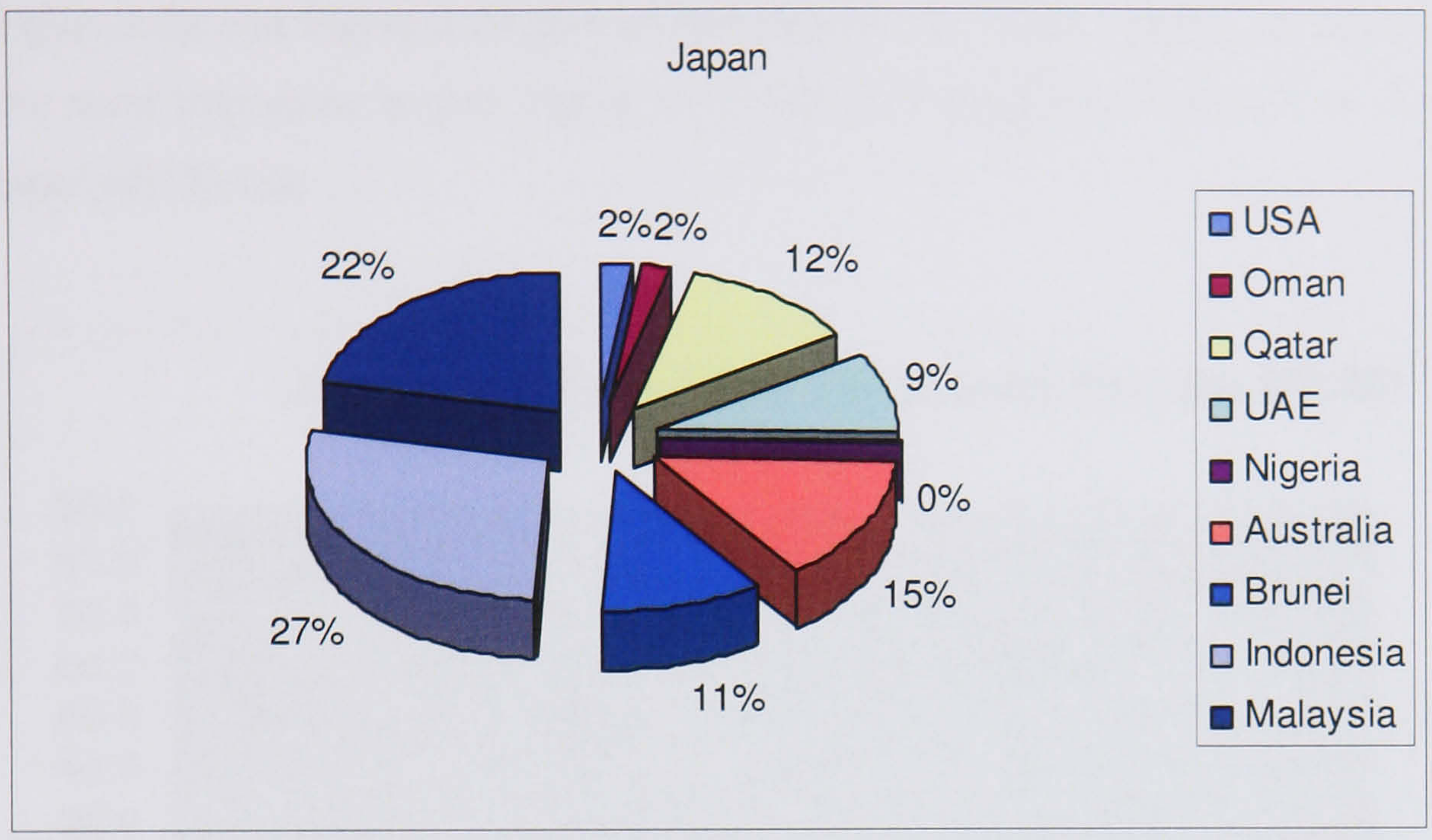


Figure 2-22 Japanese portfolio of exporters of LNG as of 2004[30]

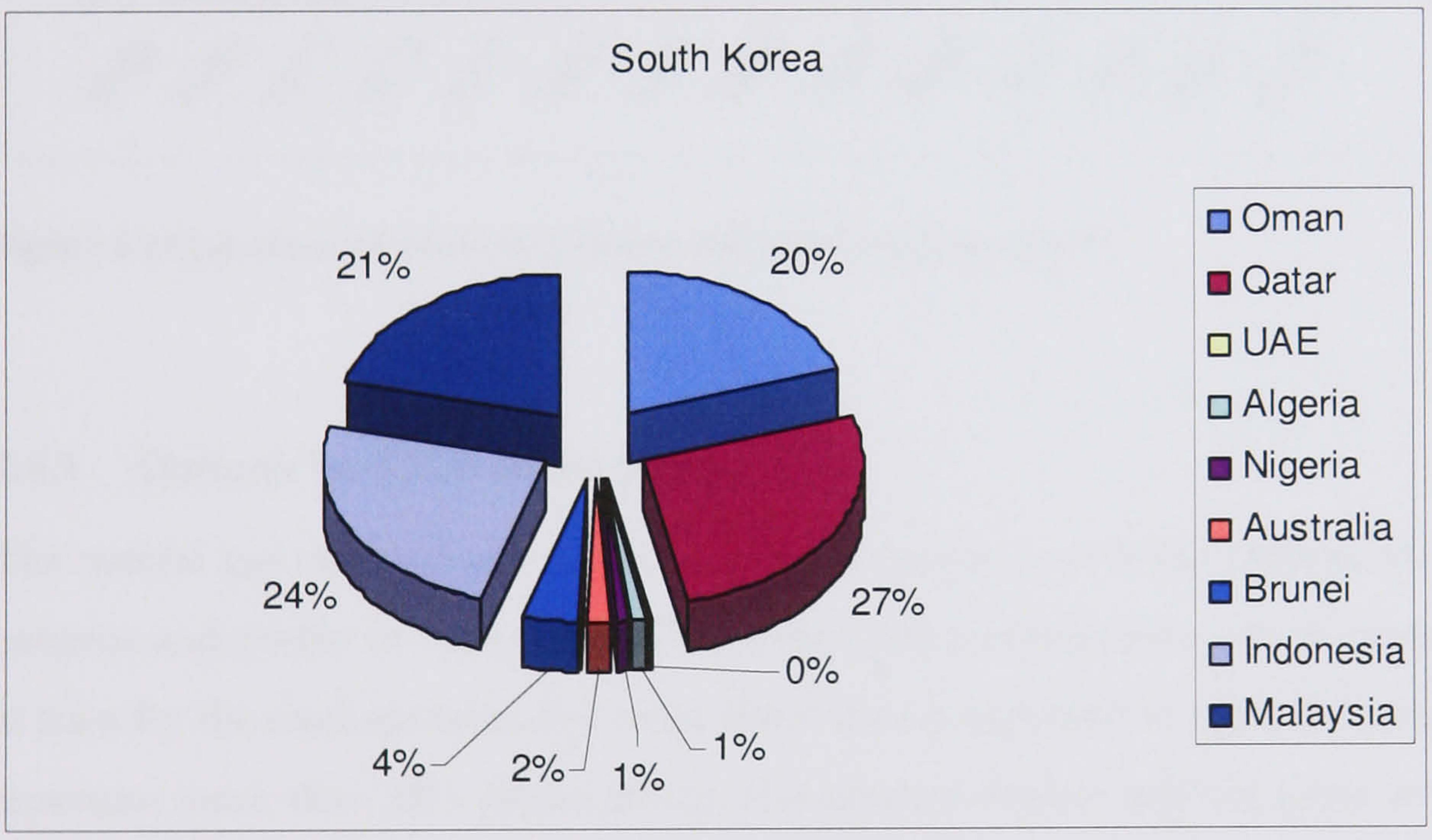


Figure 2-23 Korean portfolio of exporters of LNG as of 2004[31]

[30] BP Statistical Review of World Energy (2005)

[31] BP Statistical Review of World Energy (2005)

Figure 2-22 and Figure 2-23 give an overview of the Pacific market as Japan and Korea are the most important buyers. Figure 2-26, below, highlights the growth in consumption for Japan and Korea.

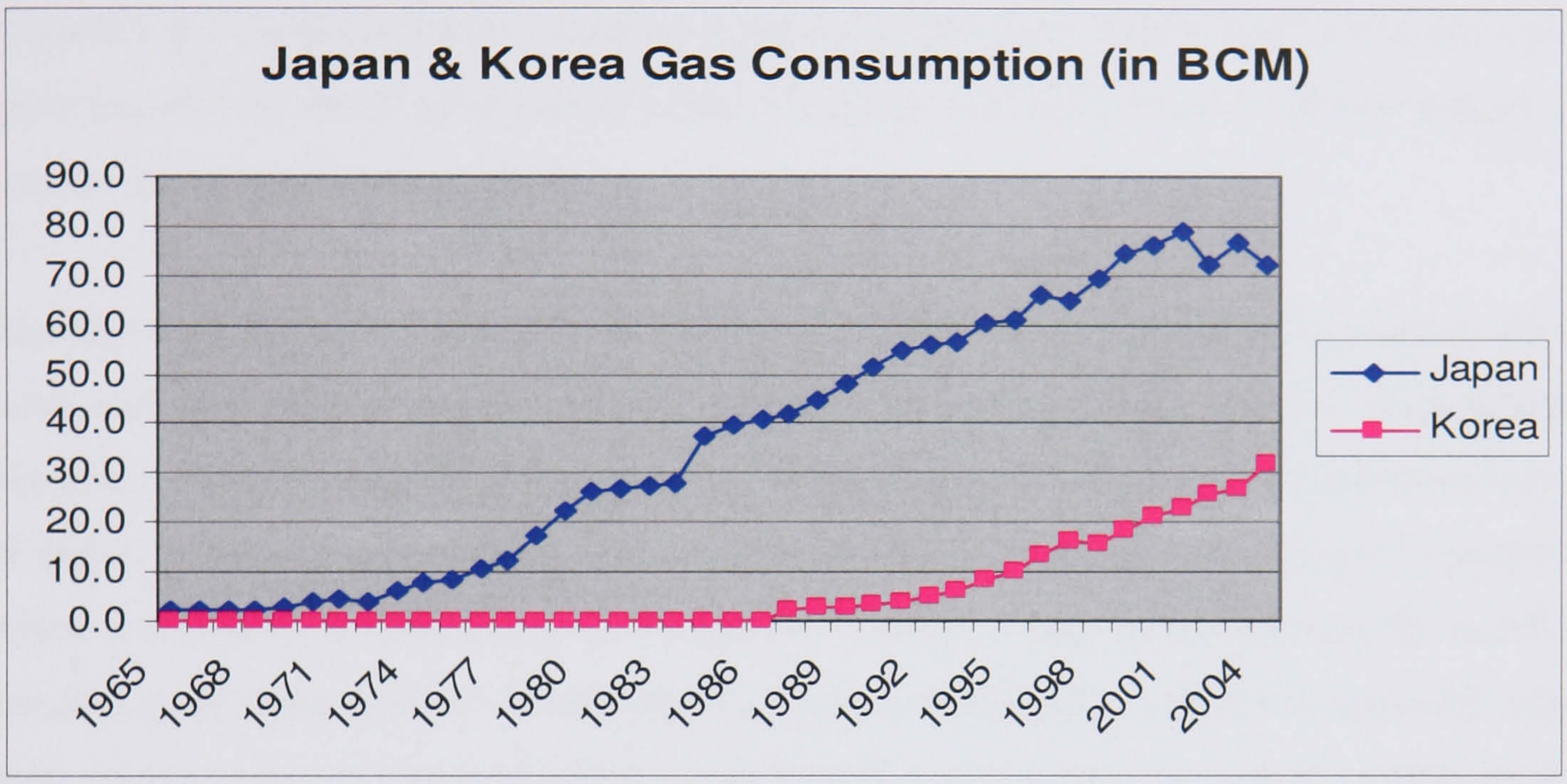


Figure 2-24 Japanese and Korean Natural Gas consumption series[32]

2.6.1 Outlook for LNG in the future

The natural gas international market is going through a profound change, in capacity, trade patterns and profile of the players. The Long Term Contract structure is expected to remain at least for the medium-term. Spot and short term is expected to grow but is not expected to represent more than 25% (Stern 2002). The pipeline market will not grow at the same pace as LNG. More flexibility is expected to the LTCs and more trading, arbitrage and swaps will take place.

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[32] BP Statistical Review of World Energy (2005)

Changes in the LNG market depend on many factors: the way financial institutions invest in LNG projects, the involvement of high credit rating oil majors, the maturity of the international infrastructure –liquefaction, regasification and shipping, and the internal market structure in the consuming countries and the legal upstream structure in the producing countries. It is believed that the number of players both on the selling and buying sides will grow fast and the development of an active US market is pushing for the Atlantic market to become more liquid (Jensen 2004).

An ongoing research by Hallouche & Tamvakis (2005)[33] has shown that a more active short term and spot market will be formed through the vertical hedge and the geographical expansion of both national gas companies like Sonatrach and Petronas, former incumbents in high consumption gas markets, such as BG, GDF and Repsol and Oil majors. In projects where a company, a consortium, or an alliance, controls a large proportion of the middle-stream supply chain (and sometimes upstream and downstream –so called ex-terminal), long term contracts are no longer required as the vertical hedge secures contracts: companies do not have to have long term contracts with themselves.

Also, opportunities of arbitrage are much higher if companies have a horizontal hedge. BG, which has a presence both in Egypt and Trinidad & Tobago can take benefit of US/Europe price differentials.

More importantly, larger companies and alliances can attract capital at lower cost and can offer balance-sheet securities for bankers who, in return, would accept offtake contracts with more flexibility, if so required. Larger companies can also reduce the level of gearing in project-financed projects. Further, they can also invest in LNG carriers not committed to a long term time charter.

[33] 'Spot Trade will Claim Increasingly Important Role', Argus Global LNG, July 2005 quoting Hallouche & Tamvakis (2005)

This liquidity will be pushed further as a large volume of contracted imports will come to expiration soon. In the light of recent developments with the destination clause and price indexation clauses, especially in the EU, these contracts are likely to be more flexible. Also, for amortized infrastructure, where new capital costs are significantly lower, new contracts will not need the long term structure.

Though it is widely accepted that long term contracts will remain, at least in the medium term, sport and shorter term trade will very likely represent and growing part of the trade.

With these expected changes in mind, chapter 3 will discuss with more details the EU market and more particularly France, Italy and Spain; the countries under study from the economic, infrastructural and regulatory perspectives.

3. Overview of the European Natural Gas Market

This chapter will discuss the economics and regulatory aspects of the European gas market as well as provide a more comprehensive overview of the French, Italian and Spanish markets. This chapter will also discuss ongoing debate on security of supply vs market liberalisation.

3.1 The legal framework of the European gas market

Europe has been undergoing over the past few years important changes to its energy market structure, especially with regards to natural gas deregulation. Natural gas, which now accounts for roughly one fifth of primary energy consumption there, is expected to gain considerable market share in the future and efforts are being made to create the appropriate legal and financial environment to cater for this. At the same time, there are environmental concerns amid growing carbon emissions and there are also significant security-of-supply and dependence concerns. This should be added to market uncertainty provoked by recent international political and military unrest and major energy related company failures.

The natural gas industry in Europe was generally dominated by state-owned/operated monopolies, with the exception of the UK. These companies usually operated in the import, processing, transmission and distribution of natural gas to the final customer of their respective countries. End user prices are usually based on competition from other fuels and import prices are usually calculated using formulae with a base price and a differential to crude oil prices or, but much less frequently, coal prices. A cost-plus approach is also sometimes used.

As of now, Europe depends on the rest of the world for 50% of its energy needs and this is expected to increase to 70% by 2030[34] as the European resources will move towards depletion and new or renewable energy will probably be too costly to gain a noteworthy market share. The cost of production of coal in Europe is on average 4-5 times the world market price and that of oil is 2-7 times the world market price. The reserves of natural gas are 2% of the world reserves with an R/P ratio of 20 years. Nuclear technology cannot expand without collegial political will and some solution to the problem of waste.[35]

It is with these issues in mind that the Energy Green Paper was thought in November 2000 and debate of which was concluded in the Barcelona Summit in March 2002[36].

3.1.1 The Green Paper for Energy

The Energy Green Paper is an unprecedented 'comprehensive thorough-going discussion' for Europe's energy future and how it should fit with the other economic and environmental strategies of the European Union. It aims to tackle the issue of security of supply as stated above. Also, it aims to look at the internal energy market, uncertainties of oil prices and environmental challenges.

The Green paper discusses the reduction of coal consumption due to its environmental impact, looking for substitution for oil especially in the transportation sector. Also, it highlights the dependence of the EU for 90% of its oil and long-term contracts on countries perceived as politically unstable. The Paper also stipulates that investments and tax incentives should be given for the promotion of the production of renewable energy with view of increasing its market share to 12% by 2010.

[34] Source: The EU Energy Green Paper

[35] Source: EuroGas 2000 Annual Report

[36] Source: EU Website http://europa.eu.int

Further, the Paper also addresses the issue of greenhouse emissions and recommends that the Union reduce its greenhouse gases by 8% to their 1990 level in the same spirit as the Kyoto Protocol. The Paper also addresses the issues of taxation and transparency of state aid. It further discusses the opening of internal markets of gas and electricity to commercial competition which is also further dealt with by the 1998 Gas Directive.

3.1.2 The Gas Directives

The aim of the EU Gas Directive of 1998[37] was to liberalise European gas markets by providing for non discriminatory access to gas infrastructure, the accounts unbundling of monopoly activities and the publication of a market opening timetable spanning from large natural gas consumers (such as power plants and large industrial consumers) to domestic consumers. The Gas Directive also called for a dispute settlement authority.

Upon debate by national parliaments and application by some countries, this 1st Gas Directive was increasingly seen not to be effective enough to push the process forward. The Second Gas Directive of 2003[38] came to address the weaknesses of the 1st Gas Directive and provided for a regulated third party access to be mandatory (apart from storage). This means that non-incumbent operators should have access to national infrastructure on the same basis as former legal monopolies. The accounting unbundling called for by the 1st Gas Directive is now required to be legal unbundling. This means that vertically integrated companies (who would own the local distribution infrastructure) would be separated to a number of legal entities. The opening timetable was brought forward and an independent regulator in each country was called for. The regulator's duties are to manage and allocate interconnection capacity (cross-border capacity), to effectively unbundle accounts of the

[37] EU 98/30/EC

[38] EU 2003/55/EC

incumbent to avoid cross subsidies, to ensure a level of transparency and competition, as well as publish appropriate data and information.

The directive also calls on the commission to report on the progress of the implementation of the directive annually.

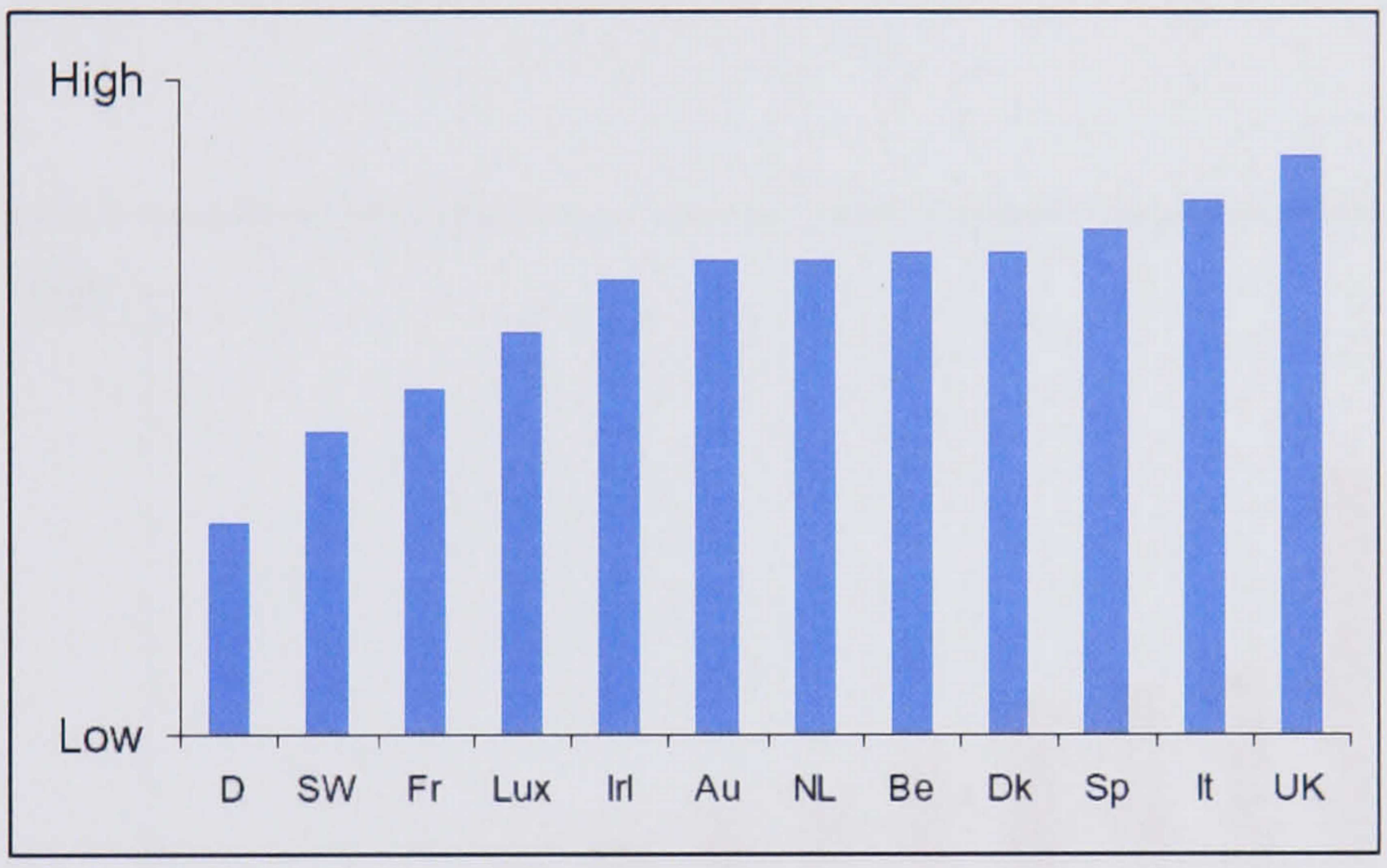

Figure 3-1 Comparative degree of implementation of the gas directive (using the Gas Strategies Index)[39]

Figure 3-1, Figure 3-2 and Figure 3-3 show the progress on liberalization achieved by selected Member States. As it can be observed, there is a wide-ranging spectrum of "degrees of liberalization", with a reasonable correlation between Gas Directive key indicators and market share of non-incumbents. The UK, which is a special case as it has liberalized its market well before the EU Gas Directives, heads both tables. Spain and Italy, who have implemented some aspects of the directive ahead of schedule, are in the top of the key indicator table. Italy lags in the market share of non-incumbents. France, who has shown

[39] This index was developed by Gas Strategies, a London-based consulting firm, that includes timetables of implementation, regulator, TPA and other indicators; as presented at the 2nd Energy Risk Management Seminar, Cass Business School, 2004

reluctance in applying the directive previously, has made progress but is still at the bottom of the table from the key indicators perspective.

The directive has faced, and is facing, many hurdles in its implementation; however progress has been made according to many market observers. As chapter 4 discusses, there is still very little evidence for price competitiveness with large consumers, but discussions with representatives of market players showed that such competitiveness is starting to emerge in the medium term.

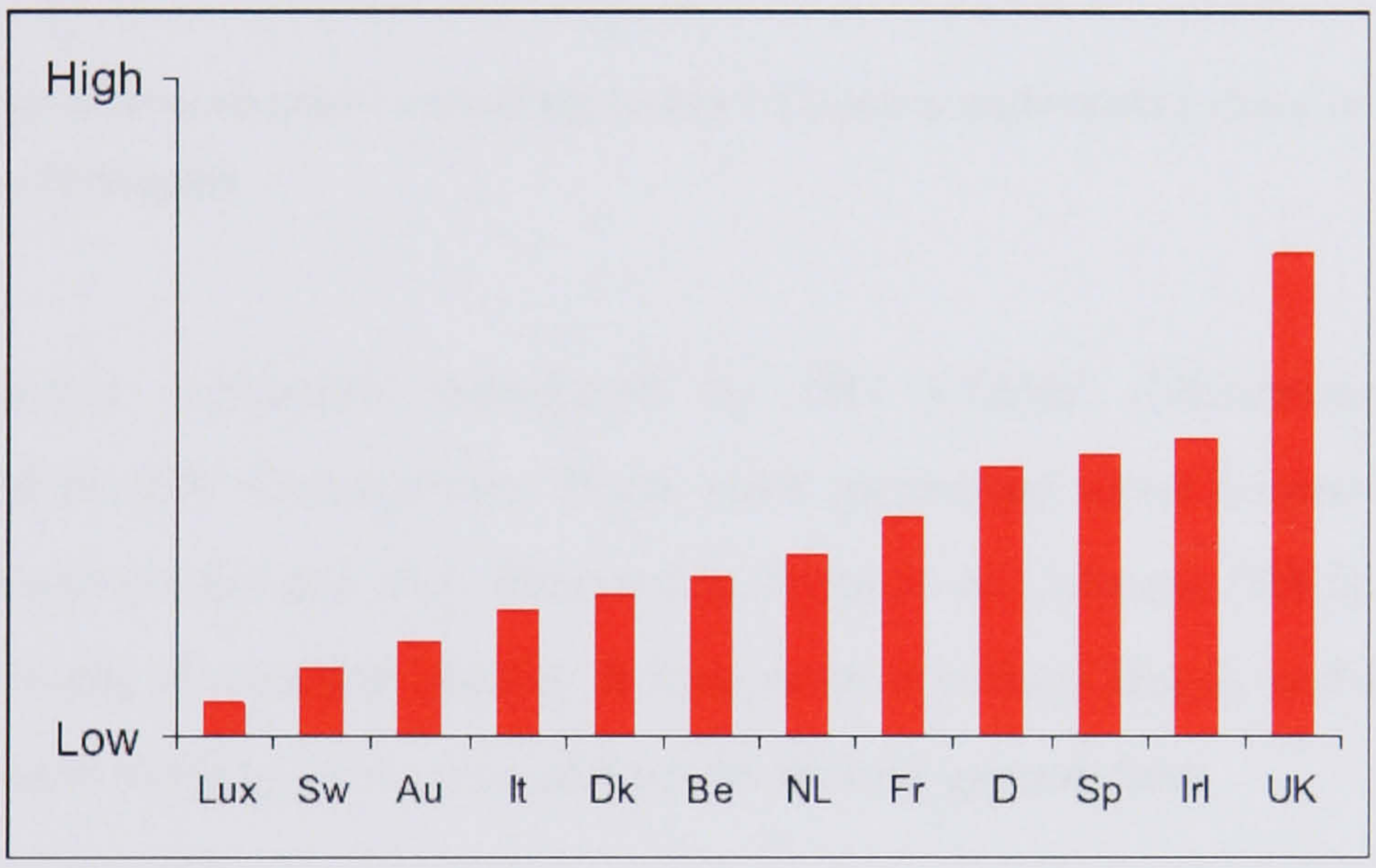

Figure 3-2 Degree of liberalization in terms of the market share of non-incumbant companies, developed by Gas Strategies[40]

Pressure by competition in home markets has also prompted incumbents to look at international markets. Indeed the level of both vertical (e.g. up the LNG chain) and horizontal (or geographical) expansions has increased tremendously since the first gas directive was adopted.

[40] As above

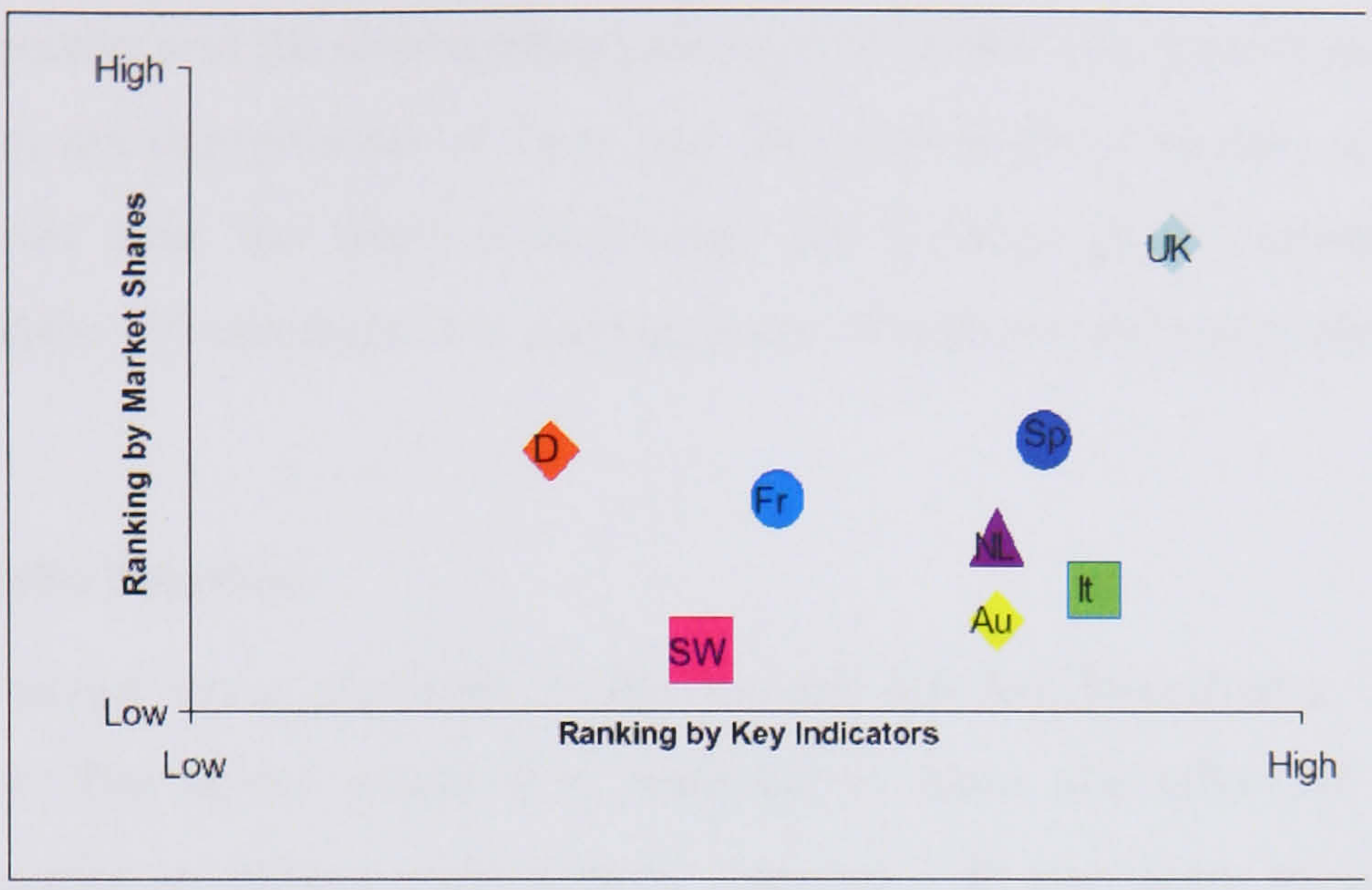

Figure 3-3 Degree of liberalization according to key indicators and market share of non-incumbents, developed by Gas Strategies

Another important regulation introduced by DG COMP (Directorate General for Competition) of the EU Commission. These rules (generated some controversy, both with Member States and producers) and discussed in Nyssens & Osborne (2005) and Nyssens et al (2004), have made destination clauses in long term contracts illegal, and have introduced restrictions to joint-bidding, joint sales and profit sharing agreements.

3.1.3 The Energy Charter

At a suggestion by the Prime Minister of the Netherlands at the meeting of the European Council in Dublin in June 1990, the commission proposed the concept of the Energy Charter in 1991. The Energy Charter was meant to promote 'east-west' industrial cooperation and provide a legal framework for investment, transit and trade of energy as well as promote environmental awareness and dispute settlement. The European Community as well as some other countries are signatories to the Energy Charter Treaty. The Energy Charter Treaty uses the same rules as the GATT and later WTO and Members of the treaty that are not members of the GATT/WTO must apply these trade laws.

Meeting the Directive and the Green paper, above, the Charter also promotes the opening of internal markets, the deregulation of them and the promotion of healthy competition. On the environmental side, the treaty incorporates the 'polluter pays' principle. As for the Directive, countries with economies in transition are offered transitional preferences.

3.1.4 The Kyoto Protocol

The Kyoto Protocol came pursuant to the United Nations Framework Convention on Climate Change. The Kyoto protocol is designed to tackle the effect of greenhouse by calling on countries to reduce their carbon emissions. It also aims to promote energy efficiency, research and development in renewable energy, the 'progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies' in greenhouse gas emitting sectors.

In practical terms, Parties to the protocol (of which the EU) must ensure (with a certain amount of flexibility) that their greenhouse emission do not exceed an amount calculated for each country on a case-by-case basis and in consideration with their commitments.

Some observers argue that while the protocol maybe beneficial for western countries; it may encourage some industries to delocalise to developing countries, which are not signatories to the protocol. The protocol has entered into force in 2004 upon ratification by Russia, in spite of the fact that the US failed to ratify it and is therefore not part of it. The EU Emission Trading Scheme has been launched, which would allow companies to trade credits for emissions, so as to meet Kyoto requirements.

3.2 Overview of the French natural gas market

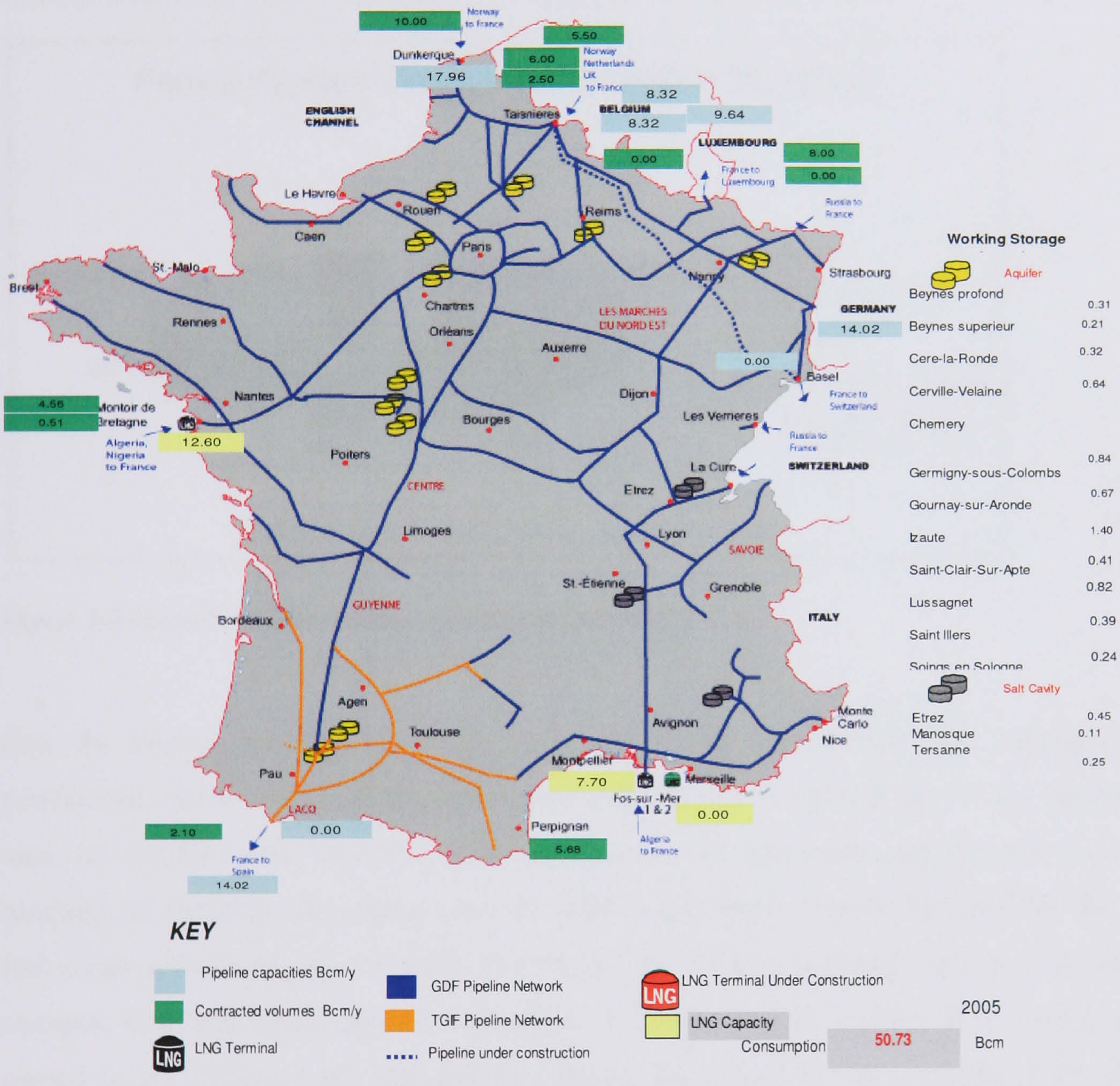

Figure 3-4 French Natural Gas Map in 2005[41]

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[41] Gas Strategies Online (2005)

France is Europe's most important importer of LNG. Its main sources of supply are Algeria and Nigeria. On the pipeline gas, France imports from Norway and Russia. France has the particularity of using less gas than the world's average, because it is poorly endowed with it and, because about 75% of its power generation is nuclear, though natural gas consumption in other sectors is in line with regional averages, refer to Figure 3-5.

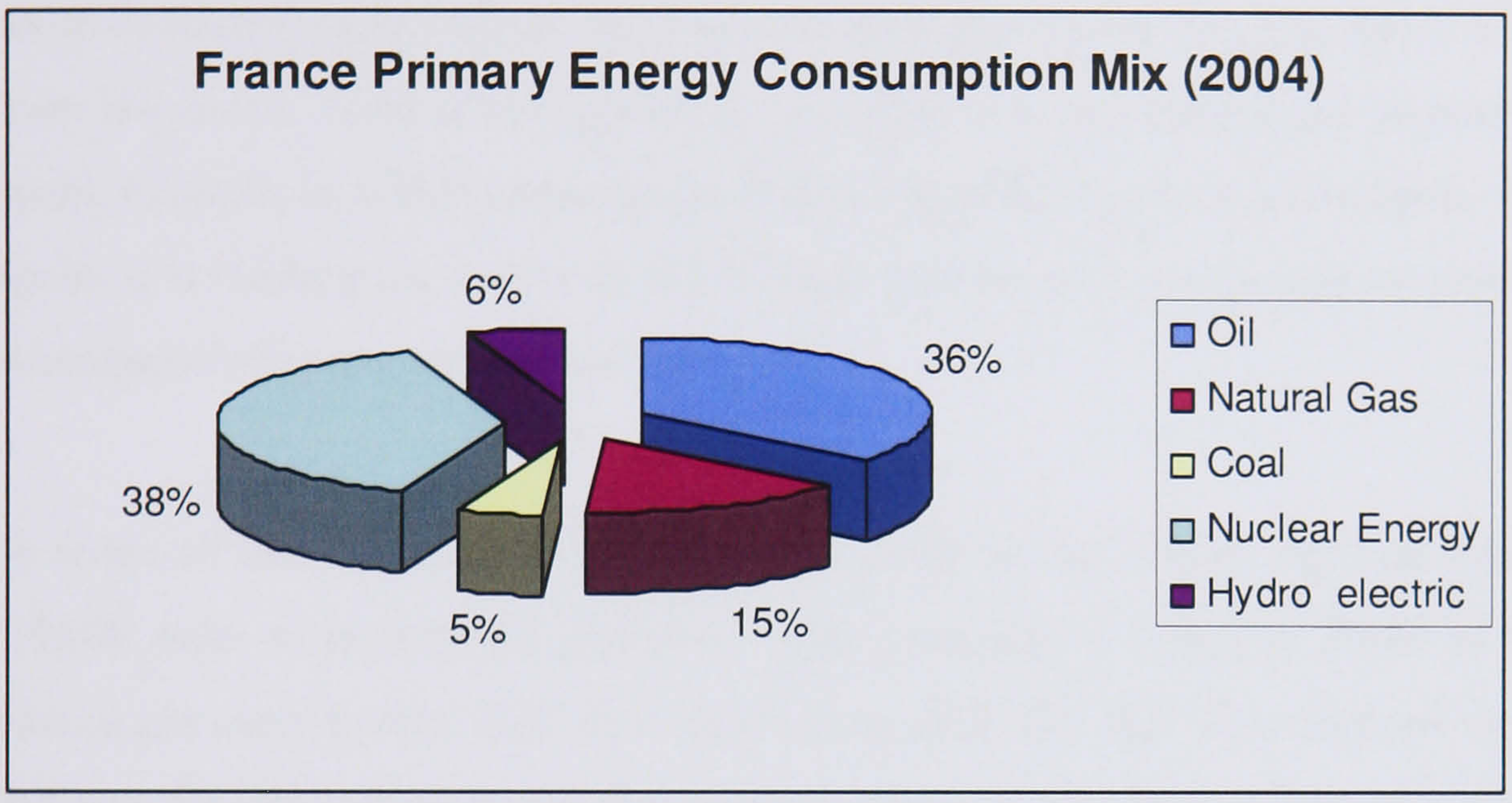

Figure 3-5 France's primary energy consumption mix (2004)

Gaz de France was the incumbent gas utility and state-owned legal monopoly for production, distribution, transportation and importation of natural gas to the country. In view of the EU Gas Directive, GdF has started an important geographical expansion reaching, at the time of writing, over 15 million customers outside France.[42] In the same fashion as other countries in the EU, the French gas industry landscape has been undergoing changes. GdF's is being opened to foreign investors, though at least 50% would remain owned by the French State (this will/can change depending on the progress of the merger with Suez). The new status of the company also entails that GdF does not enjoy the State's guarantee for debt.

[42] EIA France Factsheet (2005)

In view of liberalizing the transport system of natural gas, distribution companies are expected to be able to purchase stakes in the parts of the system that they utilize, according to the EIA (2005).

Total is the other important gas player in France. Total's strategy was to concentrate to the south of France region where gas prices are higher, as lower cost gas comes through pipeline from the north. Total is also planning to construct a new natural gas import pipeline from Spain, Euskadour, which connects the Bilbao regasification terminal in Spain to its market in Spain. It is bidding for a stake in the Medgaz project, that is expected to procure Spain, and subsequently France with natural gas.

In terms of internal market, GdF operates most of the French pipeline system with over (19,000 miles of natural gas pipelines - with a capacity 5.9 Bcf/d). Refer to Figure 3-4 for natural gas entry points. GdF also owns a reported 0.28 Bcf of natural gas storage facilities. Refer to the table below for all procurement routes to France and their respective capacities.

France currently has two LNG receiving terminals: Fos-sur-Mer, on its Mediterranean coast, and Montoir-de-Bretagne, on the Atlantic coast. GdF is constructing a new, offshore LNG receiving terminal at Fos Cavaou, and ExxonMobil has also proposed building an LNG import terminal near Fos Cavaou by 2009, according to the EIA (no further data has been obtained with regards to this terminal, it is hence not in the data presented in chapter 7).

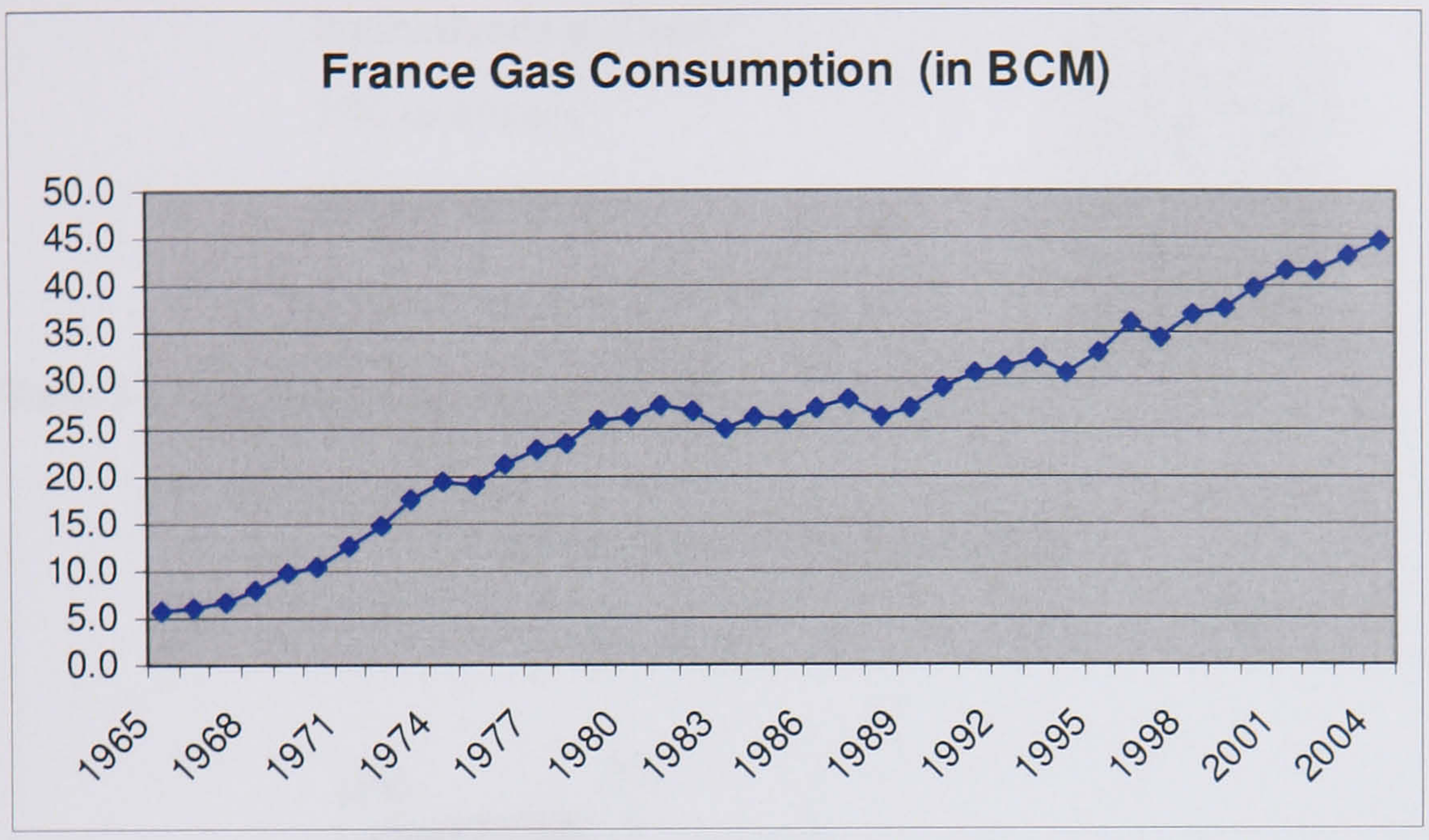

Figure 3-6 French gas consumption[43]

On the macro level, France's gas consumption has been steadily increasing with some cyclicalities (Figure 3-6). Chapter 4 will discuss this further. From the procurement viewpoint, France imports most of its gas by pipeline (Figure 3-7) and has a diversified portfolio of pipeline (Figure 3-8) and LNG (Figure 3-9) suppliers in actual as well as from the contractual side (Table 3-1).

CONTRACTS TO FRANCE		Bcm/year 2003
Norway to France		10
Norway to France		5.5
Russia to France		8
Russia to France		Unknown
Algeria to France (Fos)	LNG	5.68
Algeria to France (Montoire)	LNG	4.56
Nigeria to France (Montoire)	LNG	0.51

[43] BP Statistical Review of World Energy

Netherlands to France	6
UK to France	2.5
France to Spain	2.1
Luxembourg to France	Unknown

Table 3-1 Long term contracts to France[44]

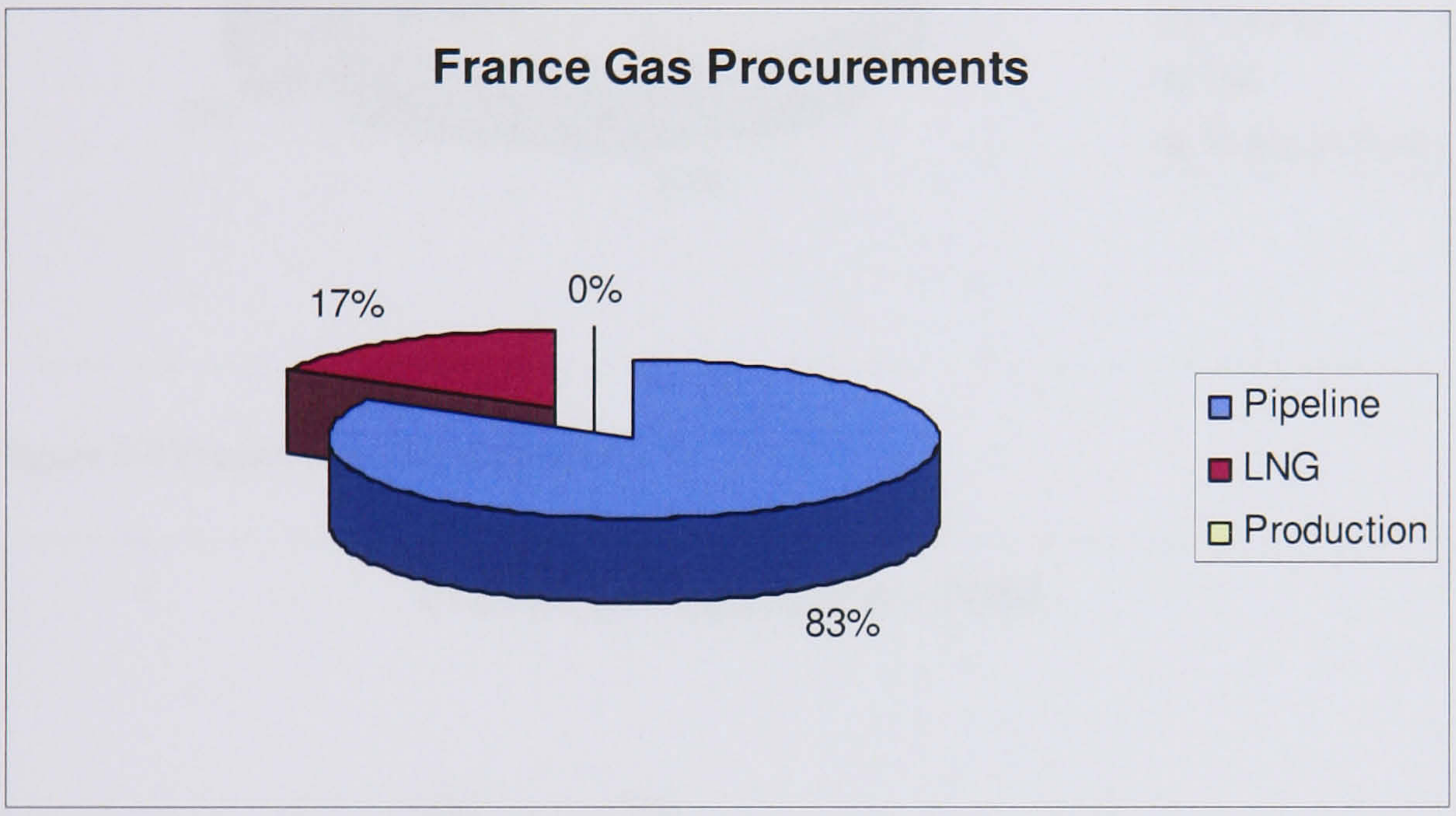

Figure 3-7 French gas procurement sources in 2004[45]

[44] Gas Strategies Online (2005)

[45] BP Statistical Review of World Energy (2005)

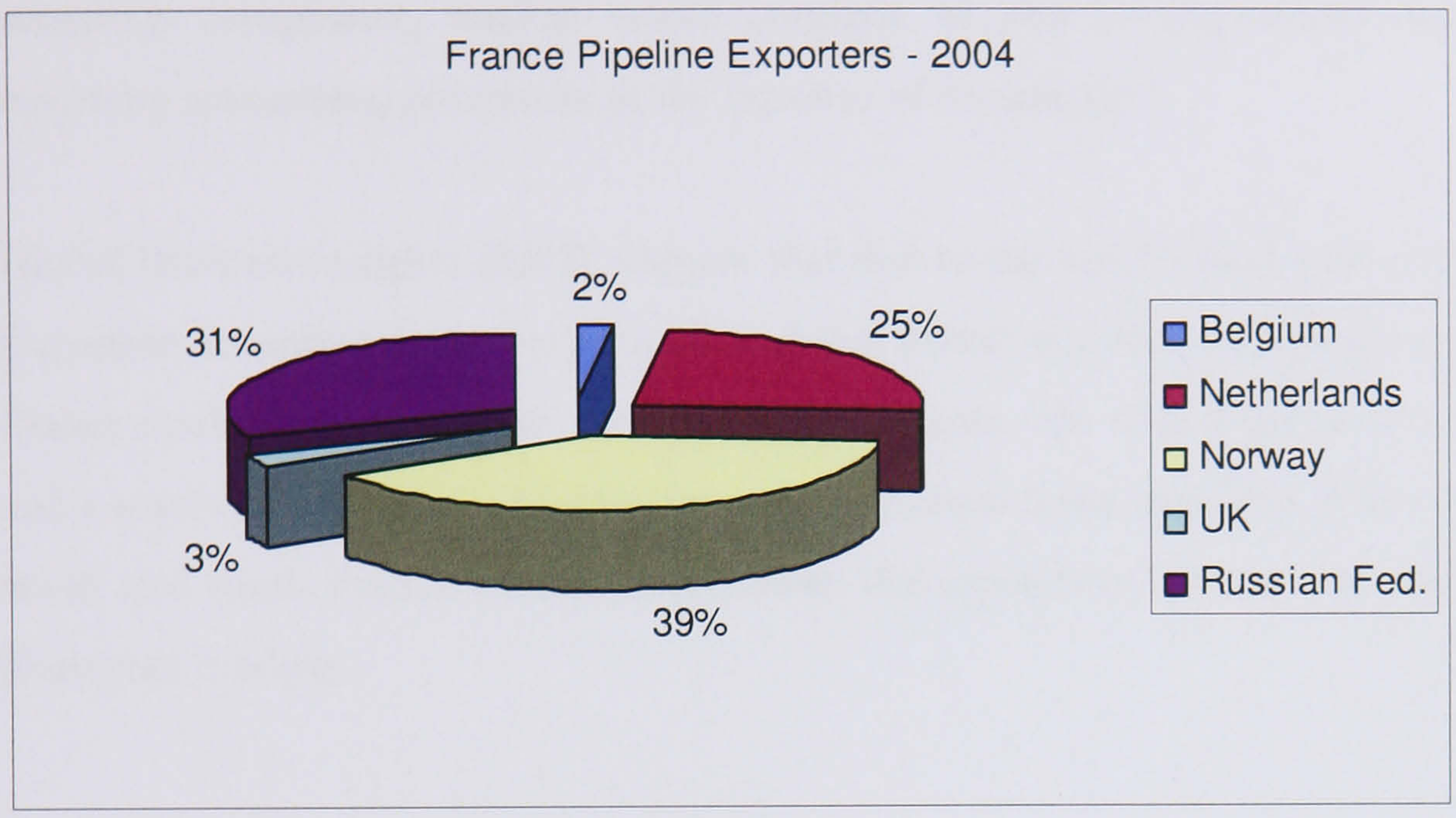

Figure 3-8 French pipeline exporters[46]

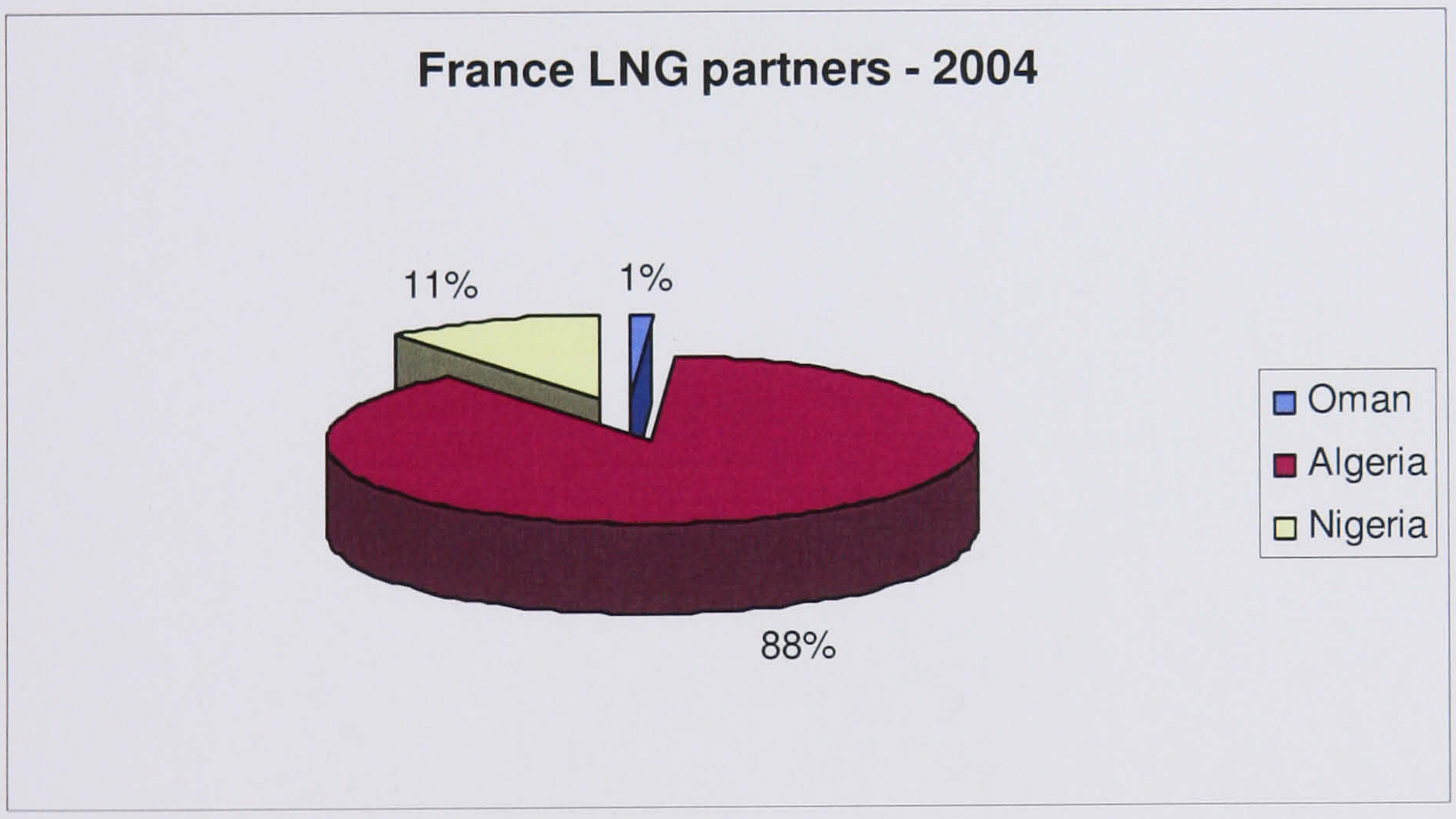

Figure 3-9 French LNG partners[47]

The White Paper published by the French government in 2003 and the national debate that was triggered suggest that, in view of security of supply considerations, cost and greenhouse

[46] BP Statistical Review of World Energy (2005)

[47] BP Statistical Review of World Energy (2005)

emissions compliance, nuclear would continue to play an increasing important role in electricity generation, potentially at the expense of natural gas.

Global Business Insights (2005), suggest that due to the lack of interconnectivity with other European countries (note projects highlighted above) and the current state of the market, France could develop to a two-tier market: a northern one with Norway as its main supplier and a southern one supplied by interconnections from Spain and Italy. The separation of the north and south French market could mean the separation between the North and South European markets.

3.3 *Overview of the Italian natural gas market*

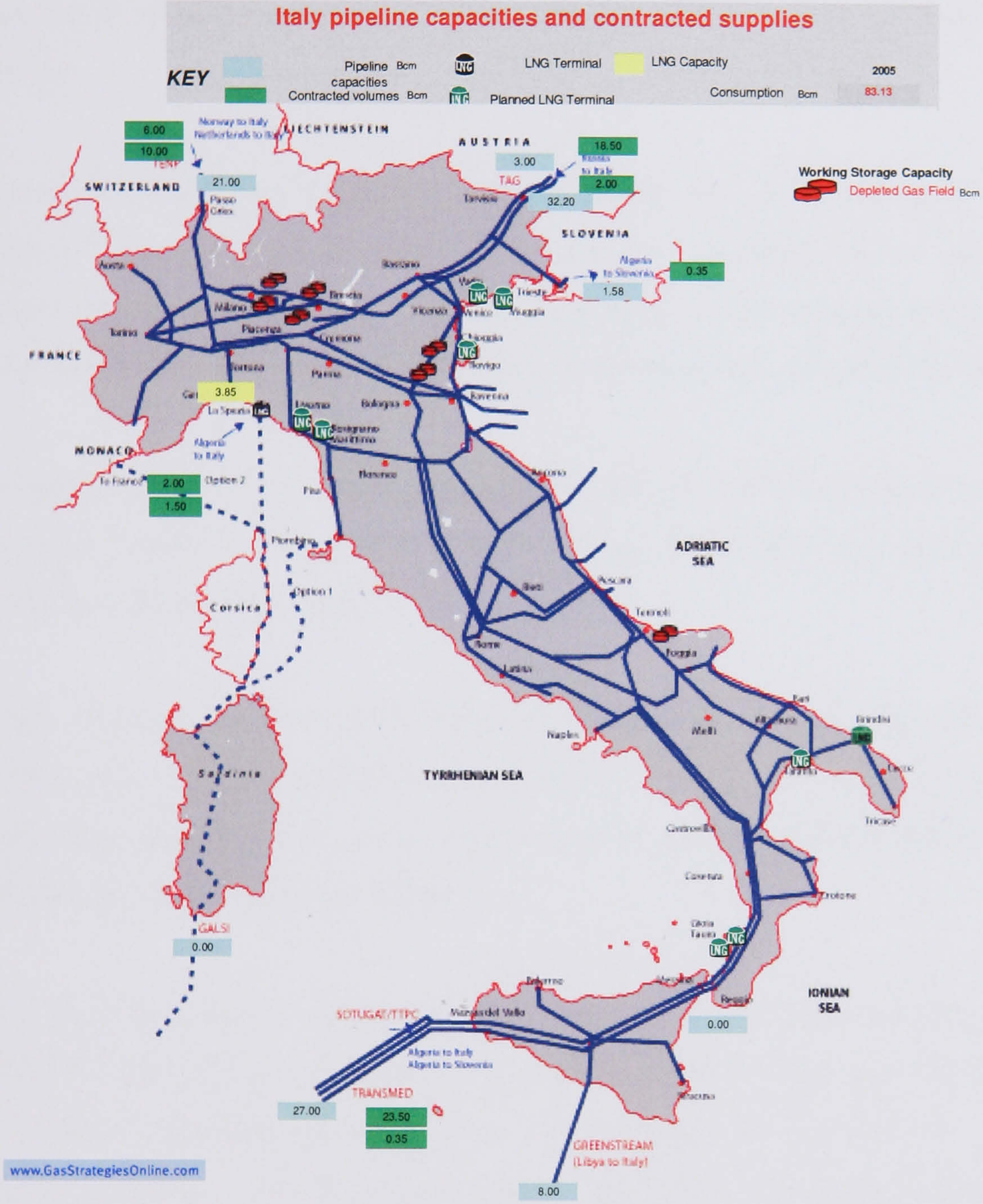

Figure 3-10 Natural gas map of Italy in 2005[48]

48 Gas Strategies Online (2005)

According to the BP Statistical Review of World Energy 2005, Italy is the fourth-largest gas reserves in the EU. However, its production is in decline, as can be observed from Figure 3-11. Italy's consumption has been pushed by a series of investments in CCGT (Combined Cycle Gas Turbine) power stations. Italy's requirements in natural gas imports are therefore growing.

Eni is probably the most important player in energy markets in Italy as it controls most of the gas production. Snam Rete Gas S.p.A. (Snam), a subsidiary thereof –though ownership of Eni is due to decrease from 50% to 20% by 2007-, owns and operates the internal natural gas transportation system, over 19000 miles of pipelines with a capacity of 432 BCF.

Stoccaggi Gas Italia S.p.A. (Stogit), another subsidiary of ENI, manages most of the natural gas storage facilities in the country. Finally, Italgas, also a subsidiary, controls one quarter of the retail gas distribution market.

As Italy's compliance with the Gas Directive was consistent, Eni's dominance of the market has been declining, effectively losing more than 30% of its market share to date. Two players have been gaining that share of the market. Edison, owned by Fiat and Electricite de France, and Enel, the Italian electricity utility.

One of the important procurement sources of natural gas to Italy is the Transmed (or Enrico Mattei) 670-mile pipeline, o exports Algerian Transmed-transported gas to Slovenia. In 2004, the 370-mile Greenstream pipeline, from Lfrom Algeria, through Tunisia, which now has a capacity of 2.3 Bcf. Other important pipelines are the Trans-European Pipeline (TENP) and the Transitgas (from the Netherlands and Norway). Italy also imports natural gas from Russia through Austria and Slovenia. Italy alsibya was inaugurated. The Galsi project is a direct planned pipeline from Algeria to Sardinia. Enel and Sonatrach (the Algerian national oil/gas company) are in advanced stages of this project.

Though Italy only operates one LNG regasification terminal, there are several projects being planned, for instance the Brindisi terminal by British Gas and Enel which is due to start operating within the next few years (with gas coming from Egypt). ExxonMobil and Qatar Petroleum, together with Edison, are also building a terminal in the northern coast of Italy (with gas coming from Qatar). There are also a number of proposed terminals as per

Figure 3-10.

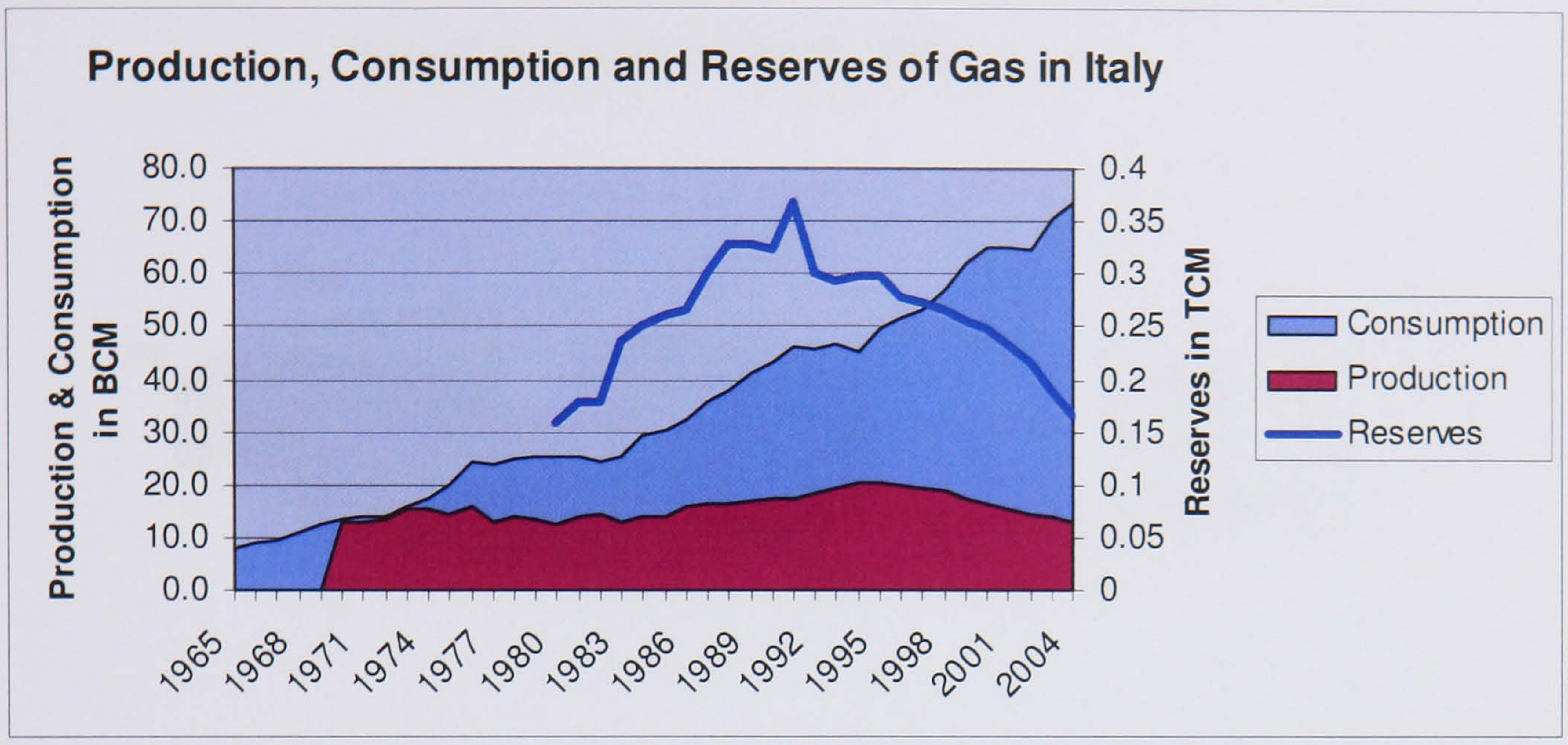

Figure 3-11 Gas production, consumption and reserves for Italy[49]

On the macro level, Italy is a comparatively important gas consumer in terms of primary energy mix (Figure 3-12). Due to its more important -relatively- reserves profile, it is able to maintain a more balanced portfolio of pipeline, growing LNG imports and domestic production (Figure 3-13). In terms of suppliers, Italy enjoys the most diversified portfolio for pipelines one of the most diversified ones for contracted gas in the region (Figure 3-14, Figure 3-15 and Table 3-2).

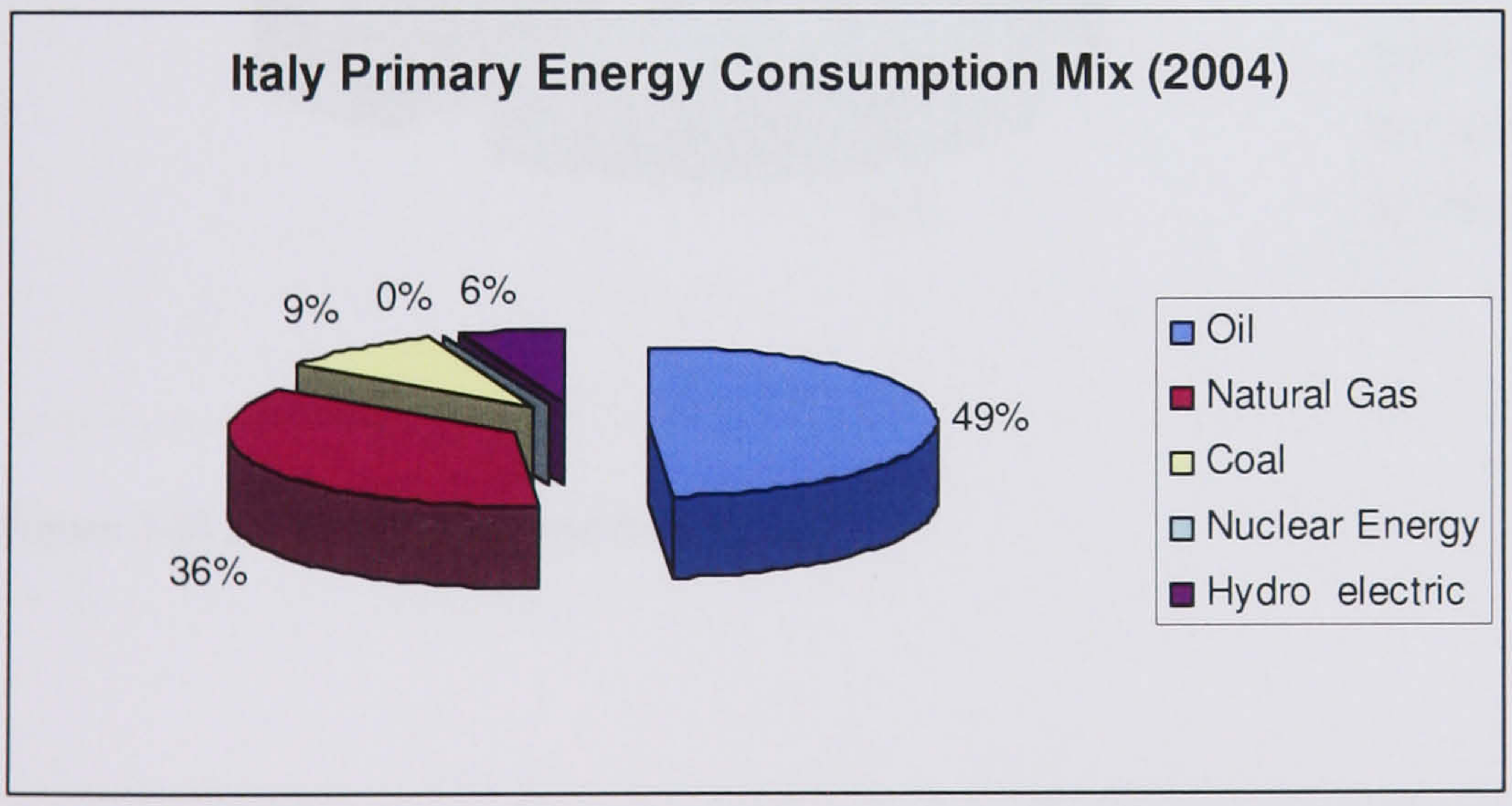

Figure 3-12 Italy's primary energy mix[50]

[49] BP Statistical Review of World Energy (2005)

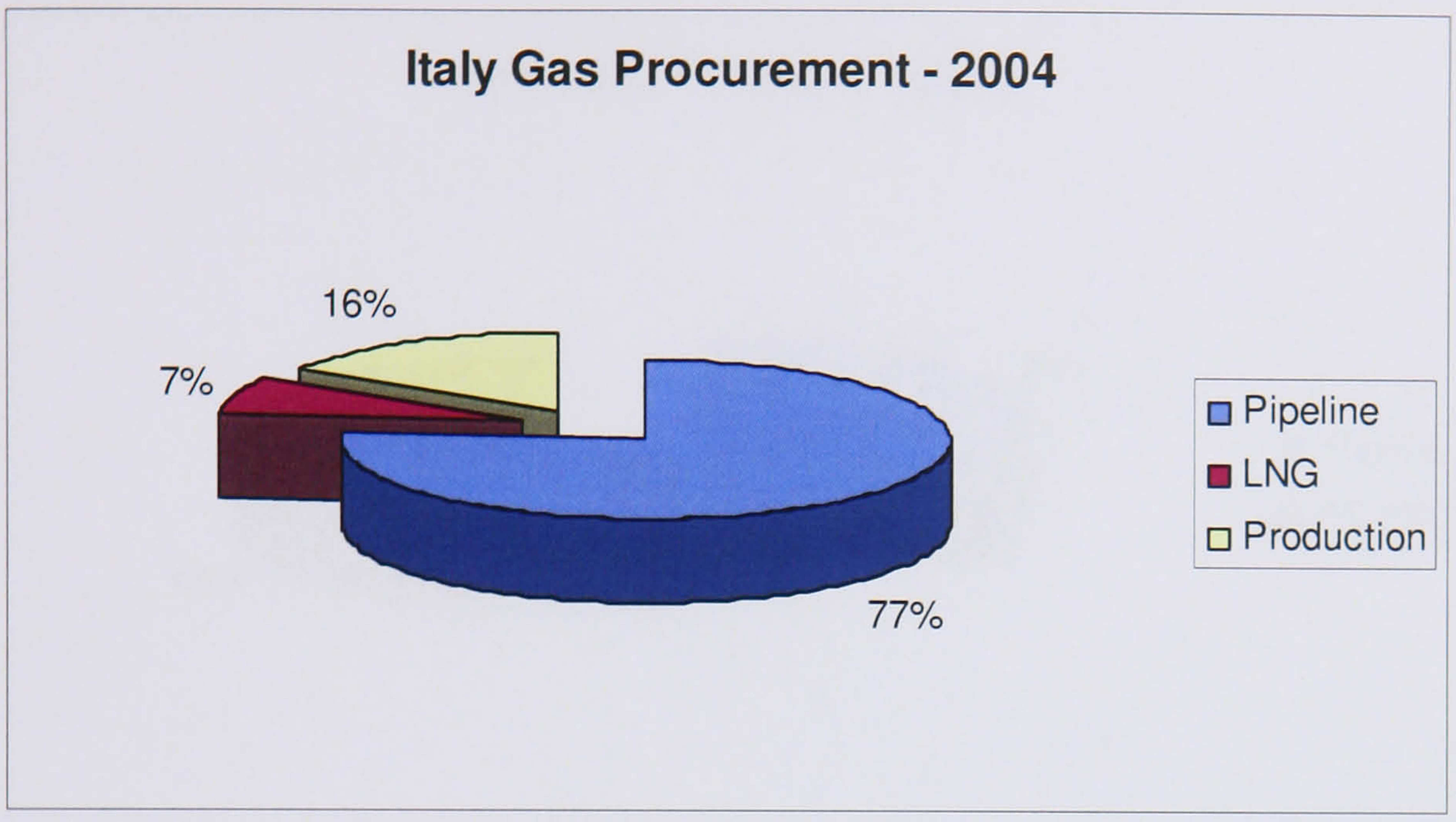

Figure 3-13 Italy gas procurement sources[51]

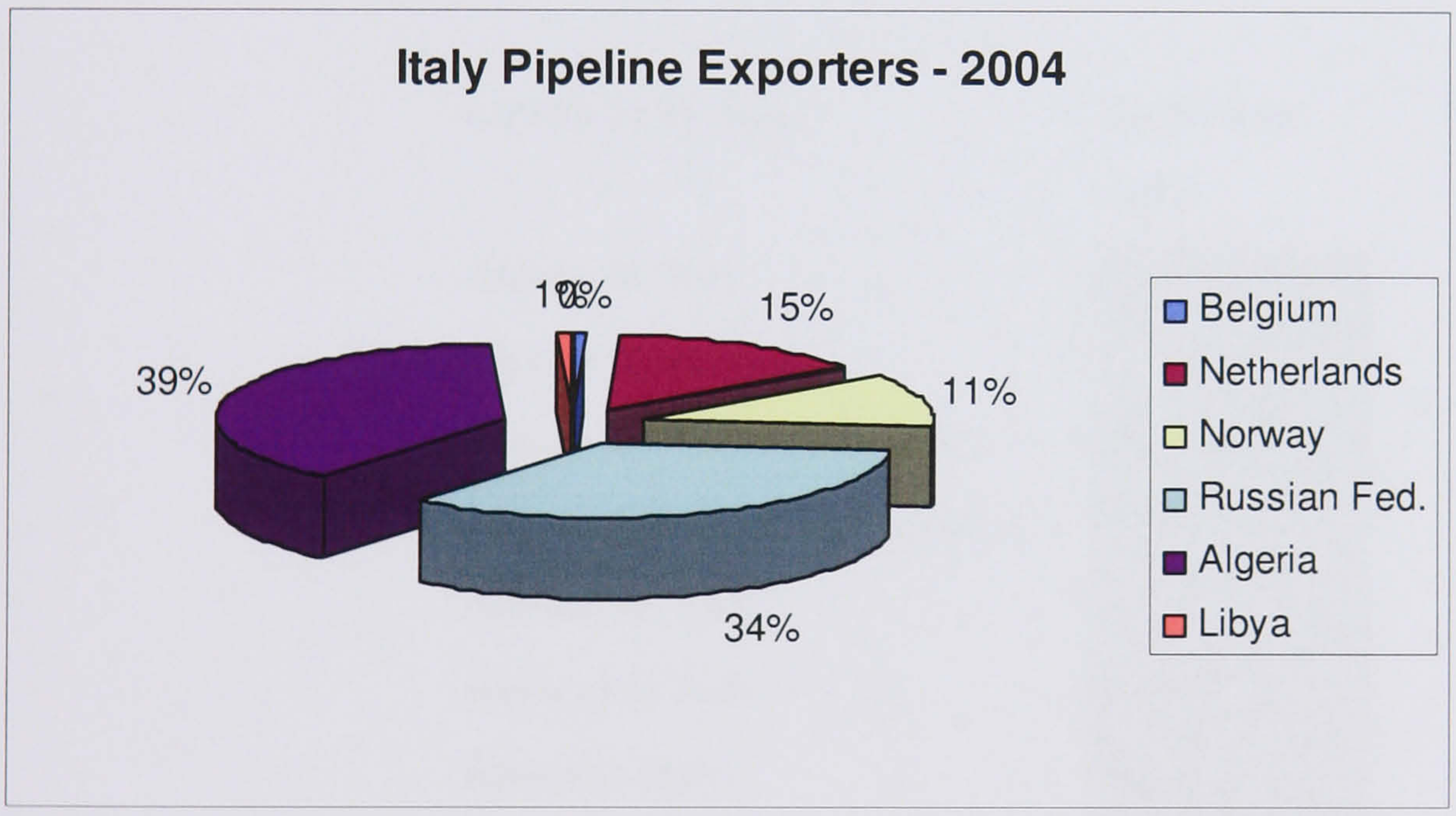

Figure 3-14 Italy's pipeline partners[52]

[50] BP Statistical Review of World Energy (2005)

[51] BP Statistical Review of World Energy (2005)

[52] BP Statistical Review of World Energy (2005)

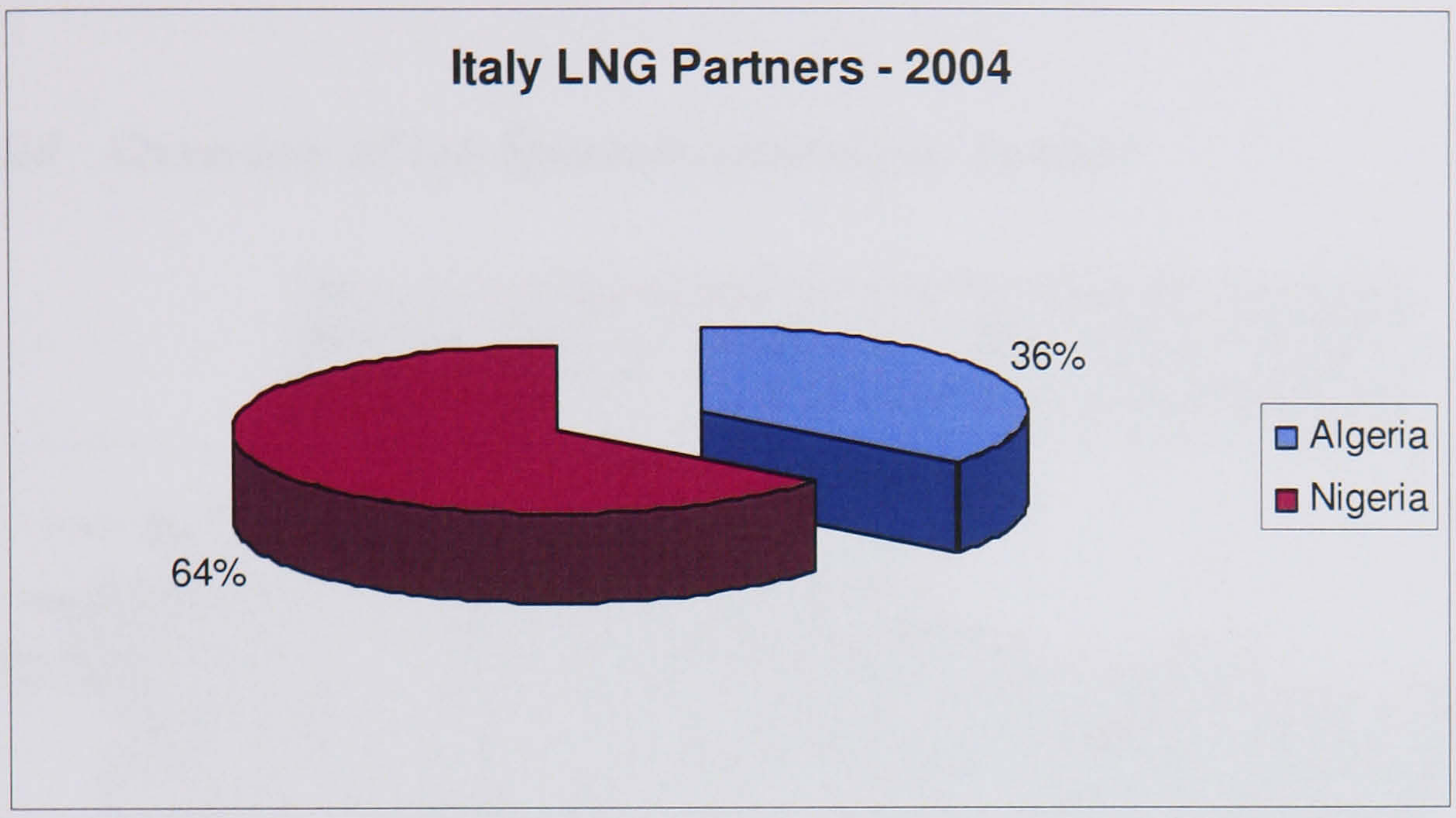

Figure 3-15 Italy's LNG partners[53]

Contracts to Italy		Bcm/year 2003
Algeria to Italy		23.5
Algeria to Slovenia		0.35
Algeria to Italy	LNG	2
Algeria to Italy	LNG	1.5
Norway to Italy		6
Holland to Italy		10
Russia to Italy		18.5
Russia to Italy		2

Table 3-2 Contracted gas to Italy[54]

[53] BP Statistical Review of World Energy (2005)

[54] Gas Strategies Online (2005)

3.4 *Overview of the Spanish natural gas market*

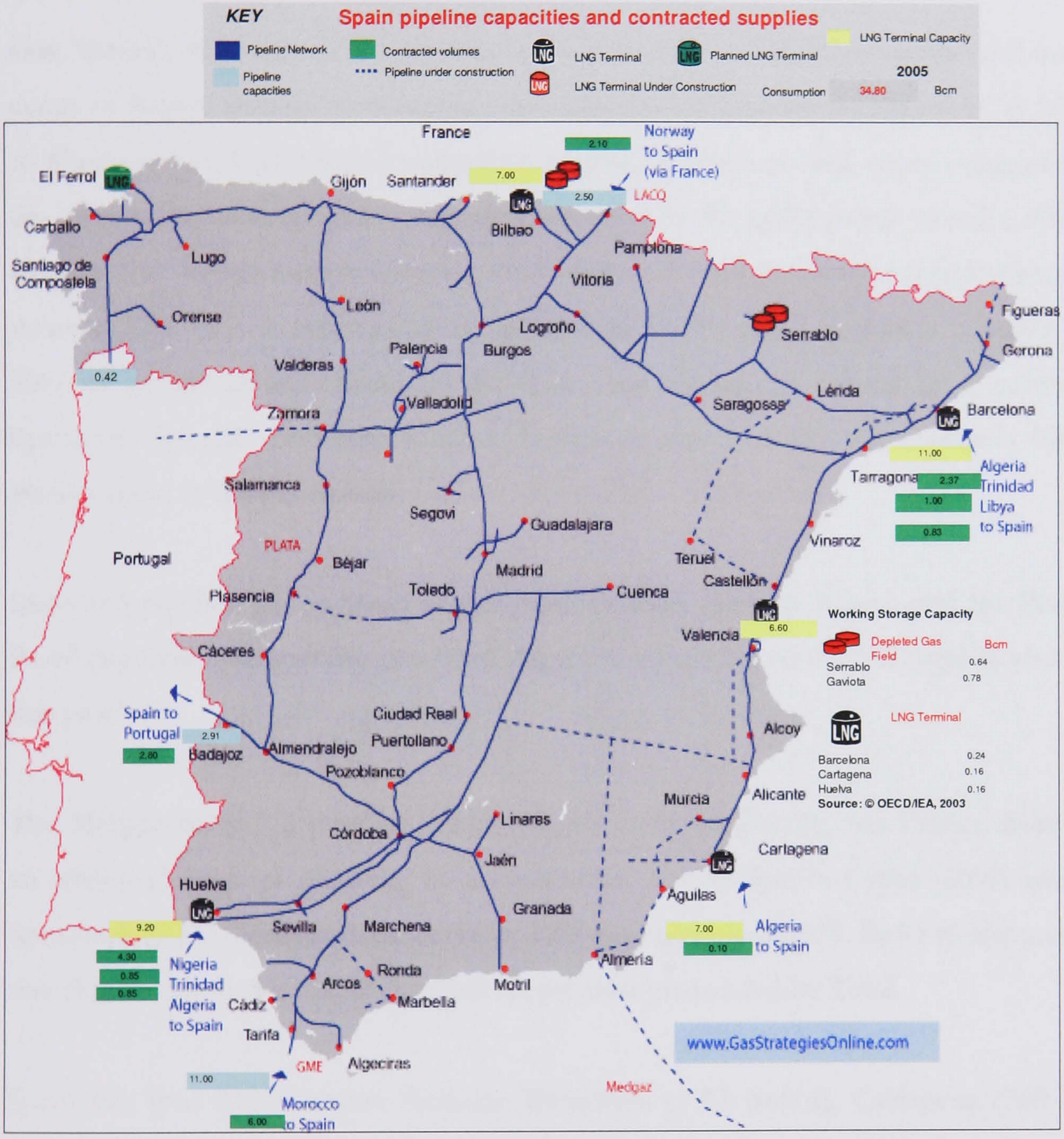

Figure 3-16 Natural gas map of Spain in 2005[55]

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[55] Gas Strategies Online (2005)

The Spanish market has been the fastest growing one in the EU since 1980 due to the introduction of a large number of CCGTs. The overwhelming majority of the gas consumed in Spain is imported. Spain has also complied with the Gas Directive faster than required.

Gas Natural, the result of a merger between Catalana de Gas, Gas Madrid and some of the assets of Repsol Butano, is the most important natural gas player in Spain (EIA 2004). Prior to liberalization, Gas Natural controlled supply, distribution and transportation of natural gas. Upon liberalization, Gas Natural was forced by the government to sell a 40% stake in Enagas (the transportation operator, 4500 miles of infrastructure), henceforth reducing its stake to 25% -this is expected to be reduced to 5% by 2007. Enagas is a public company, 50% of its shares are owned by the state, and the rest is owned by a number of gas operators. Spanish electricity utilities: Endesa, Union Fenosa, and Iberdrola have gained market share in the gas market.

Imported pipeline gas to Spain comes from Norway through France and the Pedro Duran Farell pipeline, transporting gas from Algeria through Morocco. Portugal is also linked to this pipeline.

The Medgaz project, a pipeline linking Algeria to Spain directly, and France thereafter, is in an advanced stage of planning by a consortium led by Spain's Cepsa (20%) and Algeria's Sonatrach (20%). Medgaz is expected to start operating in 2008/9. Refer to the section 3.2 in this chapter for details about the Euskadi pipeline project led by Total.

Spain has four LNG import facilities: Barcelona (1.12 Bcf/d), Cartagena (760 Mmcf/d), Huelva (760 Mmcf/d) and Bilbao (740 Mmcf/d). A terminal in Valencia is being built by Union Fenosa, Iberdrola, and Endesa. Union Fenosa and Endesa are also building a terminal in northwest Spain, El Ferrol.

Union Fenosa also owns a stake in the Damietta terminal in Egypt and has a minority interest in the construction of an expansion to the Qalhat terminal in Oman. Gas Natural and Repsol have also been awarded the integrated project of Gassi Touil in Algeria (including upstream production, liquefaction and shipping).

On the macro level, as discussed earlier, Figure 3-17 shows the exponential growth that natural gas consumption witnessed in Spain. Natural gas now represents a significant part of Spain's primary energy mix (Figure 3-18). From the natural gas procurement viewpoint, Figure 3-19 shows the more LNG intensive nature of Spanish procurement (compared with France and Italy). Finally, Figure 3-20, Figure 3-21 and Table 3-3 show the pipelines, LNG and contracted volumes portfolios for Spain.

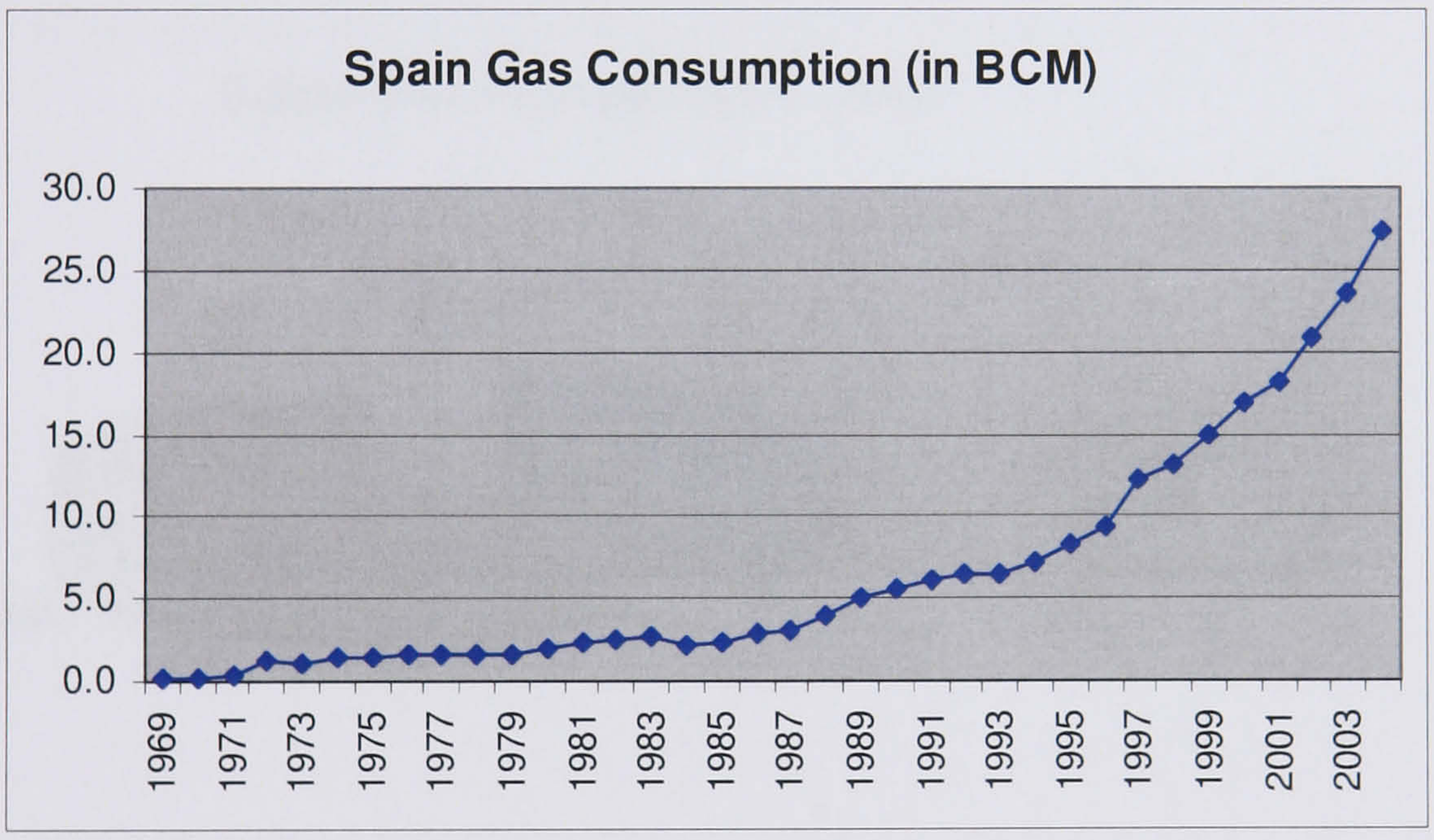


Figure 3-17 Natural gas consumption in Spain[56]

[56] BP Statistical Review of World Energy (2005)

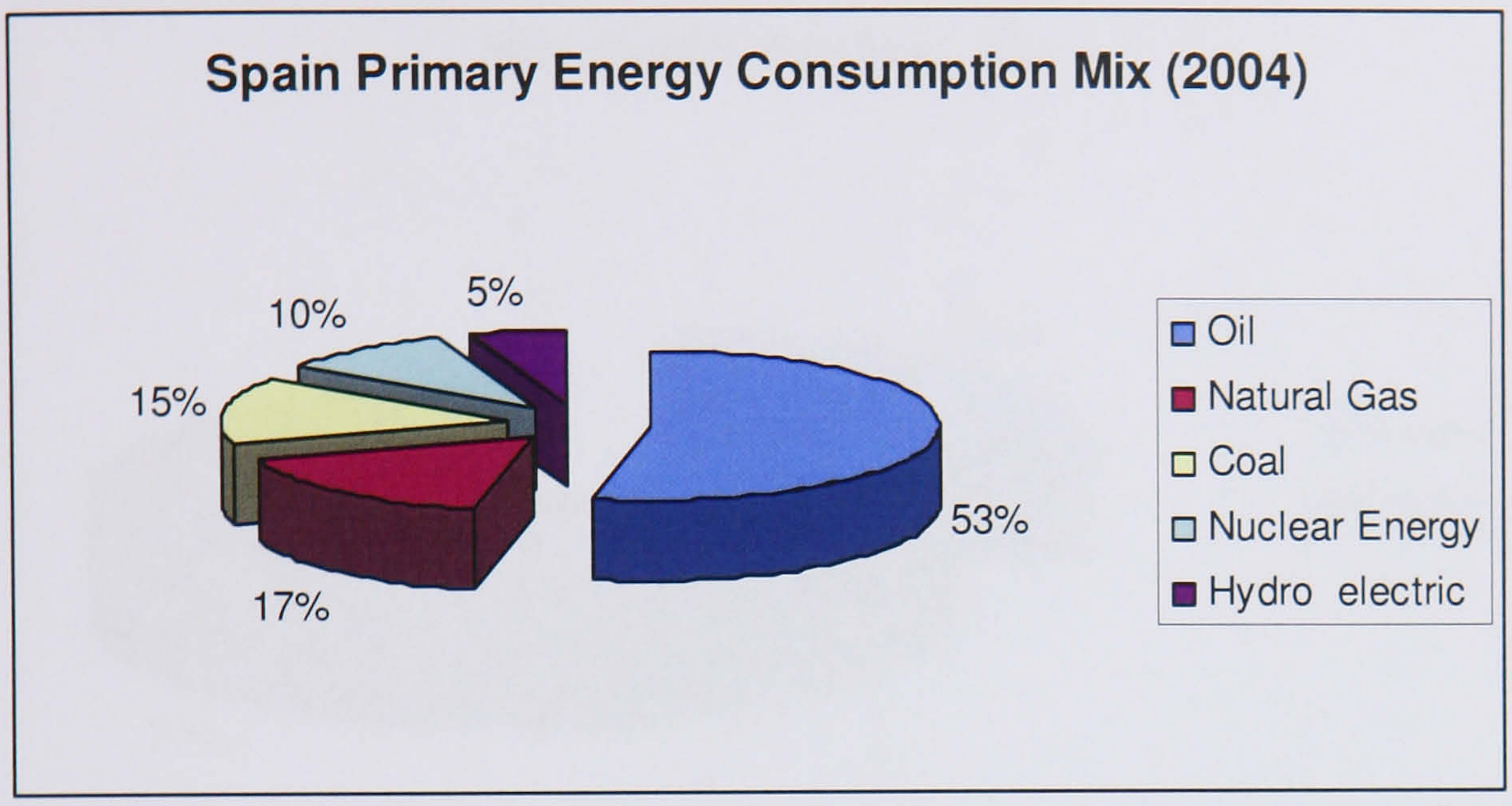


Figure 3-18 Spain's primary energy consumption mix[57]

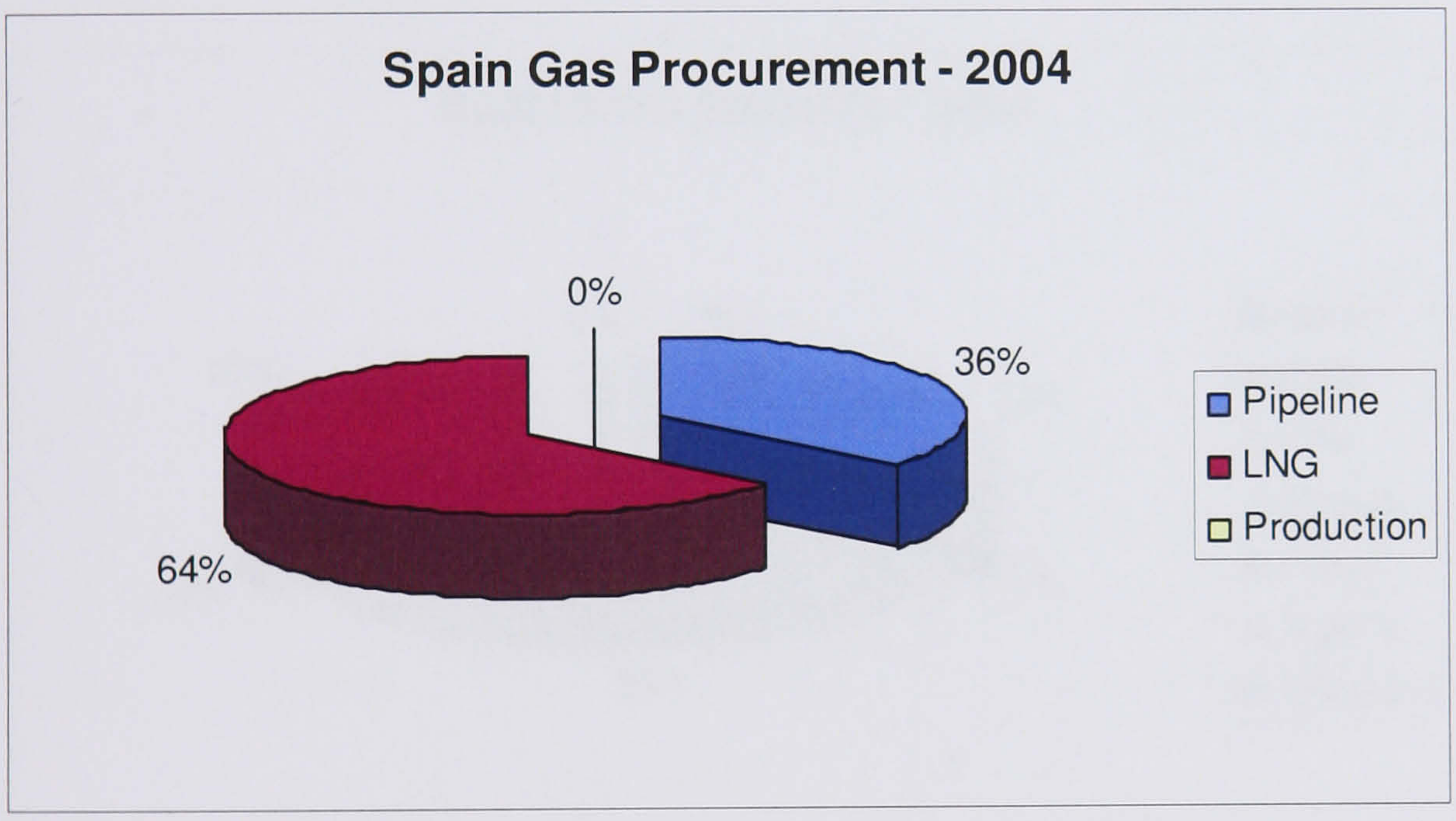


Figure 3-19 Spain's natural gas procurement sources[58]

[57] BP Statistical Review of World Energy (2005)

[58] BP Statistical Review of World Energy (2005)

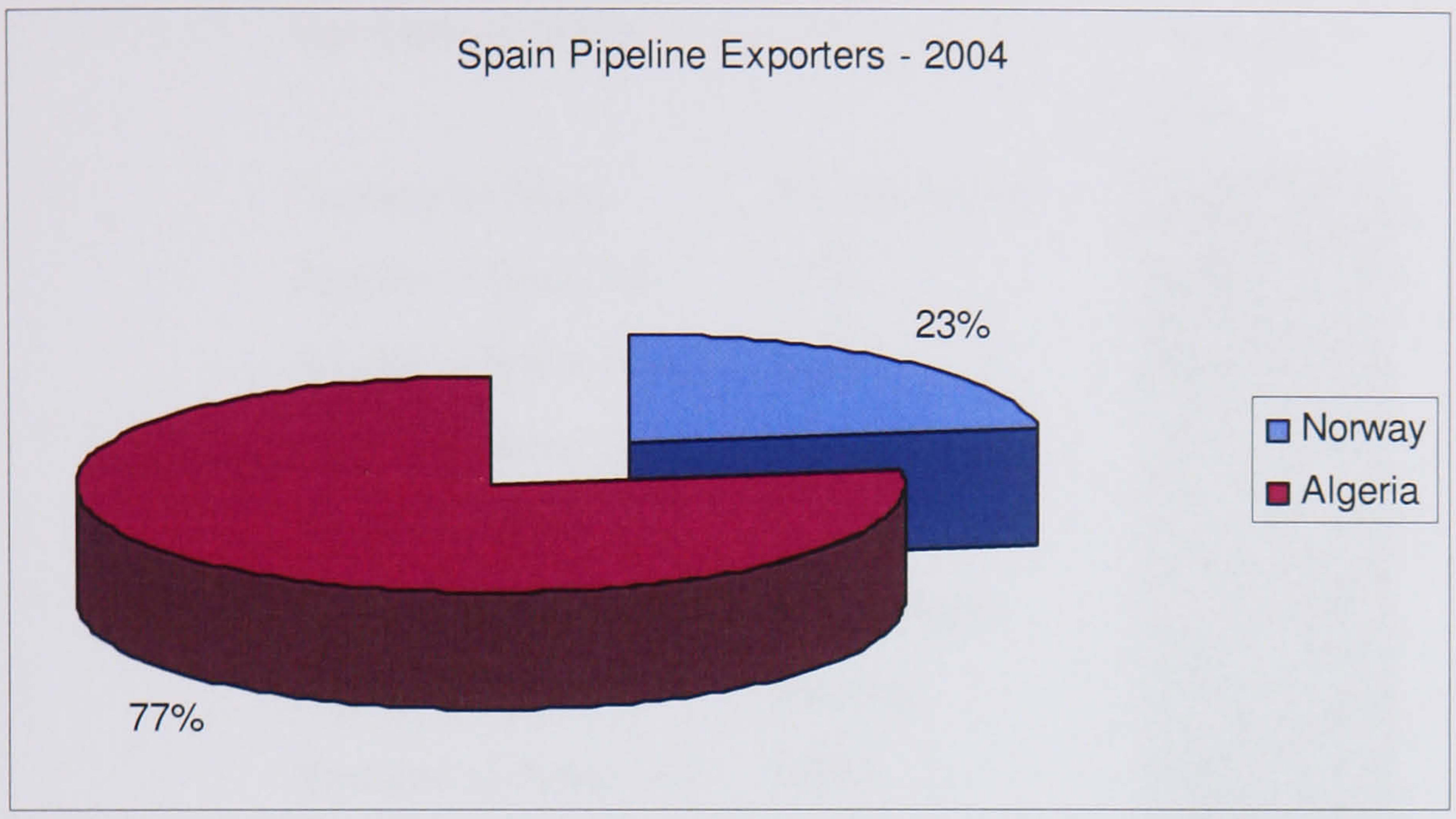


Figure 3-20 Spain's pipeline partners[59]

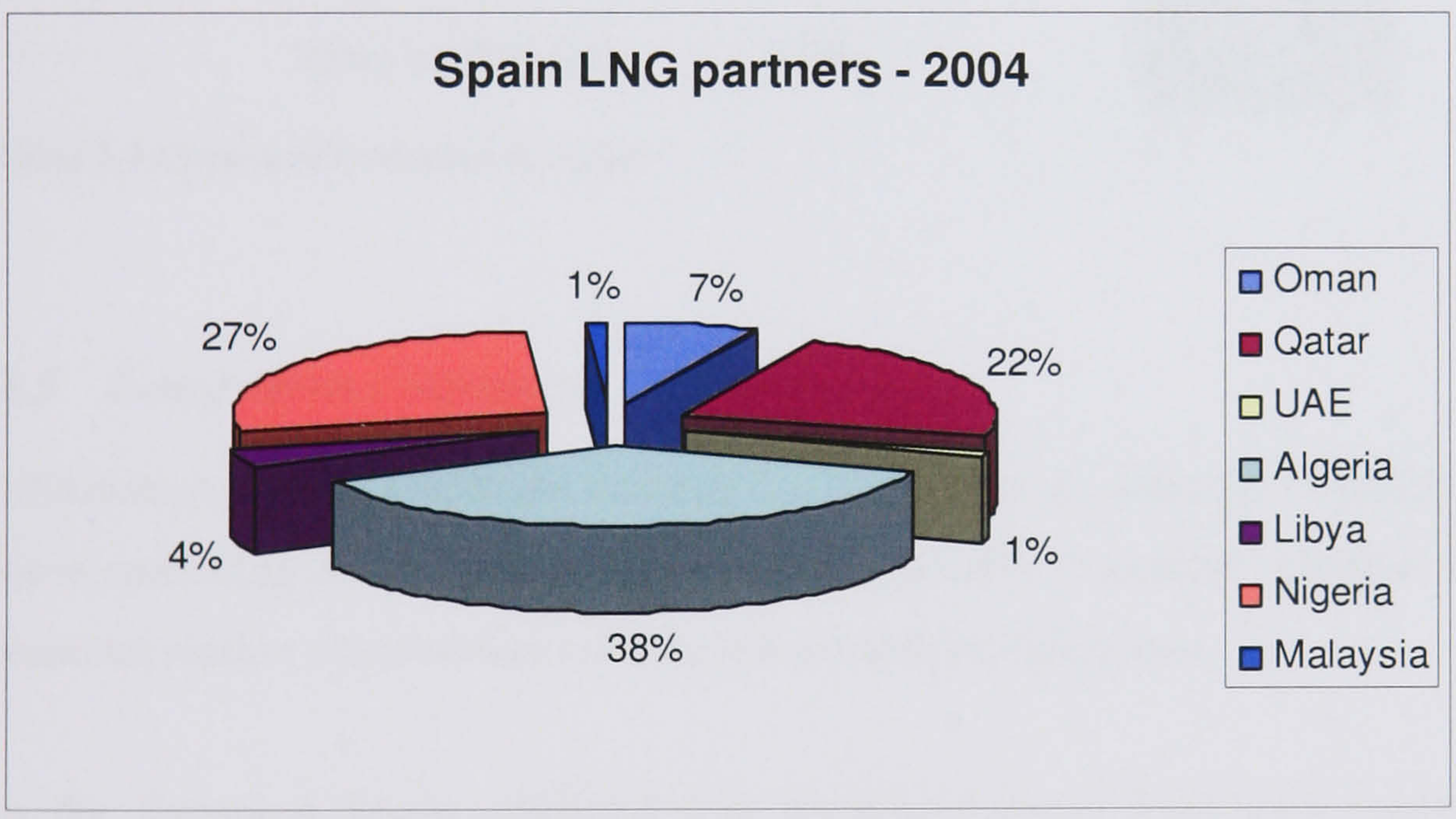


Figure 3-21 Spain's LNG partners[60]

[59] BP Statistical Review of World Energy (2005)

[60] BP Statistical Review of World Energy (2005)

Contracts to Spain		Bcm/year 2003
Norway to Spain	Port de Larau	2.1
Algeria to Spain (H)	LNG	0.83
Algeria to Spain (C)	LNG	0.1
Algeria to Spain (B)	LNG	2.37
Nigeria to Spain	LNG	4.3
Algeria to Spain	G.Maghreb-Europa	6
Trinidad to Spain (H)	LNG	0.85
Trinidad to Spain (B)	LNG	0.85
Libya to Spain	LNG	1
Spain to Portugal	LNG	2.8

Table 3-3 Contracted volumes to Spain[61]

3.5 Long term contracts

Information about natural gas contracts in the region is normally confidential. However, some consulting firms, such as Gas Strategies, publish "assumed" contract terms that are based on market observations and discussions with market actors.

In the European Market, Natural Gas purchased under long term contracts is priced according to substitute commodities often crude oil and sometimes –but rarely nowadays- coal.

[61] Gas Strategies Online (2005)

According to the assumptions of Gas Strategies, the system used to calculate the price prevailing is a formula comprising three "variables" (Data period – Time lag – Price recalculation frequency). The price is calculated using the weighted differences added to a price P_0 which is negotiated upfront.

For example the Algeria-Spain LNG contract is priced, on a netback basis (that is to calculate P0), indexed to a basket of crude on a "6-0-3" formula. This means that Natural Gas will be priced according to the average of Breakeven Rotterdam Price Average of eight crudes (Sahara Blend, Brass River, Zueitina, Murban, Kirkuk, Light Iranian, and Light Arabian) for the last six months. Immediately prior to the contract pricing point (the second variable is 0) and that the price will be recalculated every three months.

From	To	Type	Pricing
Algeria	Spain	LNG	Basket of crudes @ 6-0-3
Libya	Spain	LNG	Unknown
Nigeria	Spain	LNG	LSFO[62] (40%), HSFO[63] (26%), Gas Oil (34%) @ 6-0-3
Trinidad	Spain	LNG	LSFO (30%), HSFO (30%), Gas Oil (40%) @ 6-0-3
Norway	Spain	Pipeline	LSFO (35%), HSFO (27%), Gas Oil (38%) @ 6-0-3
Algeria	Spain	Pipeline	LSFO (30%), HSFO (30%), Gas Oil (40%) @ 6-0-3
Algeria	France	LNG	Brent @ 6-0-3
Netherlands	France	Pipeline	Unknown

[62] Low sulfur fuel oil

[63] High sulfur fuel oil

Norway	France	Pipeline	LSFO (37.5%)@ 6-0-3, Producer Price Index (22.5%), Gas Oil (40%) @ 9-0-3
Norway	Germany	Pipeline	Gas Oil (63%) @ 6-1-3, LSFO (37%) @ 3-1-3
Netherlands	Germany	Pipeline	Gas Oil (55%) @ 9-0-1, LSFO (45%) @ 6-0-1
Russia	Germany	Pipeline	Gas Oil (75%), LSFO (25%) @ 9-0-1
Algeria	Italy	Pipeline	Unknown
Netherlands	Italy	Pipeline	Unknown
Russia	Italy	Pipeline	Gas Oil (75%), LSFO (25%) @ 9-0-1
Nigeria	Italy	LNG	Indexed to coal prices, as detailed below

Table 3-4 Examples of LTC terms to Europe[64]

Another example is the Italia – Nigeria contract to ENEL. Gas Strategies believes that these contracts are priced as using the following components:

30% Brent Crude (FOB Sullom Voe) @ 6-0-3

20% High Sulphur Fuel Oil (HSFO - CIF Med.) @ 6-0-3

20% Low Sulphur Fuel Oil (LSFO – CIF Med.) @ 6-0-3

20% Coal (CIF Italy ports average) @ 6-0-3

10% Inflation factor (OECD average)

However, coal indexation is rarely used due to the low substitution factor between coal and natural gas if compared with crude oil and the difficulty of finding reliable coal pricing data.[65]

[64] Source: Gas Strategies 2003

3.6 Producing countries

Suppliers to the North Mediterranean block are numerous and trade through pipeline is significantly higher than that through LNG. Pipeline trade flows are usually Long Term Contracts whereas LNG trade flows are mixtures of LTCs and spot trade. In terms of LNG, Spain has the most diversified supplier-base, in accordance with its energy import policy of diversification. Due to its geographical proximity, Algeria is by far the largest LNG exporter to the block. In terms of pipeline, Russian, Algerian and Norwegian gas compete, followed by the Netherlands and the UK (small quantities to France). Spain only imports pipeline gas from Algeria and Norway whereas France and Italy import from other suppliers such as the Netherlands and Russia. There is no direct pipeline connection between Algeria and France, which explains the high quantities imported by LNG.

Algeria is the first natural gas exporter to the block with 45.16 BCM, 60% of which is exported via pipeline. Italy is Algeria's first client with a 50% export share followed by Spain (27%) and France (23%). Algeria's reserves are estimated to 4.52 TCM with a current R/P ratio of 56 years. Algeria has a privileged position due to its geographical proximity resulting in low transportation costs as well as low extraction costs. There are two major projects underway for the construction of two new pipelines in the next 5 years from Algeria to Italy and Spain, which will come to supplement the pipelines already operating[66].

The Russian Federation does not yet export LNG but is the second supplier of the block and the first one by pipeline (30.70 BCM). Russian gas going to Italy represents 63% of the former exports. France is the other client of Russia in the block. The Russian Federation sits on the world's largest reserves with 47.57 TCM (more than 10 times those of Algeria) and a

[65] Source: Gas Strategies 2002

[66] Source: Benbouzid. H, Sonatrach London, personal communication (2003)

high R/P ratio with the current production figures of 554.9 BCM covering both local consumption and exports. Russian gas is impeded by high costs of transportation to the block.

Norway and the Netherlands follow in the list. Both of these countries are perceived as suppliers with much lower credit risk and higher (geo)political stability, the Netherlands being a member of the European Union, which provides their gas with preferential tariffs and other trade treatments. Norway and the Netherlands exported 21.32 and 16.60 BCM in 2004, respectively, exclusively by pipeline. Norway's and the Netherlands' reserves of 2.19 and 1.79 TCM only allows them for around 30 years R/P ratio at the current production levels. This has to be taken into account together with their rising consumption, especially for the Netherlands, which only exports a third of its production (compared to its competitors who export a higher share).

Nigeria is the newcomer to the North-Mediterranean gas import market. Due to its geographical position, Nigeria can only export LNG for the time being, however discussions are under way for the construction of a 2500 kilometres pipeline (the Trans-Saharian Gas Pipeline) transporting Nigerian gas to through the Algerian existing and planned pipeline infrastructure to Europe. Nigeria exports 5.91 BCM worth of LNG to the block with 60% of it going to Italy, 27% of it going to Spain and 23% to France (comparable export portfolio weights to those of Algeria). Nigeria sits on 3.51 TCM of gas with an R/P ration currently reaching 198 years.

Other current exporters are the UK (1.29 BCM by pipeline to France). Spain imports small quantities of LNG from a number of other countries: Trinidad and Tobago 0.46 BCM, Oman 0.76 BCM (Oman also exports to France), Qatar 2.20 BCM, The UAE 0.50 BCM, Libya 0.63 BCM, Australia 0.07 BCM and Brunei 0.08 BCM.

Libya's 1.31 TCM reserves and its low consumption give it the potential to be an exporter with growing market share. Egypt is also involved in LNG projects and negotiations for LTCs with some countries of the block and with its reserves of 1.66 TCM it is also expected to grab a growing market share. Both Libya and Egypt are favoured by the low transportation costs due to their proximity to the market.

Iran and Qatar with their important reserves of 23 TCM and 14.4 TCM respectively, their low cost of extraction and their high R/P ratios (356 and 491 respectively) make them serious contenders for market, the former by pipeline and the latter by LNG.

3.7 Market liberalization, Security of supply and the Mediterranean, a discussion

The ongoing liberalization of markets in Europe and the increasing awareness about security of supply has prompted discussions about whether the former could represent a problem to the latter.

If firms evolve in a competitive market, there is a price response to supply and demand. If also total demand is assumed to be less price elastic than supply[67], this will create a market where prices are determined mostly by supply and capacity. However, infrastructurally-constrained markets of this sort usually display strong cyclical behaviour, driven mainly by investment lags. When there is abundance of capacity, prices are low. Accordingly, profits are squeezed and there is small investment in infrastructure which leads, when demand catches on, to a scarcity of capacity which itself pushed prices up.

[67] This is a reasonable assumption since markets are not fully open and that evidence in other energy markets including oil and electricity suggest that demand is more responsive to exogenous variables than endogenous ones –i.e. price

This can be observed in many already regulated markets. Taking the UK as an example, Wright (2004) "contests the view held by the current UK government and its industry regulator, OFGEM, that liberalization is good for security of supply". In fact, he argues, "it has increased uncertainty and failing to signal adequate appropriate investment". The IEA in its "Security of Supply in Open Markets", discussing the EU market liberalisation, argues that open markets will not by themselves value investment in insurance assets to ensure secure supplies to the end-consumer under low-probability/high-impact events. Banks (2004) also argues that blackouts and crises similar to the California electricity crisis could happen under specific market conditions if the market is liberalized.

The EU Council Directive concerning measures to safeguard security of natural gas supply lists provisions such as minimum targets, gas coordination group for cases of major supply disruption and other policies. When asked about the link between liberalization and security of supply, the EU Commission Directorate for Transportation and Energy (DGTREN) stated that there were no major issues and that it was the role of EU mechanisms and national regulators to tackle this. Indeed, Frisch (1999) suggests that new forms of contracts, under liberalised markets, would ensure security of supply.

In effect, the DGTREN argues, the liberalization of the market and the implementation of the competition rules will create an environment where market forces and regulators are more responsive to market signals than governments and monopolistic firms.

From a trade point of view, liberalization means that decision-making in infrastructure investment (regasification terminals) and partners, which used to be taken at a macro level (government and incumbent), will now be taken at the micro level (by competitive, theoretically non colluding, firms). This means, in line with the cyclicality argument above, that there will be periods of over regasification capacity and period of under regasification capacity. In fact, there is an increasing concern the Spain and Italy, who are the most liberalized LNG importers of the EU, are already over/under supplied. In the winter 2005/2006, the UK has also witnessed strong upward price-pressures due to under-supply.

It is worth pointing out that there are attempts to address this problematic of security of supply in the Mediterranean at the political levels also. In the spirit of the Barcelona Process (the dialogue of EU Member States with their neighbours of the South initiated in the Barcelona Conference of November 1995), the Euromed Forum for Energy has been established and has met several times to discuss promoting infrastructure projects, empower institutions and encourage integration and standards uniformisation. This institution is still loosely structured and meets infrequently[68].

It is in this framework that the next chapters will provide a tool to assess infrastructure needs and partner choices, by modelling new capacity and new trade flows and allowing for the simulation of incidents, based on the assumption that security of supply is best safeguarded if decisions are made on the macro-level and comparing these benchmarks produced by the model with current proposed projects.

The next chapter will discuss with details the consumption patterns in France, Italy and Spain.

[68] Hallouche (2005)

4. Natural gas demand in France, Italy and Spain

This chapter examines, econometrically, the past trends of natural gas consumption in France, Italy and Spain for the domestic and industrial sectors and discusses the results.

Natural Gas, the so-called fuel of the 21st century, is gaining market share as a primary energy source in world consumption, particularly in Europe. The need to decrease dependence on other sources, such as oil, and on foreign imports as well as a move towards more energy efficient and environment friendly fuels provides natural gas with high prospects of growth both in nominal consumption figures and in market share in the medium-term future.

Natural gas infrastructure investment calls for large capital outlay, comparatively to other energy sources like oil refining and transportation. The investment profile is also front-loaded. Understanding the demand dynamics of natural gas is of paramount importance for infrastructure planning, especially in a market in the infant stage of its liberalization, as the French, Italian and Spanish markets are. There is, nonetheless, little research work on how this demand is evolving in these markets.

4.1 Literature review

Literature on the estimation of demand for energy, and natural gas, is abundant. Most of it, however, is concentrated on the US market, this is principally due to the availability of data.

MacAvoy & Moshkin (2000) attempt to predict long-term well-head natural gas prices in the US using simulations and a partial equilibrium model. The system consists of simultaneous equations for production from reserves and for demand for production in the residential, commercial and industrial sectors. The model has predicted a long-term negative price trend in the US well-head natural gas market.

One of the important features of this model, one which is relevant to this research, is the equations related to the demand side of natural gas in the US. The model uses the following variables as explanatory ones:

Industrial demand:

- Industrial production
- Lagged NG industrial consumption
- Natural Gas price for industry
- Weighted average of other fuel prices for industry (coal, gas and oil)
- It is worthwhile noting that the model assumes –and proves- a breakpoint using dummy variables

Electric Utility demand:

- Lagged consumption of NG for electrical utility
- Personal consumption expenditure
- Natural Gas price for electricity generation
- Weighted average other fuel prices for electricity generation (coal, gas, oil and nuclear)

Commercial demand:

- Lagged consumption of NG for commercial use
- Personal consumption expenditure
- Natural Gas price for commercial use

Weighted average of other fuel prices for commercial use (coal, gas, oil and nuclear)

Residential demand:

- Lagged consumption of NG for residential use

- Personal consumption expenditure
- Natural Gas price for residential use
- Weighted average of other fuel prices for residential use (coal, gas, oil and nuclear)

Putting together the latter demand model with a set of six equations used for the supply side and involving new exploratory activity, reserves, development activity and production, the paper constructs a partial equilibrium model with total demand and total supply functions.

With R square figures between 93% and 95% the model predicts a long term significant decrease in US well-head natural gas prices due to new technologies of exploration; however the depletion of natural gas reserves reduces faster relatively to the demand. Such relationship puts downward pressure on the price as supply increase is, in relative and expected terms, proportionally higher than demand.

The demand side of this model has some features of the top-down approach. It takes into consideration both total energy demand and shares of different competitor sources. On the supply side, the model takes into account the most important variables, but does not include the cost of extraction, which is widely considered to be an important factor for the supply estimation. The paper displays a strong model with robust estimation results in terms of R-square and also forecasts that can be checked against actual development. However, it deals with natural gas in an internal market, with market driven supply, demand and prices, and in a region where data is available. As important as the contribution of this paper is, it cannot be used for an international market with a different, and changing, structure. Only components thereof will hence be exploited.

Garcia-Cerrutti (2000) estimates elasticities of residential energy demand from a panel county data using dynamic random variables models with heteroskedastic and correlated error terms. This piece of research is inspired from Dahl (1993) who looks at the cross-sectional responses of energy consumption due to changes in demand factors. The variables used are energy prices, income and weather. This research conducted using panel data and attempting both cross-sectional fixed and cross-sectional variant coefficients and testing the models resulting therefrom. The Garcia-Cerrutti (2000) research looks at a panel of 44 counties in California, US. These counties are chosen to represent different population and population growth profiles. The panel data uses a dynamic random variables model that treats the constants of the regression as cross-sectional and time varying, as opposed to having fixed constants or cross-sectional variant constants.

The research aims mainly at calculating natural gas residential elasticity but addresses also electricity's. This research concludes that "county variations in the responses to changes in prices, income and weather make ineffective the use of econometric techniques assuming complete cross-county homogeneity or heterogeneity of the responses in both electricity and natural gas demands". Panel data at the county level, according to the paper, represent accurately the variations in prices, income and weather that occur within the state. These inspire partly from Hsing (1994) which constructs three models using a log-lin approach for the regional residential demand for electricity based on panel data of five southern states of the USA during 1981-90. The three models are: OLS; a CSHTWA (cross-sectionally heteroskedastic time wise autoregressive) model; and a CSCTWA (cross sectionally correlated and time wise autoregressive) model. The variables used are price of substitution, disposable income, price of natural gas, and weather (Heating Degree-Days and Cooling Degree-Days). The latter model, namely CSCTWA, yields more efficient estimates. Under this model, all the elasticities are found to be significant and in a sign suiting economic theory, however some elasticities are found to be different from those obtained in other research for the United States.

Both of the above articles use similar estimation methods for natural gas consumption and its elasticities towards different other factors such as prices, weather and income. Depending on the stationarity conditions of the data these papers do not attempt to look at different term elasticities through the use of cointegration methods nor do they discover any short-term and long-term elasticities effects. Additionally, it is possible to check for elasticities for upward and downward price movement separately (asymmetric price response) which was not expressed in both articles. Indeed the literature of price asymmetry, notable example of which are Ryan & Plourde (2002) find significance for non-transport oil demand and Griffin & Schulman (2005) find significant price asymmetry in energy per capita.

On the other hand, some of the approaches used for these articles are potentially useful to the present research, as the data frequency available does not allow for more elaborate econometric analysis.

Balestra & Nerlove (1966) use the panel data method to estimate a regression panel of 36 states over six years (time series and cross-sectional data) and uses a number of macro-economic and endogenous variables. Other approaches include Bohi (1981) and Hartman (1979), respectively offering methodologies for some of the papers above and discussing the frontiers of energy modelling. Also, Halvorsen (1978) offers econometric models for the US energy demand. A research for the OPEC review of 1990, by Brennand & Walker, looks at the effect of the level of income growth on income elasticities for the demand of energy. Beenstock & Willstocks (1981) look at the relationship between economic activity and energy demand in industrialised countries.

Liu & Lin (1991) in turn look at the patterns of residential natural gas consumption in Taiwan. Price and a proxy for weather are used as explanatory variables. The objective of this research is forecasting. An intervention model and outlier detection and adjustment methods are used to tackle governmental price intervention and the treatment of outliers, respectively. Both monthly and quarterly data are used and quarterly data offers a higher performance in terms of RMSE both in sample and out-of-sample. The weather proxy used is the temperature, although the data set normally utilized in the literature is HDD and CDD (Heating Degree Days and Cooling Degree Days). Further, the paper identifies some problems regarding the reality of the data for prices used and its potential effect on the integrity of the model (i.e. the government price interventions.)

Uri (1989) offers a parsimonious model for the estimation of agricultural natural gas demand with respect to other variables including substitution prices. The model estimated is a log-log model with natural gas prices for agriculture use, weighted average substitute prices for agriculture use, total income for farmers, CDD and HDD. The data are monthly between 1978 and 1980 and cross-sectional by states. The results show an R-square of over 90% with significant (and with signs concordant with theory) parameters. The paper suggests that natural gas prices affect consumption and other energy prices also affect natural gas prices through substitution. Income and weather also have a significant effect.

Engle & Granger (1987) and Johansen (1991) have offered new grounds for the estimation of energy consumption/demand, especially for the long term, through error correction models and cointegration. Lin, Chen & Chatov (1987) pioneer modern cointegration analysis of energy demand, using an error correction component model composed of nine equations; it analyses the demand for natural gas, electricity and heating oil in the United States. The Avery Component Model is used on a system of simultaneous equations with a SUR correction, due regard being given to short term and long term income and price elasticities and speeds of adjustment. The nine equations are residential, commercial and industrial estimates for natural gas, electricity and fuel oil, and the variables are prices and income. The results of the estimation show that the elasticities for price and income against consumption are significant in the short run and increases in the long run. Also, the elasticities are significantly different across fuel, region and use and, again, between the short run and the long run. One of the interesting results of this paper is the cross-elasticities of prices between the three fuels used, which shows that there is some level of substitution.

This paper exhibits an interesting research on the patterns of energy consumption for regions and sub-regions in the United States; it also shows results compared by fuel, by sector or use, by region, by sub-region, nationally and also compared between long-term response and short-term response. The model is parsimonious and the results concord with economic theory. For the needs of the present research, this paper's methodology may be highly important; the only problem is the frequency of data and the number of data-points needed. One other remark is the non-inclusion of weather variables.

Bentzen (1994) and Bentzen & Engsted (1993) both use cointegration techniques for the estimation of energy sources demand in Denmark and they are both interested in short run and long run elasticities using Danish annual data for 1948 to 1990. They both use price and income as explanatory variables as it is common in the literature. The first one of them concentrates on gasoline consumption and the second one on total energy consumption. The first paper (1994) proves that there is a stable relationship and positive long-term elasticities between the price, income and gasoline consumption. The signs and magnitudes of the parameters are said to be of the 'right expected magnitude' and no evidence of a structural break due to the oil shock of 1973-1974 was found. Again, this methodology is appropriate for the problematic at hand, but it is data-hungry.

Exactly the same results are found in the second paper (1993), which looks at aggregate consumption, both in terms of the signs, significance and magnitude of the parameters and the absence of evidence for a structural break due to the oil price shock in 1973-1974. In addition, this paper offers some forecasts, which, it claims, concord to some extent with other official forecasts. The paper, however, does not offer any in-sample forecasts that could have added to its integrity. The Stock-Watson Dynamic OLS approach is used by Al-Azzam & Hawden (2004) to estimate the aggregate demand for energy in Jordan using a lead/lag of 3 days. The model is log-log and it uses real price, real income, constructed area[69] in square meters and a dummy variable for political events. By using a normal error correction model separately and comparing the results with those obtained with the former

[69] Urban area within the land – used as a proxy for transportation needs

model, long-term bias is reported to be found. The paper found, *inter alia*, that demand was not elastic to price. The constructed area variable was initially used by Pyndick (1974) but was not predominantly used in recent literature, especially the one concerning natural gas consumption. Total area constructed is usually used for crude oil and crude oil products consumption.

Al-Azzam & Hawden follows many of the methodologies used in cointegration analysis for different energy sources consumptions, but it innovates in the use of the new Stock-Watson Dynamic OLS approach and in the use of variables not commonly used. It should, however, have commented on causalities as they have a major importance in policy implications, also the paper could have looked at short and long term elasticities, which is possible under the used cointegration technique and which would have been an interesting addition.

Note that the cointegation technique used in this paper was first introduced by Masih & Masih (1996) in an article in Energy Economics entitled "Stock-Watson dynamic OLS (DOLS) and error correction modelling approaches to estimating long and short term elasticities in a demand function: new evidence and methodological implications from an application to the demand for coal in mainland China". This paper borrows the technique introduced by Stock & Watson (1993). Masih & Masih (1996b) offer a cointegration approach but on a panel data basis.

4.2 Data

The data used for the needs of the model in natural gas consumption observations for France, Italy and Spain for residential, commercial, power generation and industrial needs. Such data covers the time period between 1978 and 2000, inclusive, and are collected from the International Energy Agency (IEA)[70] in Terra Joules (TJ) (calorific measure as opposed

[70] IEA Energy Statistics of OECD countries CD

to volume measure). Natural Gas end-user prices (including tax) for domestic, power generation and industrial consumption and assumed substitutes thereof are, when possible, also collected from the IEA[71]; the units are US Dollars per TJ. Substitutes for the three sectors are assumed to be electricity for domestic consumption, steam coal for power generation and fuel oil for industrial consumption; the units are US Dollars per respective unit. Finally, different macro-economic indicators such as population (in millions), Gross Domestic Product (in billion US Dollars), Industrial Production (index number) and Home Expenditure (in billion US Dollars) are collected from the IMF[72].

The following shall look at the statistical properties of the data collected, outlined in the table below. For power generation consumption, Italy heads the list with a little more than 350000 TJ on average followed by France and Spain. France and Italy's observations are normally distributed using the Jarque-Bera statistics. It is important to note that nuclear energy represents an average of 75% of France's electricity generation energy needs. Spain generates its electricity mainly with coal (38%), nuclear (32%) and natural gas only accounts for 3.5%. Italy, on the other hand, yields its electricity from oil (45%), natural gas (21%) and coal (13%). For Industrial consumption, Italy heads the list with an average of 61900 TJ. Italy's natural gas industrial consumption also has the highest standard deviation. Industrial consumption for all countries is normally distributed with a 5% confidence interval. France's industrial energy consumption is obtained, on average, from oil (35%), gas (28%) and electricity (23%). Italy and Spain's industrial consumption pies are 30%, 37%, 24% and 41%, 21%, 25%, respectively. Coal accounts for the rest of industrial consumption for the three countries.

For commercial consumption, France is the first with an average of almost 30000 TJ - approximately 3 times that of Italy. For residential, or domestic, consumption, Italy tops the

71 IEA Energy Prices and Taxes CD

72 IMF International Financial Statistics Database

list with 67000 TJ, approximately double France and triple Spain. All residential and commercial natural gas consumption series are normally distributed on a 5% coefficient interval. In the transport sector (included with commercial in the present analysis) oil represents virtually the totality of energy consumption for all three countries. As for domestic and commercial consumptions (combined), the market share is for France 32% oil, 35% gas and 25% electricity, for Italy 30% oil, 44% gas and 24% electricity and for Spain 44% oil, 8% gas and 42% electricity.

Moving on to prices, and noting that France's natural gas end user price for power generation is not available, it can be seen that Spain's power generation natural gas price is 25% higher than that of Italy, on average. Spain's Industrial gas price is also approximately 16% higher than that of Italy and France, on average. Finally, Spain's residential natural gas end user price is, on average, also higher than Italy's, by an average of 2%, and higher than that of France by an average of 20%. Natural Gas, for all sectors, is therefore more expensive in Spain and, notwithstanding power generation, is least expensive in France.[73]

A general trend that can be observed is that all consumption figures are increasing, with different volatilities and with different slopes. Industrial Consumption shows, in general, the highest slope of increase. The domestic consumption of Italy also shows a high slope during the studied period. The analysis herein takes into account average figures which only give an indication about the size of the industry over the studied period.

4.2.1 Descriptive Statistics of the Data

FRANCE	Power Generation	Industrial Consumption	Comma Cons	Resida cons	Industrial Gas Price	Domestic Gas Price	Power Gen. Gas price
Mean	36246.61	532959.7	295861.5	335619.9	153.2135	417.5378	NA
Range	67098	297352	232593	221395	88.92	211.48	NA

[73] All market share figures are obtained from IEA statistics

Std. Dev.	19569.34	81162.87	73710.43	65738.98	21.98556	54.6767	NA
Jarque-Bera	4.164834	1.144928	1.373806	1.22463	1.167283	1.217063	NA
Probability	0.124629	0.564134	0.503132	0.542094	0.557863	0.544149	NA

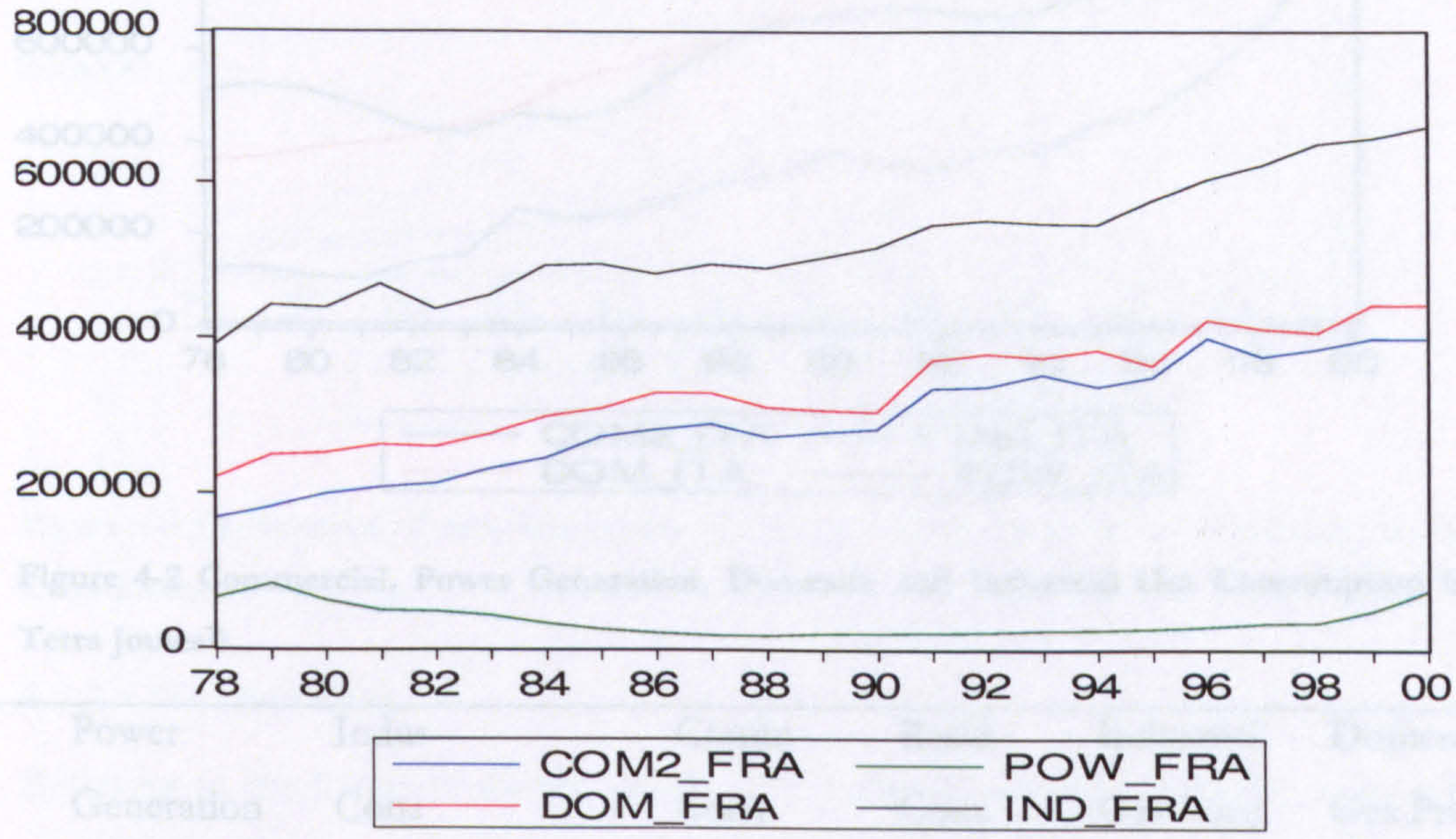


Figure 4-1 Commercial, Power Generation, Domestic and Industrial Gas Consumption in France in Terra Joules[74]

ITALY	Power Generation	Indus Cons	Comma Cons	Resid Cons	Industrial Gas Price	Domestic Gas Price	Power Gen. Gas price
Mean	348477.6	617866.8	11517.13	669768.7	155.4865	490.4	127.093
Range	763195	401512	5505	635747	114.36	625.01	132.55
Std. Dev.	203380.9	127350.7	1332.311	215736	34.40783	208.1337	34.12229
Jarque-Bera	3.823249	1.992096	3.146164	2.025371	3.211969	2.273214	0.317216
Probability	0.14784	0.369336	0.207405	0.363242	0.200692	0.320906	0.853331

[74] Source IEA (2003)

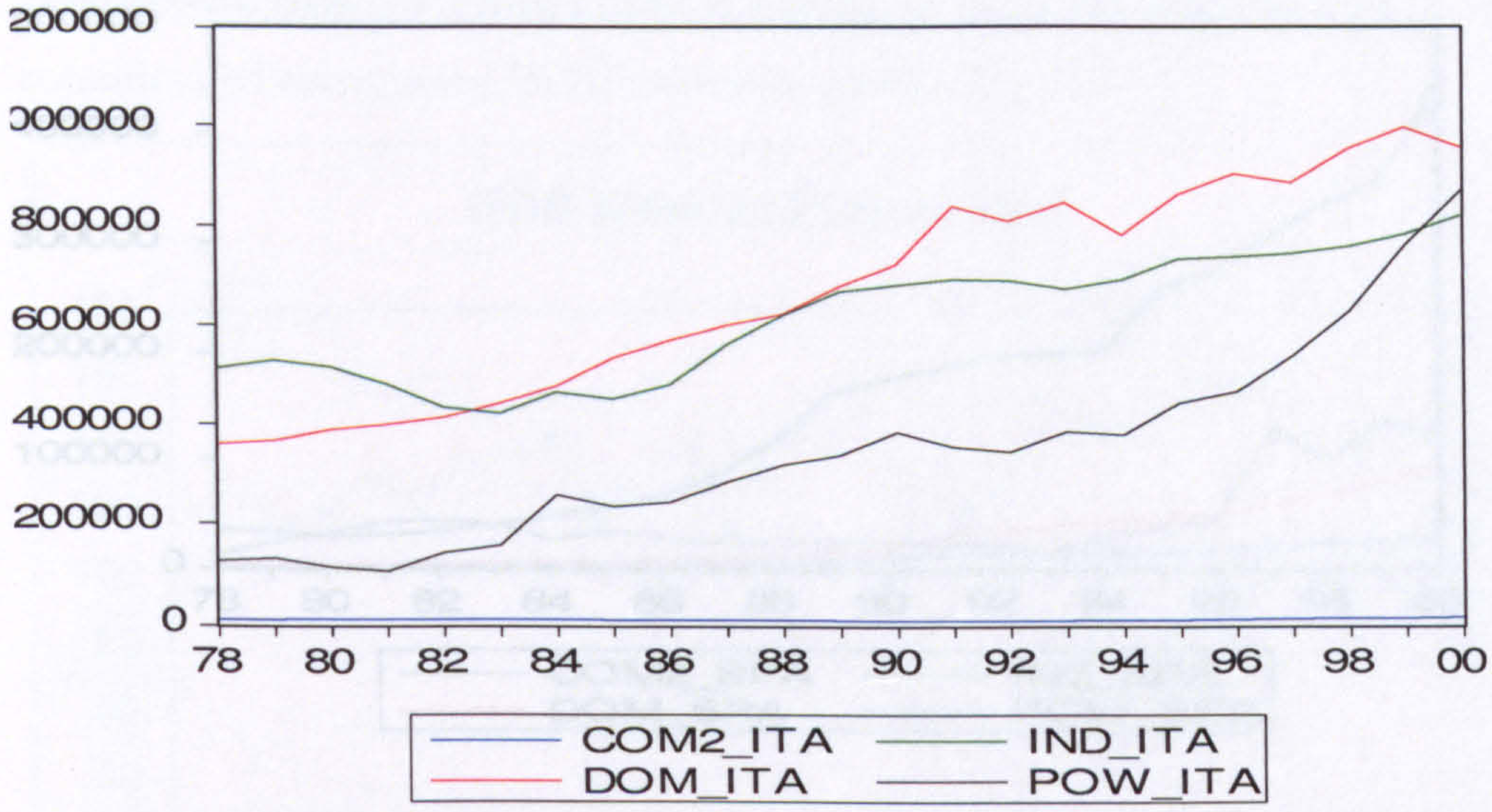


Figure 4-2 Commercial, Power Generation, Domestic and Industrial Gas Consumption in Italy in Terra Joules[75]

SPAIN	Power Generation	Indus Cons	Comm Cons	Resid Cons	Industrial Gas Price	Domestic Gas Price	Power Gen. Gas price
Mean	45113.43	160164.3	9396.783	27079.83	179.163	499.6752	167.9761
Range	125212	423889	26801	88059	193.41	463.72	163.53
Std. Dev.	37999.56	125235.2	8467.064	27289.39	54.36129	105.8579	42.93427
Jarque-Bera	11.16339	2.031688	2.823675	3.673557	8.543108	1.124159	0.418922
Probability	0.003766	0.362097	0.243695	0.15933	0.01396	0.570022	0.811021

[75] Source IEA (2003)

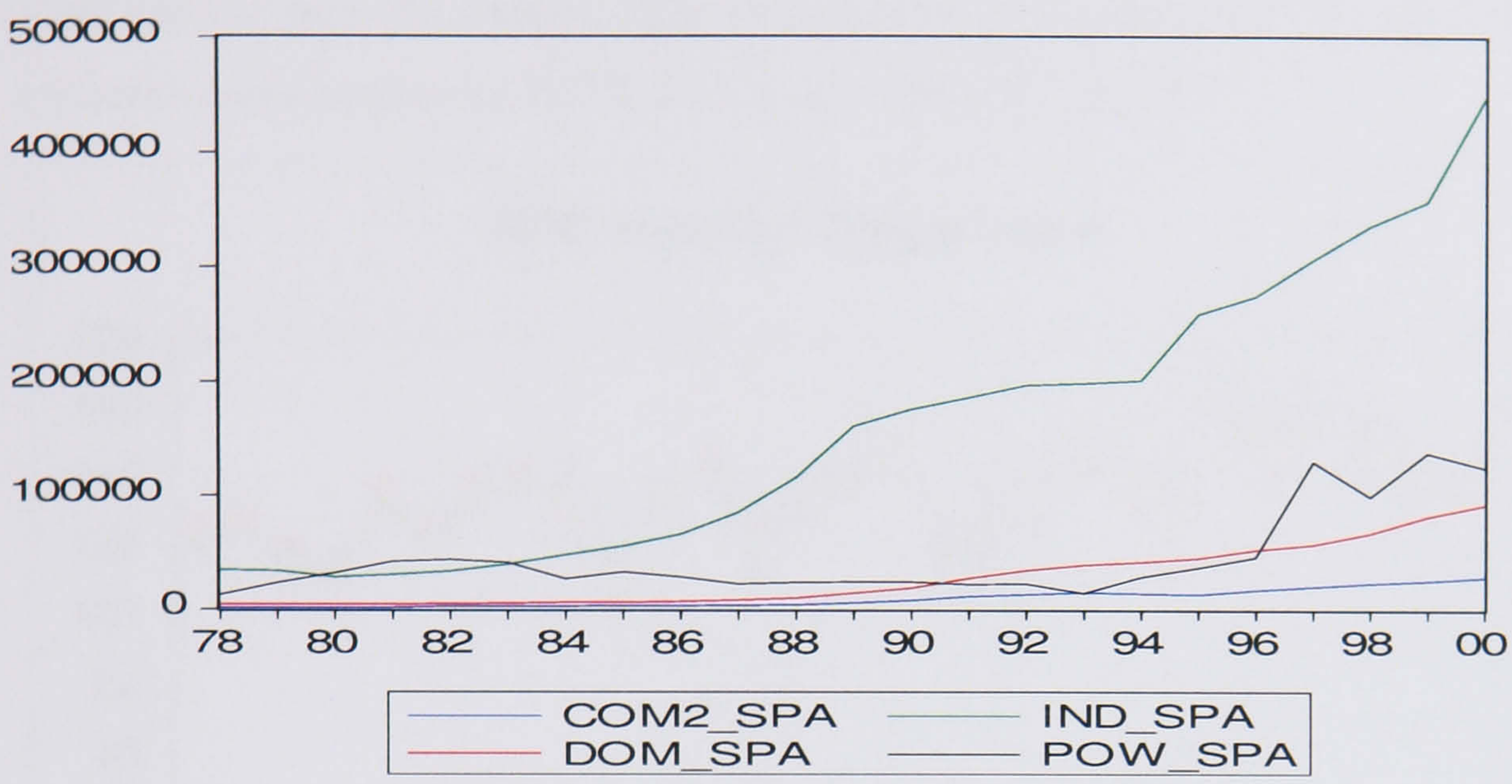


Figure 4-3 Commercial, Power Generation, Domestic and Insdustrial Gas Consumption in Spain in Terra Joules[76]

4.2.2 Weather data

Referring to the literature above, weather is clearly an important variable to be included in energy consumption estimation, particularly residential consumption. With the exception of the paper by Moral-Carcedo & Vicens-Otero (2005) who estimate electricity consumption in Spain, the literature including weather is not voluminous.

The variables normally used as a proxy for weather are HDD (heating degree days) or CDD (cooling degree days). The CDD and HDD datasets are not available for France, Italy and Spain. They have therefore to be constructed. According to Plourde (2005), in order to construct the variables, daily temperature data has to be collected. A base temperature of 18 Celcius is usually used as follows: $Day\_HDD_d = 1$, if the average temperature of day d is smaller than the base temperature. $Day\_HDD_d = 0$, if the average temperature of day d is higher than the base temperature. Then, the yearly proxy for weather is calculated as the sum of the daily HDD: $HDD_t = \sum Day\_HDD_{d,t}$

[76] Source IEA (2003)

Temperature data for France, Italy and Spain is collected from the Met Offices of these countries and constructed HDD present the following results:

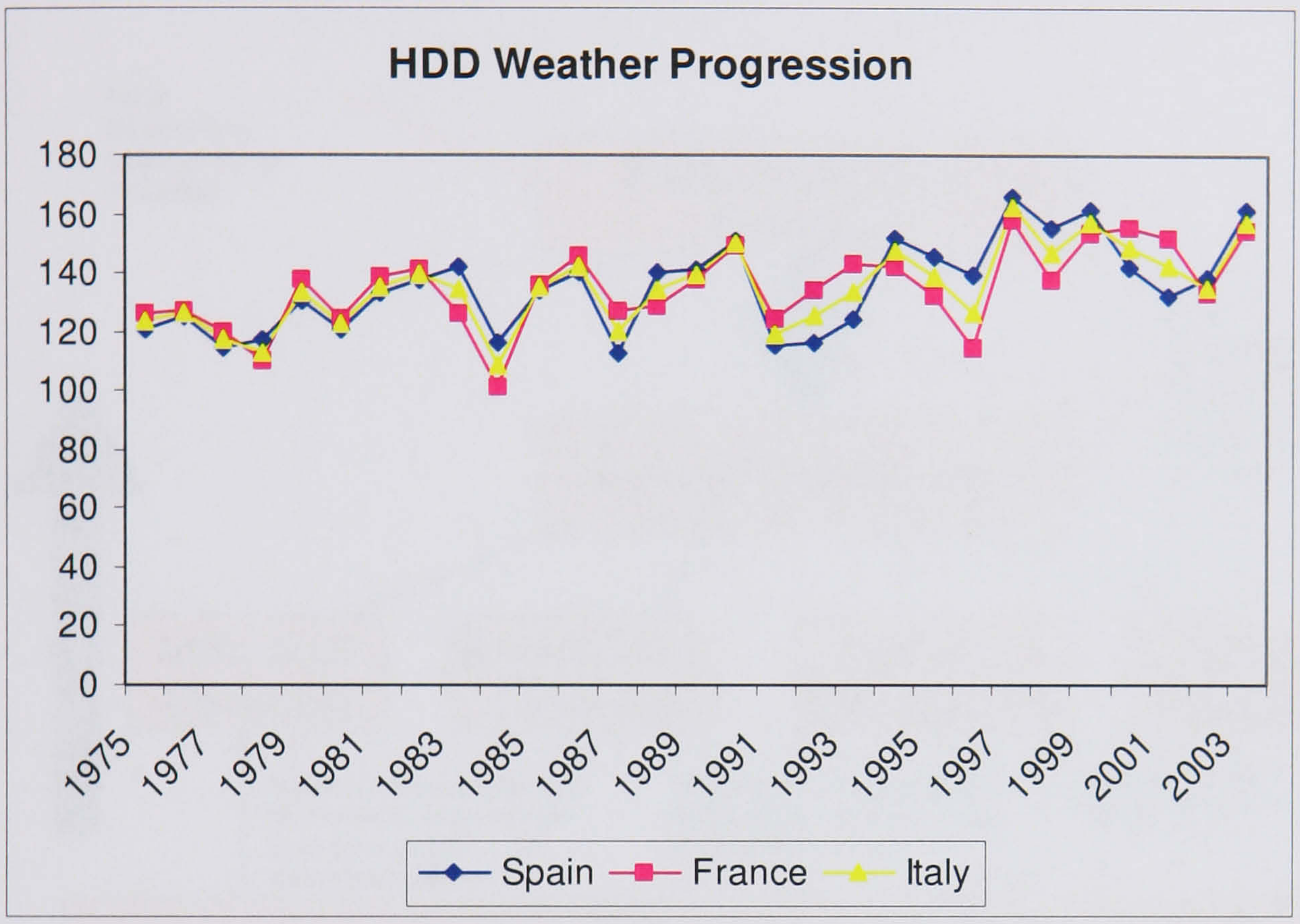


Figure 4-4 HDD data for France, Italy and Spain[77]

[77] Author's calculations based on Plourde (2005) and French, Italian and Spanish Meteorological Offices data

4.3 Estimating Natural Gas Demand

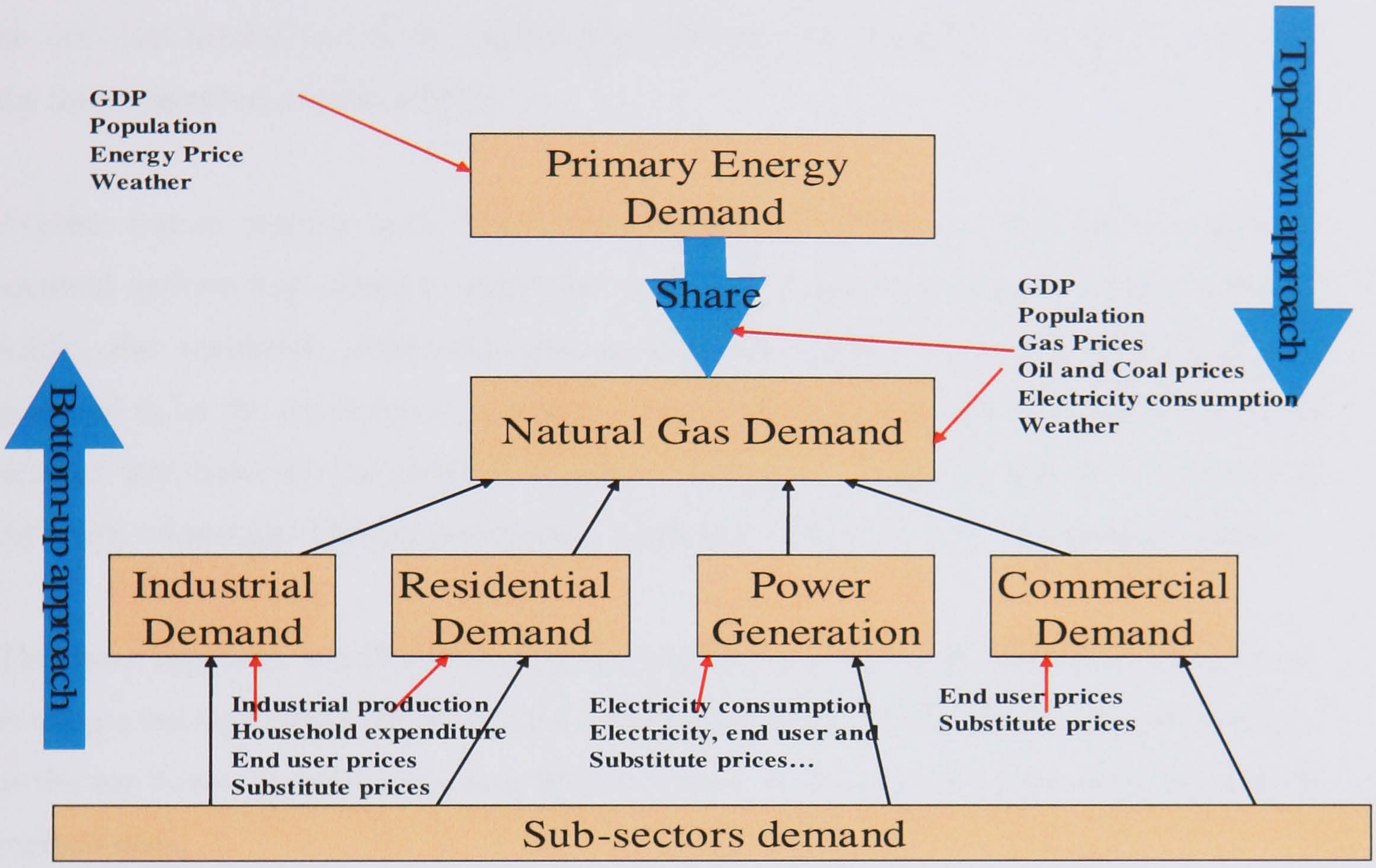


Figure 4-5 Estimation Methodologies for Natural Gas[78]

Based on the literature review, above, and other research in natural gas demand, such as Honore (2005), the above classification of estimation methods for natural gas is proposed. Natural gas can either be estimated as a share of total primary energy consumption (whereby total primary consumption is estimated –using variables detailed in the diagram, the share of natural gas therefrom is estimated). This method is referred to as "top-down". This methodology, though corresponding to many observers' beliefs in long-term economic reality, offers statistical challenges for forecasting since natural gas consumption is the result of the *product* of two econometric forecasts (forecast of the total primary energy

[78] Author's diagrammatical representation of ways by which natural gas consumption can be estimated for France, Italy and France. Arrow indicates level at which estimation in this thesis is done

consumption and forecast of the natural gas market share). This method is more appropriate for long-term (30 years) estimation and is excluded, as it is data-hungry (in terms of the historic data needed to run the regressions). Indeed, error correction models were run for the three countries, unsuccessfully.

Another way to estimate natural gas consumption is to observe the behaviour for all sub-sectorial activity (e.g. different industries such as the metal industry, food and tobacco, textile, also residential, different power generation potential...etc). This method has the potential to be the most precise one as it looks at different exogenous variables in a more detailed way, however this method offers the challenge of being too reliant on data that is difficultly obtainable. This method is more appropriate for short term forecasting (5 years).

The direct approach would have been interesting if there was elastic short-term substitution in the gas industry, which is not the case. It is excluded as it fails to capture long-term trends, as the top down approach does, and fails to capture short term variations as the bottom up method does.

Power generation demand is dependent on the power plants for each country, an exhaustive account of which is already presented by Honore (2005).

The model, presented below, takes commercial and residential consumptions as one variable. Also, the historic data availability requires the model to be estimated using a simple Panel Data method with national specificities taken into account using intercept dummy variables. In order to take into account the stationarity of the data and the medium term scope of the forecasts, log-differences are used.

4.4 Model & Results

Other estimations showed that GDP did not have any statistically significant impact on industrial consumption, neither did prices of gas and substitutes.

Household expenditure, prices of gas and prices of substitutes did not have any statistically significant impact on the residential and commercial consumptions. This is because of regulated prices, asymmetric price response and lag time in price response. It is also due to low elasticity in energy consumption.

Taking into account these realities of the natural gas in Europe, the model below is estimated:

$$LogD(\mathrm{Re}\,sid_{c,t}) = \alpha + \beta LogD(\mathrm{Re}\,sid_{c,t-1}) + \delta LogD(HDD_{c,t}) +$$
$$\gamma(DUMMY\_ITALY) + \theta(DUMMY\_FRANCE) + \varepsilon_{c,t}$$
$$LogD(Indus_{c,t}) = \alpha + \beta LogD(Indus_{c,t-1}) + \delta LogD(IP_{c,t}) +$$
$$\gamma(DUMMY\_ITALY) + \theta(DUMMY\_FRANCE) + \varepsilon_{c,t}$$

Equation 1 Model Specification for Industrial and Residential Consumption

Where:

$Resid_{c,t}$ is the residential and commercial consumption of gas in country c at time t

$CDD_{c,t}$ is the Heating Degree Days in country c in year t (expected positive)

DUMMY_ITALY takes the value of 1 for Italian consumption

DUMMY_FRANCE takes the value of 1 for French consumption

$Indus_{c,t}$ is the Industrial Consumption for country c at time t

$IP_{c,t}$ is the Industrial Production for country c at time t (expected positive)

$LogD(\mathrm{var}_t) = Log(\mathrm{var}_t) - Log(\mathrm{var}_{t-1})$

These models have yielded the following results:

Resid & Commercial

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.0941	0.0212	4.4460	0.0000
LogD(RESID(-1))	0.3390	0.1083	3.1294	0.0026
LogD(HDD)	0.1614	0.0637	2.5315	0.0137

FDUMMY	-0.0703	0.0230	-3.0563	0.0032
IDUMMY	-0.0649	0.0224	-2.9003	0.0050

R-squared	0.4160	Mean dependent var	0.0756
Adjusted R-squared	0.3812	S.D. dependent var	0.0893
S.E. of regression	0.0702	Akaike info criterion	-2.4072
Sum squared resid	0.3305	Schwarz criterion	-2.2491
Log likelihood	91.6592	F-statistic	11.9329
Durbin-Watson stat	2.0356	Prob(F-statistic)	0.0000

Table 5 Results of the Estimation of residential & commercial consumption of gas

Industrial

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.057818	0.018241	3.16963	0.0023
LogD(IND(-1))	0.367527	0.102687	3.579094	0.0006
LogD(IP)	0.889552	0.267982	3.319446	0.0015
DUMMY_ITALY	-0.062453	0.021174	-2.949569	0.0044
DUMMY_FRANCE	-0.058863	0.020633	-2.852894	0.0058

R-squared	0.469207	Mean dependent var	0.055554
Adjusted R-squared	0.437518	S.D. dependent var	0.087639
S.E. of regression	0.065728	Akaike info criterion	-2.539671
Sum squared resid	0.28945	Schwarz criterion	-2.38157
Log likelihood	96.42817	F-statistic	14.80657
Durbin-Watson stat	1.938455	Prob(F-statistic)	0

Table 6 Results of the Estimation of industrial consumption of gas

The results yielded significant variables with the expected signs.

The first model shows that in Spain, the driving force for growth is of 9% (constant term). In France and Italy, the trending growth will be of 2% and 3% respectively (this is calculated by adding up the constant term and the intercept dummy for each country).

On top of these growth figures, France, Italy and Spain's gas consumption will also grow by 33% of last years' growth, this is due to the legacy of decisions. The important contribution of this model shows that the growth in gas consumption is also affected by 16% of the increase/decrease in weather proxied by the HDD (the more days of heating needed, the more gas is consumed).

On the industrial production side, again Spanish growth, *ceterus paribus*, is of 6%. French and Italian growths are close to nil. On top of this, all countries grow at 36% of last year's growth and 88% of Industrial Production. The reason why this is not a one-for-one growth is due to gained efficiency.

4.5 Discussion

The medium term (2013) prospect for energy, one where structural breaks will not have a noteworthy impact, given that the fleet of appliances is relatively young, will show a steady increase of industrial production of about 8% in Spain, which should be expected to slow down towards the last period. In France and Italy, this growth should be expected to be around 2.5% per year.[79] For residential consumption, it will continue its strong growth in Spain and will slow down from the current double-digit growth rates, and will have a steady increase by 2-3%, depending on the weather conditions, in France and Italy.

[79] Assuming a 2% industrial production growth

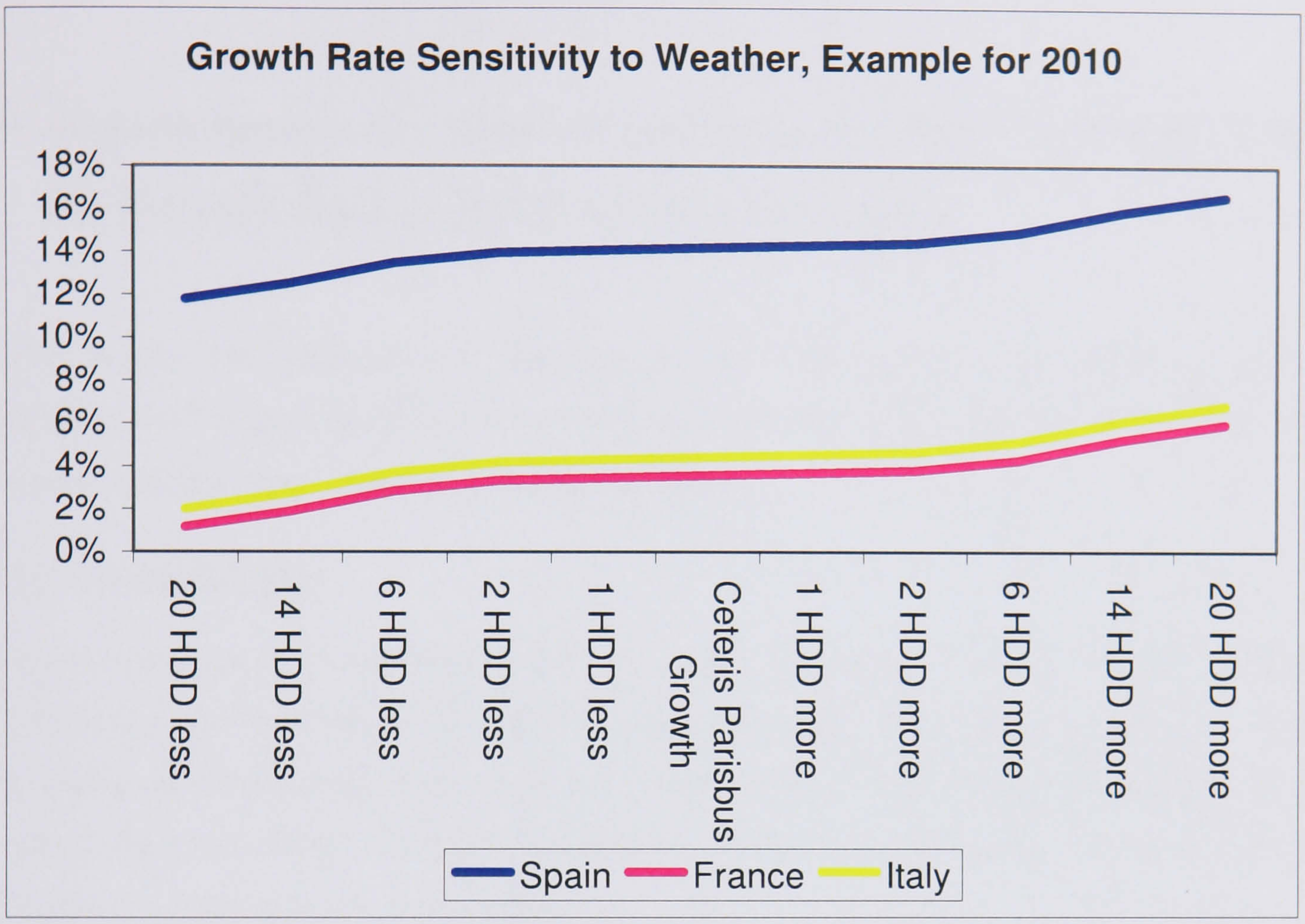


Figure 4-6 Sensitivity of Growth to Weather in France, Italy and Spain

Taking into account that the these countries are not self sufficient in natural gas imports and that pipelines have their limitations, the timing of investment in LNG infrastructure is henceforth crucial. The following chapter looks at the French, Italian and Spanish gas consumptions and the investment patterns in LNG infrastructure.

5. Determinants of decision marking in import infrastructure for French, Italian and Spanish gas markets

This chapter will investigate the determinants of decision making in the timing of the investment in import infrastructure as well as the choice of the partner in gas trade for France, Italy and Spain, using econometric methods.

5.1 Introduction

Decision-making on investment projects are usually based on the economic viability, usually expressed as the Net Present Value (NPV) based on a given discount rate. This discount rate is usually calculated based on the elements of risk that the project may entail. Other methods such as the Internal Rate of Return, Payback Periods and other more advanced valuation and investment appraisal tools are also used.

Middle-stream projects for natural gas buyers refer to regasification terminals and pipelines, in effect capacities of import. The determinants of decision making for these projects are different.

Arguably, natural gas is a strategic commodity. Continuity of supply is henceforth crucial, especially in winter. Notwithstanding also the industrial use of natural gas, this fuel is more notably used for electricity generation, which is highly strategic to any economy. This is particularly true in countries where indigenous supply is low and where exports, either through pipeline or –more importantly- through LNG, are required.

Natural gas projects, be it pipelines or LNG regasification terminals, are very highly capital intensive. A typical pipeline may cost in the region of $1 million per kilometer and an LNG regasification terminal may not cost less than $600 Millions[80]. Some of these projects are highly leveraged and bankers usually require long-term contracts as collateral. These Long Term Contracts (LTCs), traditionally have rigid Take-or-Pay provisions, indexed pricing mechanisms and, in some instances, destination clauses.

The most important reason for the difference in determinants of natural gas middle-stream investment, however, remains the market structure of this industry. So far, natural gas projects were conducted by so-called "legal monopolies" (large utilities, usually state-owned) effectively acting on behalf of the state. Investment decisions were therefore not motivated solely –if at all- by the profitability of the project. Indeed, it was not a competitive market.

Evidently, the market structure of the industry has been witnessing some changes, arguably important ones. The EU Commission Gas Directives[81] that provide for a progressive liberalization of internal gas markets and the implementation thereof by EU member states should theoretically transform the market structure into a more competitive one. This being said, a slow implementation of this directive, past liberalization experiences for the EU (e.g. the telecommunications market) and the strong state involvement in some cases, raise questions about how imminent a possible structural break in the natural gas external trade is to be foreseen.

In addition, natural gas differs from other industries in one other aspect of the trade: trade partners. While price, quality and credit-worthiness are the market determinants for "choosing" a trade partner, determinants in natural gas are also subject to its "strategic status".

[80] Willem Bloem, Shell, Presentation about Outlook for LNG at the 2nd Energy Risk Management Seminar, Cass Business School, 2004

[81] EU Directive 98/30/EC of 22nd June 1998

As mentioned above, LTCs are usually necessary to secure financing. In fact, LTCs are common, even predominant, trade instruments in natural gas. Because the length of LTCs has normally been 25-30 years, the relationship between the importing and the exporting company is of a high importance. Consequently, since both companies were (sometimes still are) typically monopolies in their respective countries, the relationship between the countries themselves became very important.

The issue of security of supply, therefore, rose high up on the agenda. Buyers started to take measures to tackle that. Among the recommendations of the EU Commission Gas Security of Supply Directive[82] was diversification of suppliers. Each of the studied countries -France, Italy and Spain- started in effect to diversify their portfolio of suppliers, refer to Figure 5-1, Figure 5-2 and Figure 5-3.

In fact, they have all moved from 1-2 suppliers to about 7 in a less than 20 years. Further, the Spanish government has even enforced a law banning any single producer from supplying more than 60% of the Spanish imports.

The present chapter aims to (i) identify the elements of decision making for investment in middle-stream projects as well as (ii) the 'choice' of partners as an *a priori* model. This model will then be tested using the discreet choice models. The chapter will comment on the results and have a forward looking analysis onto how these dynamic are likely to change in the future.

[82] EU Commission Directive 2004/67/EC concerning measures to safeguard security of natural gas supply of 26 April 2004

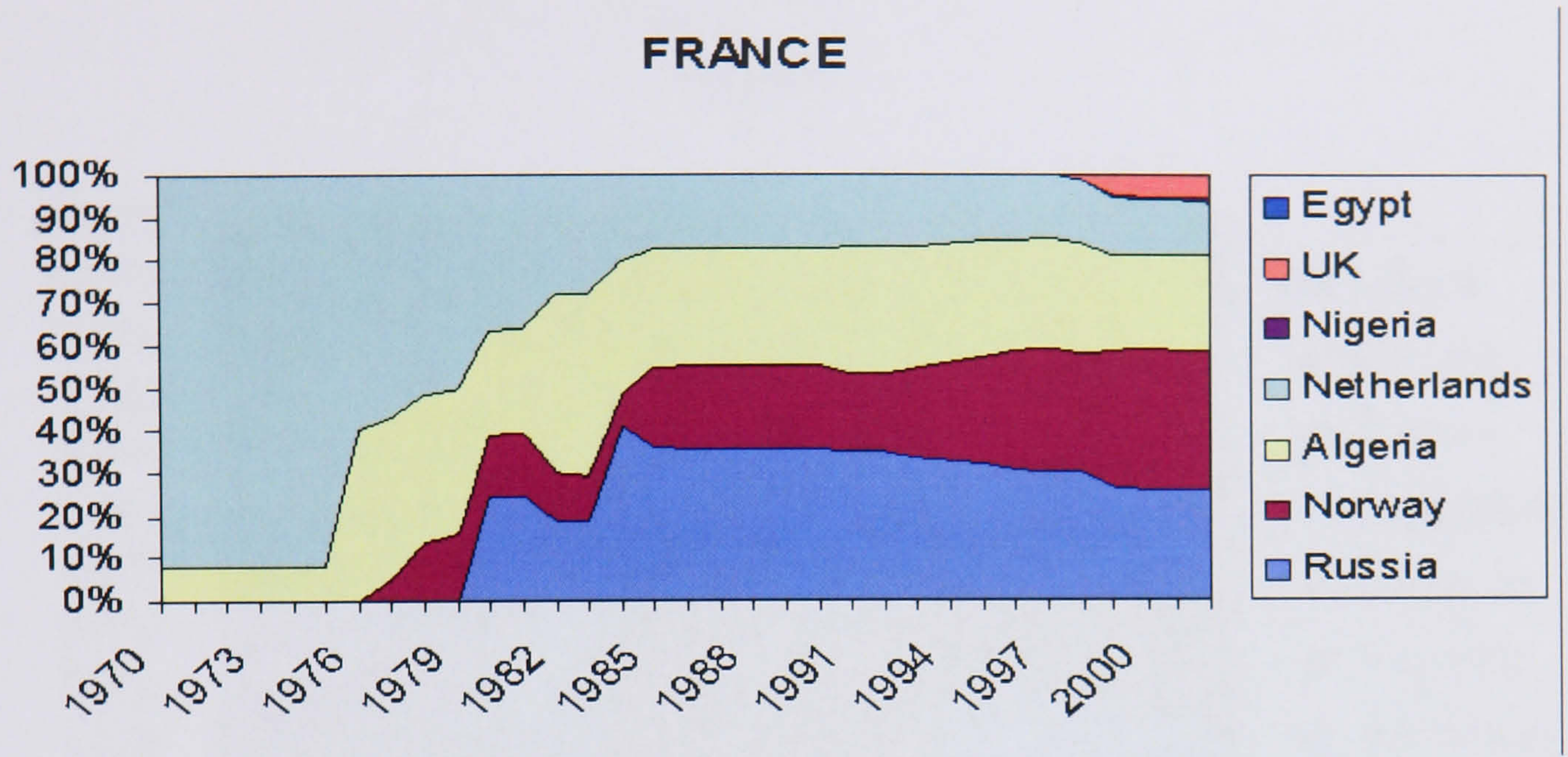


Figure 5-1 French Contracted Volumes of Natural Gas, time series[83]

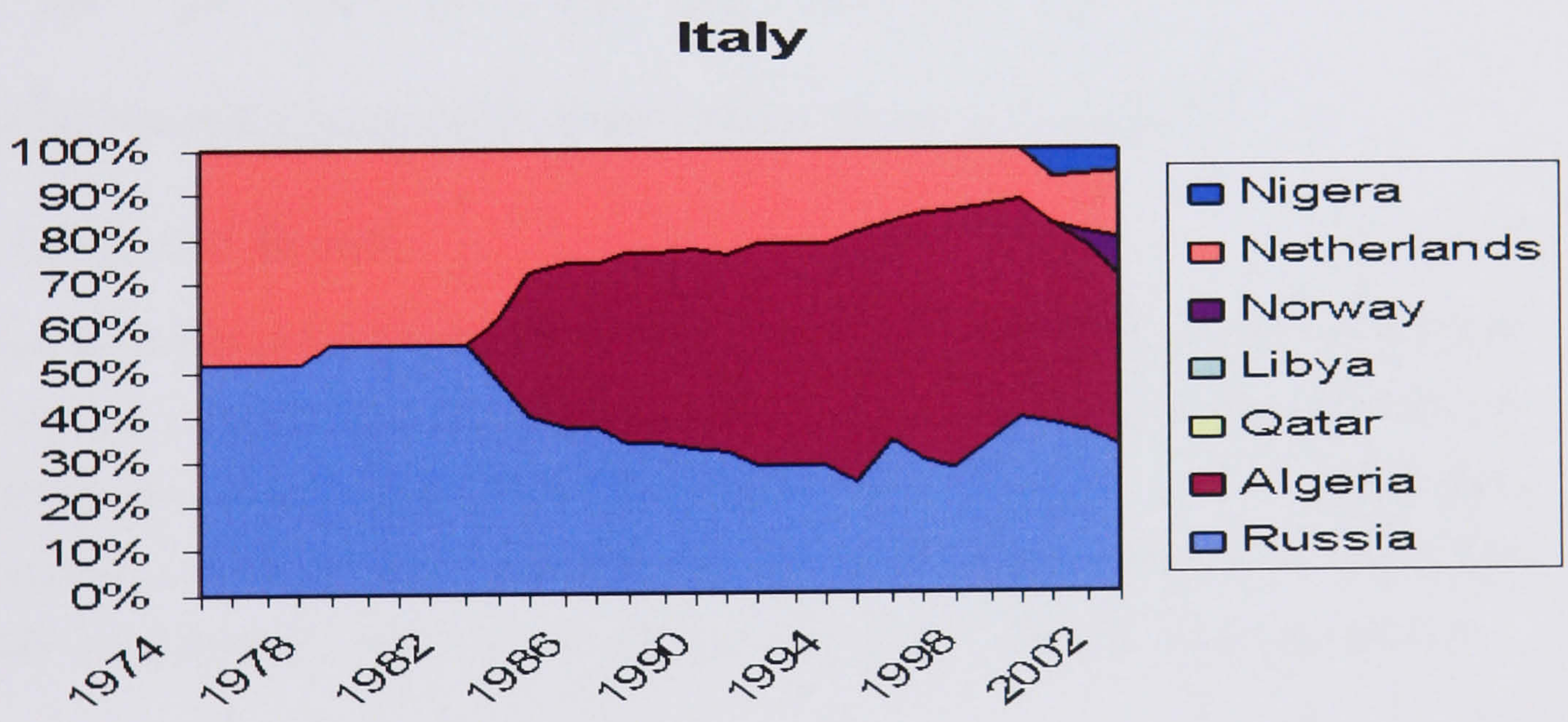


Figure 5-2 Italian Contracted Volumes of Natural Gas, time series[84]

[83] Author's calculations using BP Statistical Review of World Energy (2005), IEA (2003) and Gas Strategies Online (2005)

[84] Author's calculations using BP Statistical Review of World Energy (2005), IEA (2003) and Gas Strategies Online (2005)

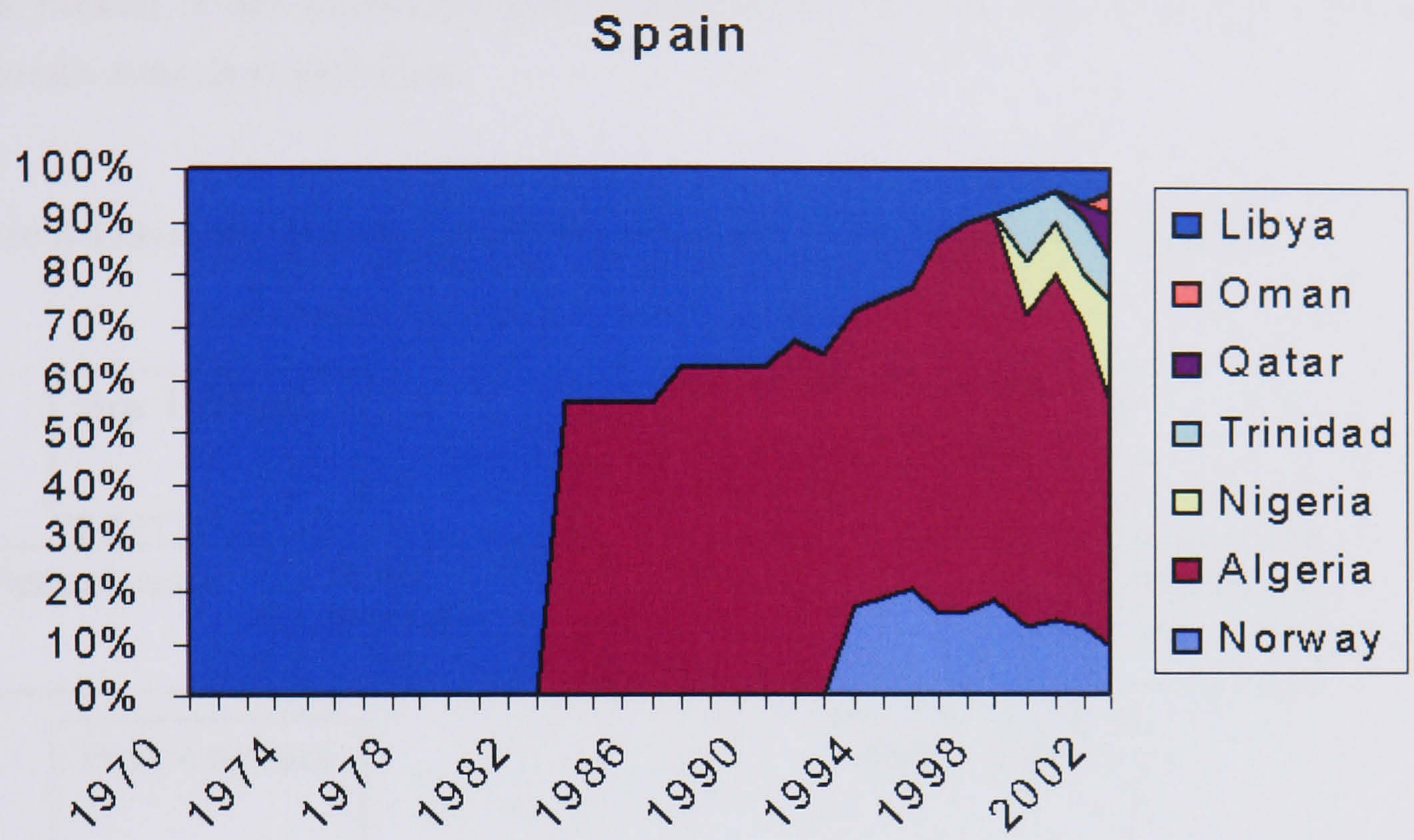


Figure 5-3 Spanish Contracted Volumes of Natural Gas, time series[85]

5.2 Literature Review

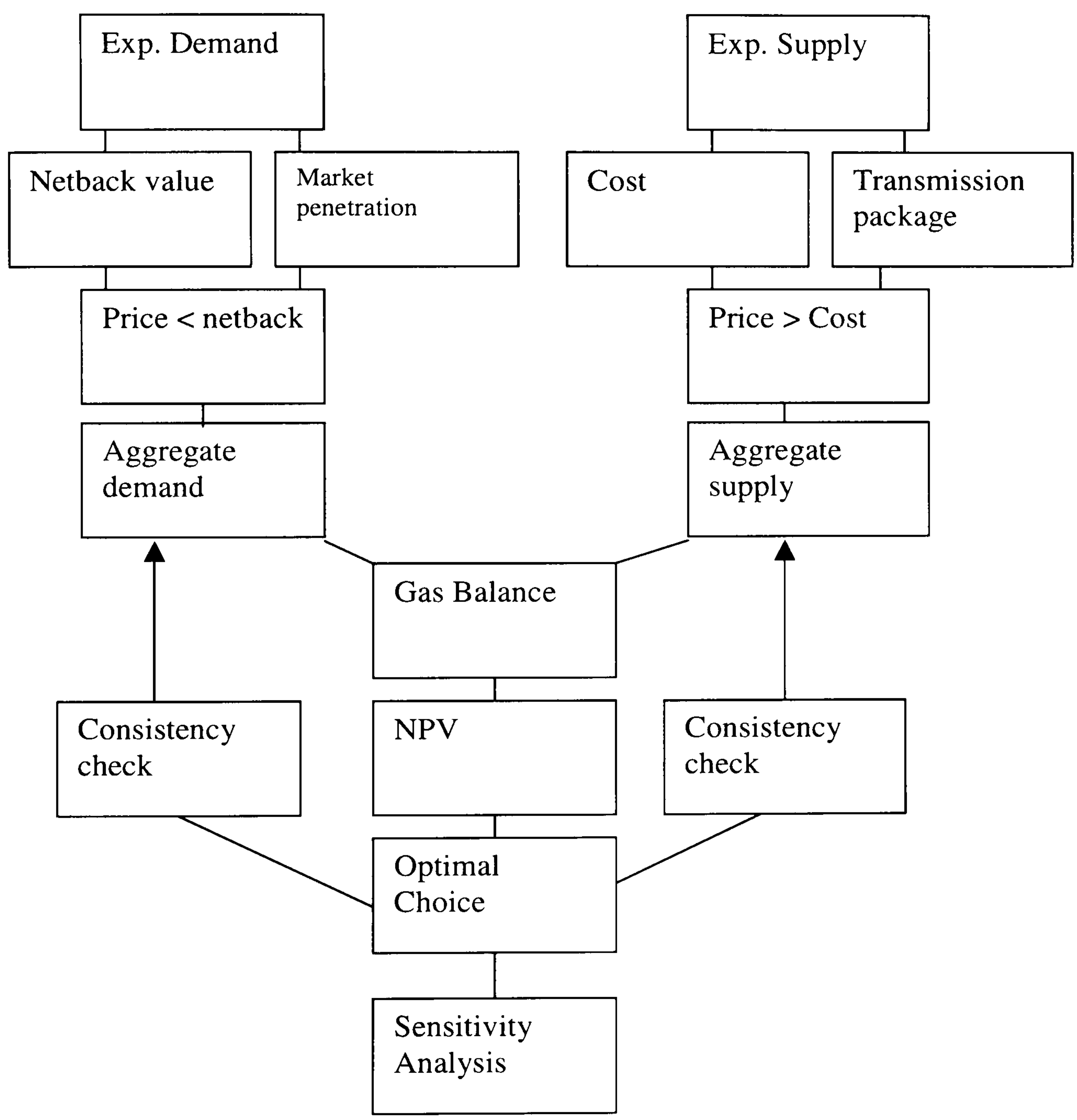
Van Groendendaal (1998) provides a comprehensive analysis about the economic appraisal of natural gas projects. The elements identified are financial viability, economic viability, demand for natural gas, energy pricing policy, gas reserves, economic growth, identification of investment for the gas transmission system and environmental implications. The model that Van Groendendaal (1998) has been adapted from Julius (1985) and is presented below.

As it can be observed, this model assumes availability of endogenous supply and is tested on Indonesia, which is in fact a gas exporter. It is believed that net gas exporters, particularly those with a high dependence, have different patterns for investment. Also, in modelling

[85] Author's calculations using BP Statistical Review of World Energy (2005), IEA (2003) and Gas Strategies Online (2005)

terms, because of lack of data for most of the variables that this framework calls for, it is statistically difficult to implement.

Figure 5-4 Decision Making Model Developped by Van Groendendaal (1998)



In terms of decision making, Van Groendendaal (1998) also presents a number of Decision Support Systems bespoke for natural gas infrastructure, the most relevant one being the Mintzberg, Raisinghani and Theoret (1976) Strategic Decision Model, outlined below.

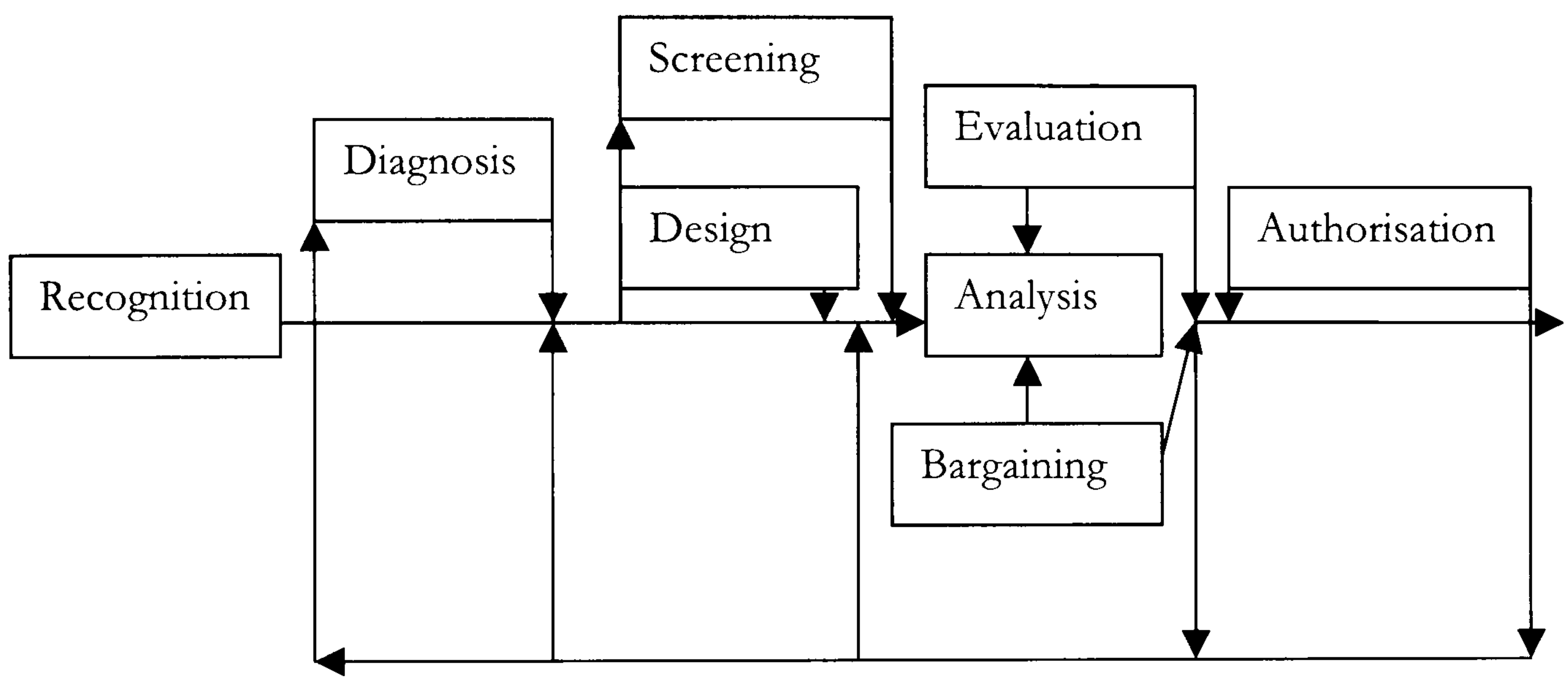


Figure 5-5 Decision Making Model Developped by Mintzberg, Raisinghani and Theoret (1976)

The present paper focuses more on the first stage of “Recognition”, in terms of infrastructure investment.

Hayes & Victor (2005) provide some grounds into the determinants of natural gas cross-border transportation. This paper has a global focus and discusses analytically factors that determine investment in natural gas transport infrastructure. One of the models of this paper, below, is relevant both to the infrastructure investment and partner choice problems:

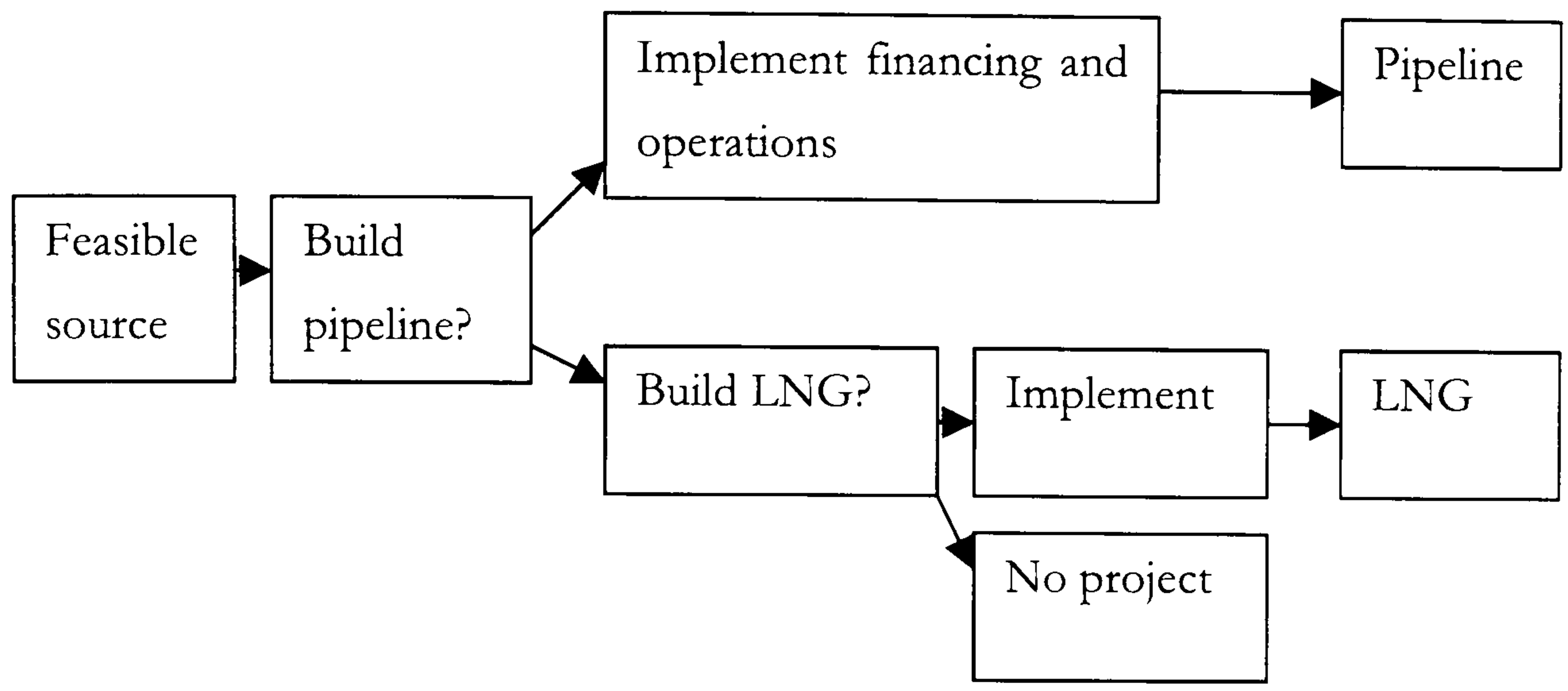


Figure 5-6 Decision Making Model Developed by Hayes & Victor (2004)

While this paper pays more attention to pipelines and liquefaction terminals (not to regasification terminals), it provides an interesting framework: Factors for partners are looked at using an index system taking into account government stability, investment profile, internal conflict, corruption, law and order, ethics tensions and bureaucratic quality. A decision tree approach is then introduced based on these elements.

The above model offers an interesting framework for a supply led micro (by project) system. The needs for the market under-study are different in that the model is assumed to be demand-led, which is a reasonable assumption based on the fact that most LNG projects are only undertaken if there is an off-taker. This leads on to assume also, on a macro level, that supply is abundant.

In terms of analysing Long Term Contracts, Neumann & von Hirschhausen (2004), (2005) have looked extensively –using econometric tools, at their determinants. They find that Long Term Contracts are getting, *ceteris paribus*, shorter though Long Term Contracts linked to assets, such as liquefaction and regasification terminals, are longer. This research stems from work by Coase (1937) on amendments of institutional economics, Richter and Furubotn (1999), Joskow (1987, 1988) who shows that the duration of contracts in the American coal industry is positively related to the level of asset-specificity, Crocket and Masten (1985, 1988) who have looked at the effect of institutional changes on the US gas market, Adelman et al (1986) who looked at security of supply in the oil markets and long term contracts, Bolle (1989) who investigated the ToP provisions of long term contracts.

In order to determine a parsimonious model for decision making processes for infrastructure and partners for natural gas infrastructure, notwithstanding models presented in the literature above, discussions were held with several industry actors from the buyers and sellers as well as governments and industry observers including representatives from Sonatrach (the Algerian national oil company), the Algerian Ministry of Energy and Mines, representatives from the Qatar Government, The *Observatoire Meditteraneen de l'Energie* (OME - a research organization sponsored by major energy companies in the Mediterranean and Europe), Cepsa, Repsol, Egyptian National Gas Company, OPEC, the International Energy Agency (IEA), the EU Commission Directorate for Transportation and Energy (EU DGTREN), the French Ministry of Economics and Industry, Gas de France, ENI, Enel, Gas Natural, Gas Strategies and others.

From these meetings, a pattern emerges. The *a priori* expectation is that infrastructure investments are motivated by expected spare capacity which in itself can be proxied by current spare capacity: Decision makers decide to invest in infrastructure at time t for this infrastructure to be operational at time $t+n$ (n being the lag for financing and construction of the project) based on what they believe spare capacity will be in time $t+n$. This belief stems from the current spare capacity, the growth in consumption and other decisions on infrastructure projects that have been made prior to time t for completion prior to time $t+n$.

In terms of choice of partners, diversification seems *a priori* to be the most important factor together with the distance (which proxies the competitiveness of the LTC; the shorter the period, the more competitive the partner) and the political relationship. The dynamics were, from the discussions held for the present chapters and from the above-mentioned literature, that a buyer requiring a quantity of gas looks at different aspects to chose the partner: One of them is the current market share of this partner at the time of decision (*a priori*, the higher such market share the lower the probability of choosing this partner should become), which should reflect the drive for partner diversification for security of supply. Besides, the shortest physical distance between the two trade partners and their political relationship are also said to be important factors.

As mentioned in the introduction, LNG and pipeline projects are highly capital intensive and front-loaded. On top of this, liquefaction, regasification and transportation account for more than 70% of the final border price[86] of gas in some projects[87]. This is the reason for which distance is included as the sensitivity of price to the distance (both via pipeline and LNG) is relatively high.

The model opted for is a discreet choice model. Discreet choice models are used when the dependent variable is discreet (taking a finite number of possible values, e.g. 0 or 1). Discreet choice modelling started by Daniel McFadden (1974) and further developped by Jaccard et al (2003), Train (2002) and Ben-Akiva (1985). It is widely used in the transportation industry, for example Bunch et al (1993), looked at the demand for clean fuel vehicles in California, Hall (1983) looks at inter-fuel substitution.

In this case, the dependent variable is qualitative (a binary, dichotomous, variable is used as a dependent variable – 1 for decision, 0 for no decision). A number of econometric tools can be used in this instance, including the Linear Regression Model (LRM) with the classical

[86] The border price is the price paid at the border for pipeline gas and DES (Delivery Ex-Ship) just at the LNG terminal

[87] OME (2004)

OLS (Ordinary Least Squares). However, with this method, a set of problems arise: While the dependent variable would return the probability of dichotomous variable to equal '1' there is an issue with the heteroskedasticity of the data as well as result values falling beyond the range [0,1]. The former problem can be partly resolved using GLS (Generalized Least Square) or WLS (Weighted Least Square) (Goldberger 1964). The latter, however, can only be solved with difficulty (Alrich and Nelson 1981). Besides, because of the nature of the dependent variable at the estimation stage, the R-Square that LRM regressions would yield will not have an explanatory effect. While the LRM methods can, in some instances, be used, it is not the desirable methodology otherwise (Cohen et al 1970).

The LOGIT and PROBIT models guarantee that the estimated probabilities will lie in the probability range [0,1]. The LOGIT model's logistic distribution function is presented as follows: $P_i = 1/1+(e^{-x_i'\beta})$. As P goes from 0 to 1, z –the distribution function- will vary from -∞ to +∞. While the LOGIT model uses the cumulative logistical distribution function, the PROBIT method uses the cumulative normal distribution function $[F(I_i) = 1/(\sqrt{2\Pi}\int_{-\infty}^{X_i'B} e^{-z^2/2} dz]$. The PROBIT method is preferably used in systems where the level of the dependent variable turns from 0 to 1, or *vice versa*, due to a threshold value – proxied by one of the independent variables (Gujarati 2004).

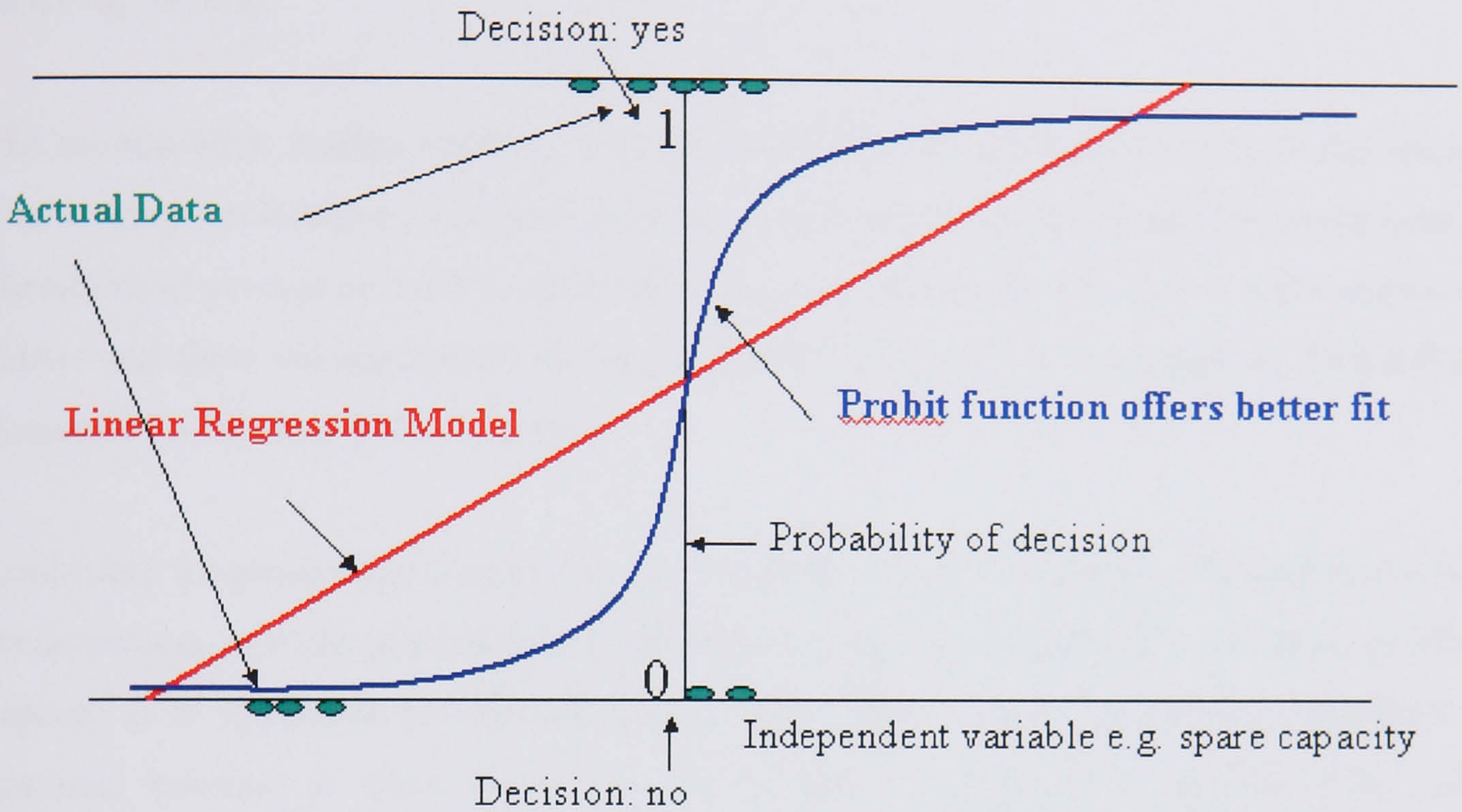


Figure 5-7 Author's diagrammatical representation of the Probit approach using Gujarati (2004)

Though PROBIT and LOGIT coefficients cannot directly be compared, it is accepted that differences in the estimation between the two methods are usually not significantly different (Gujarati 2004). The PROBIT method is used for the present paper as some of the dependent variables may be thresholds for the change in probability.

5.3 Model

5.3.1 Assumptions

One important assumption is that natural gas is a demand led market. Projects and LTC contracts are initiated from the buyers' perspective, subject to availability, feasibility and economic viability of the projects from the sellers' viewpoint. This assumption is recognized, from the discussions held, to be a strong one as, to date, the market seems to have been behaving this way.

The monopolistic market structure in domestic markets is also taken as part of the model. This assumption however, though true in the previous period, may change due to the market liberalization process in the EU, particularly France, Italy and Spain. This is still a matter of debate and there are arguments, among academic observers[88], for and against. This will be discussed further later in this chapter.

Lead-times for projects are assumed to be 4 years from the decision time. Evidently, this is a crude average, as some projects take a different time lag than others due to technical or other aspects. It is important to mention that it takes about 3 years to build a regasification terminal, however it takes about 5 years to build a liquefaction terminal. Also, with liberalisation in Europe, and decisions moving from *macro* to *micro*, the permitting time should also be added to the building time.

Another important assumption is that pipelines and regasification terminals had the same pattern of decision-making in terms of fulfilling capacity. This assumption was discussed throughout the meetings held and was seen to be a reasonable one.

Also, the assumption is made that the same patterns of decision are present in the three studied countries. While the three countries have different national policies (e.g. the Spanish cap on a single exporter policy), on the economic level, this is a credible assumption as the drive for diversification was a unified one at the EU level. On the statistical level, due to the data frequency, estimations will carry more statistical significance using the pooled approach.

[88] Boussenna (2004) and Stern (2004)

5.3.2 Model specification

5.3.2.1 Infrastructure investment

Estimation

$$D_t^i = PROBIT(\alpha + \beta SPARE_t^i + \gamma GROWTH_t^i)$$
$$D_t^i = 1 - \Phi(-(\alpha + \beta SPARE_t^i + \gamma GROWTH_t^i))$$
$$T(start) = T(decision) + Lag$$
$$Lag = 4$$

Validation

$$P_t^i = PROBIT(\alpha + \beta SPARE_t^i + \gamma GROWTH_t^i)$$
$$P_t^i = 1 - \Phi(-(\alpha + \beta SPARE_t^i + \gamma GROWTH_t^i))$$
$$P_t^i \geq CO \Rightarrow D_t^i = 1$$
$$CO = 0.5$$

Spare

$$SPARE_t^c = 1 - (\sum LTC_t^{i,e} / (\sum Capre_t^i + \sum Cappi_t^{i,e})), \forall e$$

Equation 5-1 Infrastucture Decision Model

Where:

- At the estimation level, *D* is '1' if an import infrastructure comes online *Lag* years after, otherwise it is '0'
- i, e, t stand for importer, exporter and time (in years), respectively
- *SPARE* is the percentage of export capacity that is not used by LTC
- GROWTH is the growth in imports
- *P* is the probability of the decision to be made, *CO* is the cut-off probability, the probability above which the model assumes an investment is made. The default 0.5 probability will be used in this case.
-Φ is the cumulative distribution function of the standard normal distribution
- *Capre* is the capacity of import of a regasification terminal of importer 'i' at time 't'
- *Cappi* is the capacity of a pipeline between importer 'i' and exporter 'e' at time t

5.3.2.2 Partner decision

Estimation

$$D_t^i = PROBIT(\alpha + \beta SPARE_t^i + \gamma GROWTH_t^i)$$
$$D_t^i = 1 - \Phi(-(\alpha + \beta SPARE_t^i + \gamma GROWTH_t^i))$$
$$Dpart_t^{i,e} = PROBIT(X_t'B)$$
$$Dpart_t^{i,e} = 1 - \Phi(-x_t'\beta)$$
$$X = [c, distance^{e,i}, political^{e,i}, MS_{t-1}^{i,e}]$$

Validation

$$Ppart_t^{i,e} = PROBIT(X_t'B)$$
$$Ppart_t^{i,e} = 1 - \Phi(-x_t'\beta)$$
$$Exporter(Dpart_t^{i,e}) = Exporter(\max(Ppart_t^{i,e} = 1 - (e^{-x_t'\beta} / 1 + e^{-x_t'\beta})))$$
$$MS_t^{i,e} = \sum LTC_t^{i,e} / \sum LTC_t^i$$

Equation 5-2 Partner Decision Model

Where:

- At the estimation level, *Dpart* is '1' if a contract is concluded between importer 'i' and exporter 'e' at time 't', otherwise it is '0'

-Φ is the cumulative distribution function of the standard normal distribution

- i, e, t stand for importer, exporter and time (in years), respectively

- *Distance* is the average distance between importer 'i' and exporter 'e', which is constant over time

- *Political* is a dummy variable describing the political relations between the buyers and the sellers and it takes '1' for Norway and the Netherlands and '0' for other suppliers – this is to proxy for favoring European countries as long term partners

- *MS* is the market share of exporter 'e' at the importer 'i' market at time 't' calculated as the sum of long term contract quantities between importer 'i' and exporter 'e' over the sum of all long term contracts quantities between importer 'i' and all exporters at time 't'

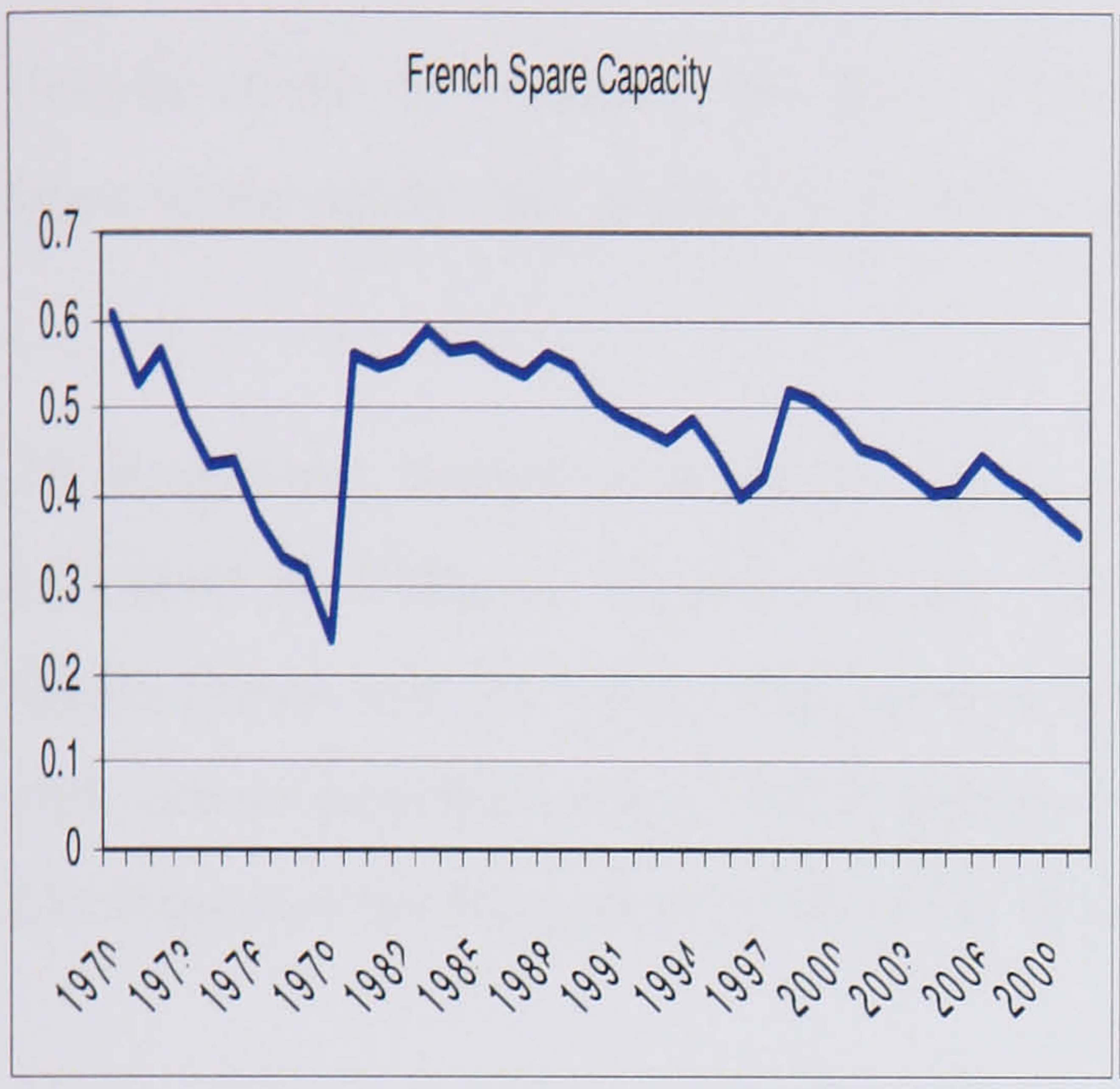
- *LTC* is the quantity of the long term contact between importer 'i' and exporter 'e' at time t

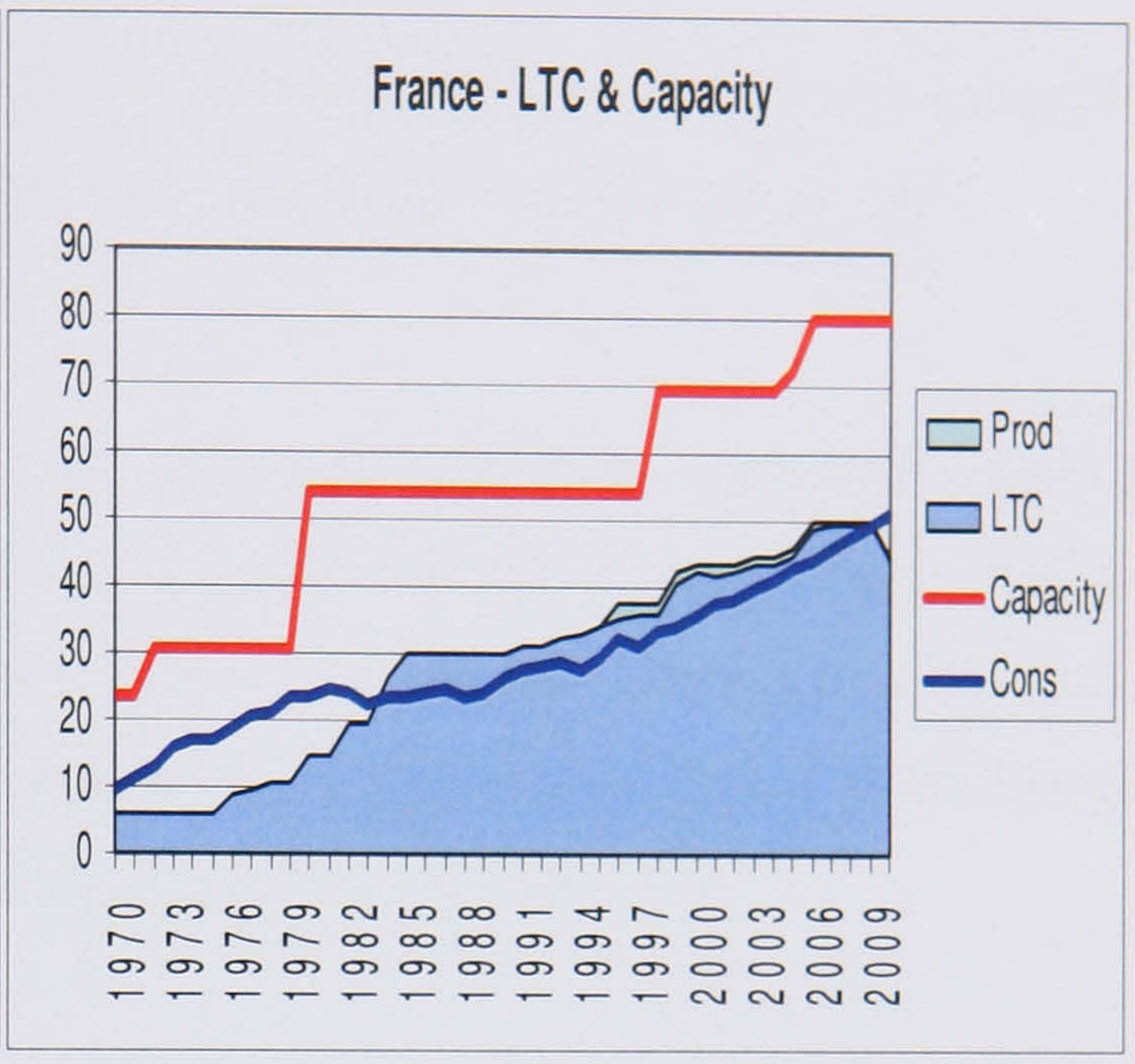
- At validation, exporters for which the highest probability is yielded are taken to as Long Term Contract partners.

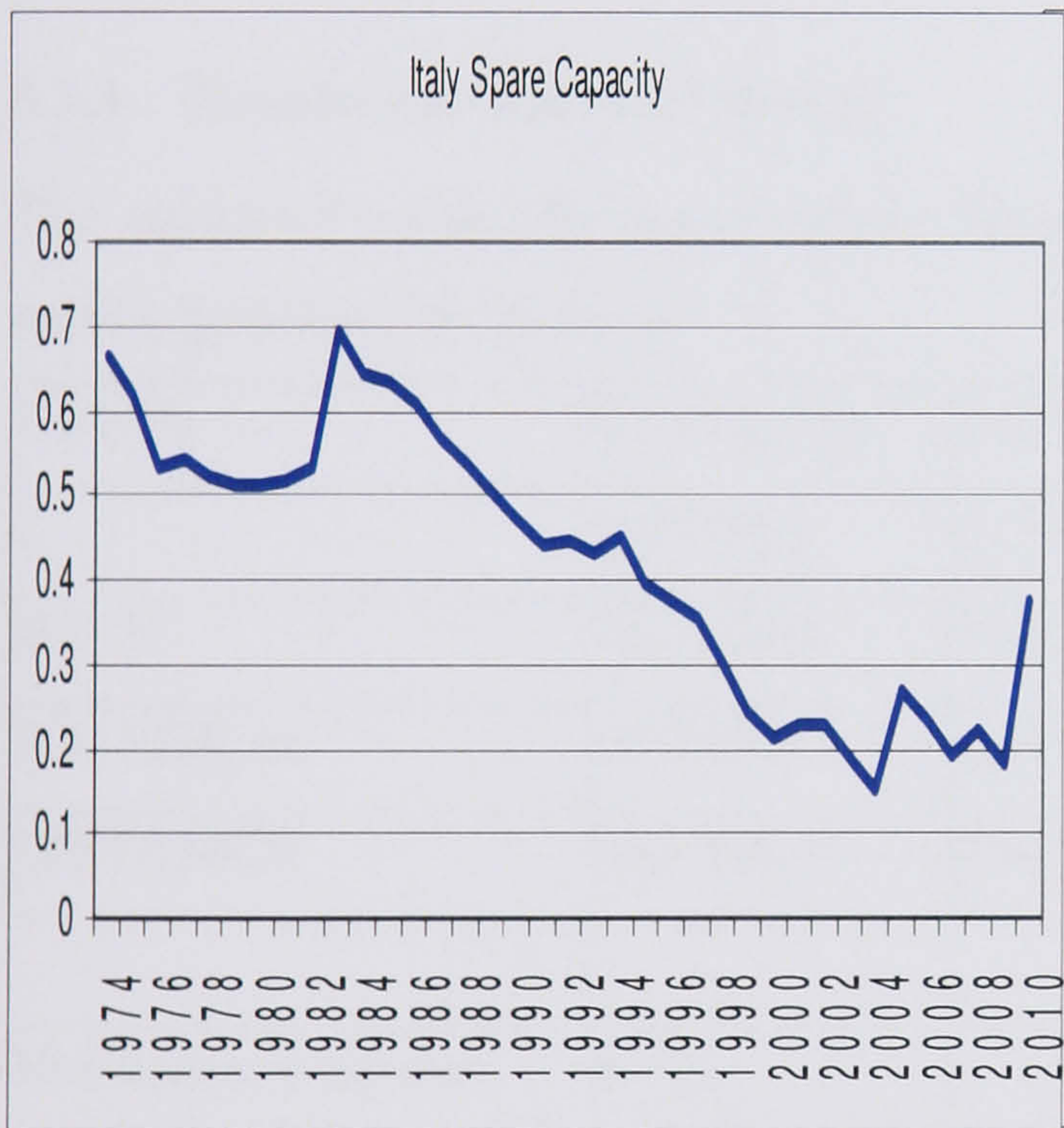
5.3.3 Data

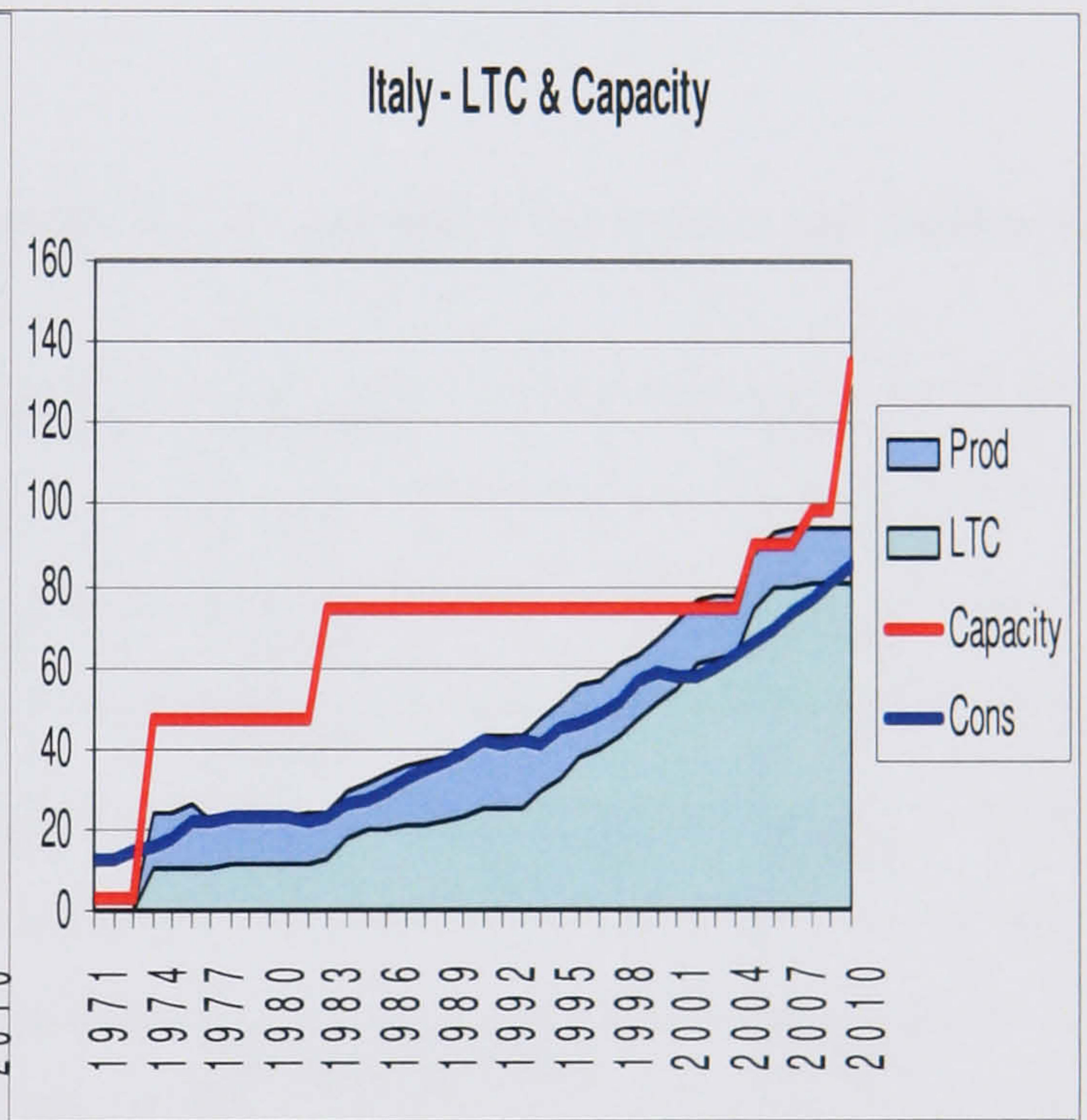
The following sources were used to collect the data:

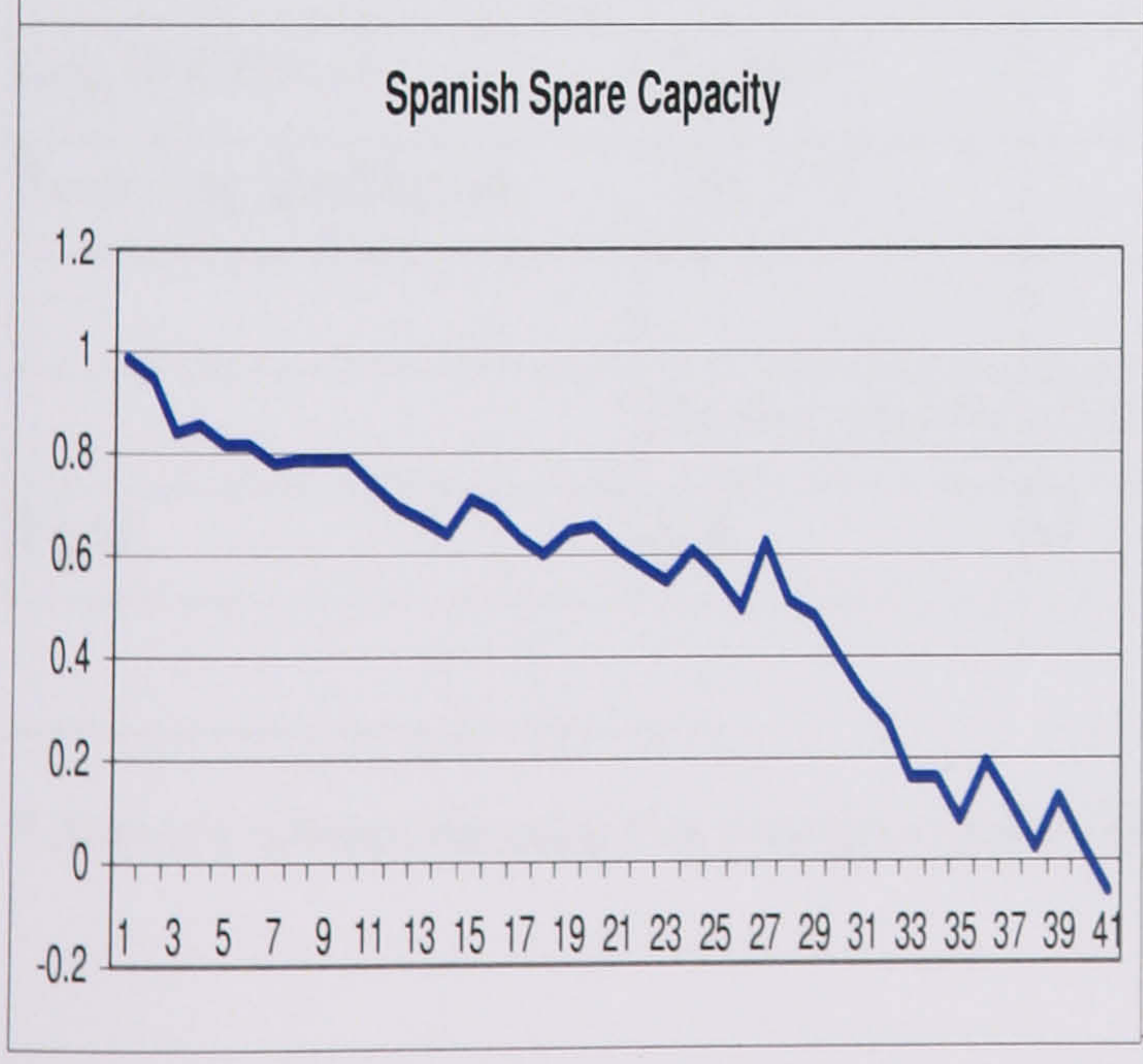
- The Gas Strategies Online Global LNG Database
- The Gas Strategies Online European Supply Database for France, Italy and Spain
- The Drewry LNGOneWorld Database
- The BP Statistical Review of Energy 2005
- Data was compared between the different sources and also with press announcements compiled by the author. When differences were found, averages were taken.
- Data was collected for:
- Regasification terminals, with respective countries, operators, capacities, number of trains, year of start and other remarks
- Pipelines, with respective importers, exporters and transit countries, capacities, year of start and other remarks
- Distance tables between all terminals from Gas Strategies Online

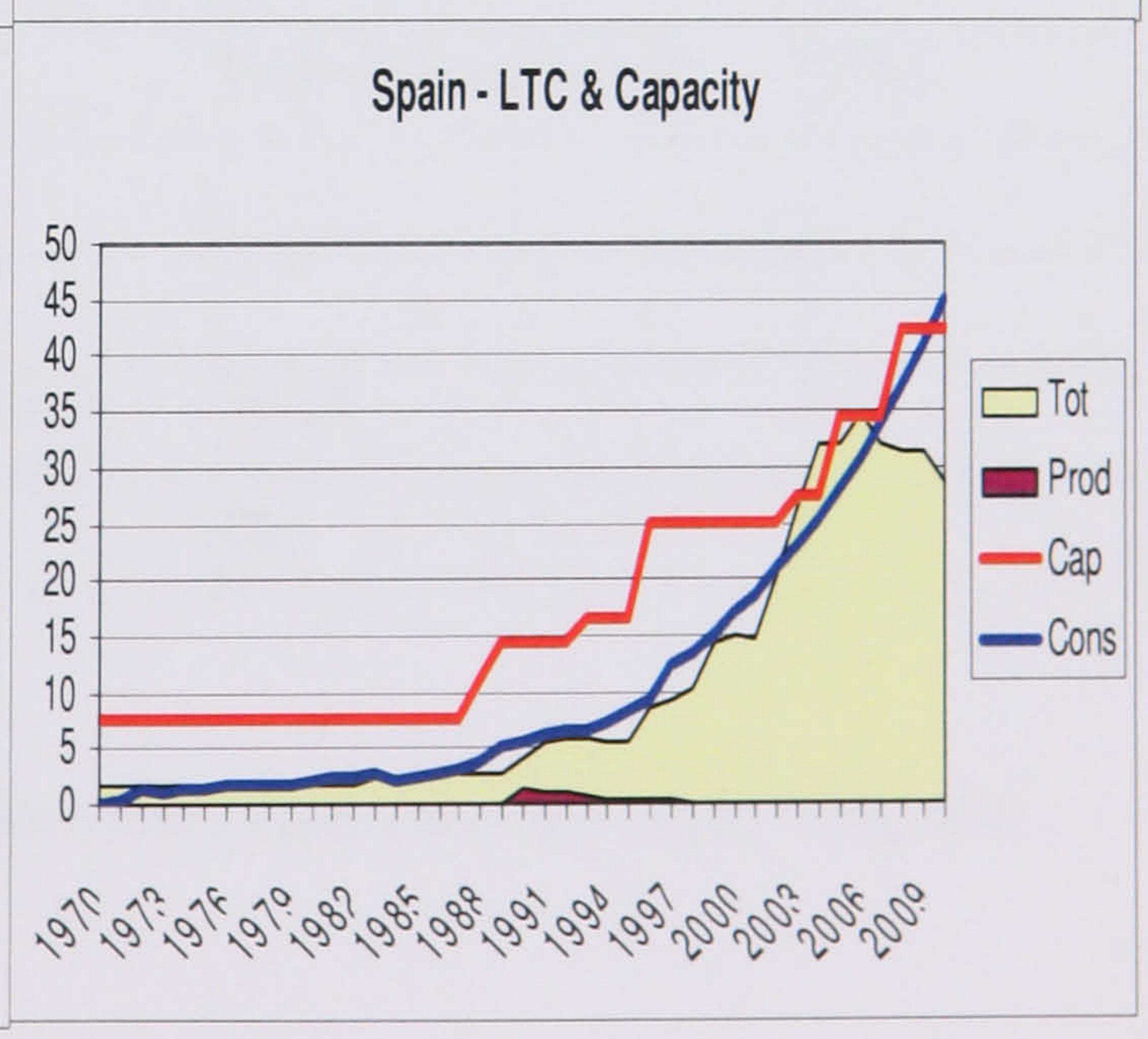

French Spare Capacity


France - LTC & Capacity
Prod
LTC
Capacity
Cons


Italy Spare Capacity


Italy - LTC & Capacity
Prod
LTC
Capacity
Cons


Spanish Spare Capacity


Spain - LTC & Capacity
Tot
Prod
Cap
Cons

Graphs of this data, namely the spare capacity, the capacity of import and the consumption (also, where applicable, production) for France, Italy and Spain, are shown above.89

All long term contracts between France, Italy and Spain and their respective suppliers (Trinidad & Tobago, Algeria, Nigeria, Russia, The Netherlands, Norway, Libya, Egypt, Qatar, Oman and the UAE), their year of start and quantities profiles as well as other clauses and –where possible- prices. The Distance Matrix of the Gas Strategies Online LNG Global Database was used to calculate distances (including Suez Canal in the route)

5.3.4 Results for 'Partner Choice'

The estimated model discussed above, Equation 5-2, is estimated and yields the following results, generated by Eviews:

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.547926	0.119	4.613	0.000
MS(-1)	-0.699864	0.424	-1.650	0.099
POLITICAL	-0.08276	0.257	-0.322	0.747
DISTANCE	-0.000224	0.000	-4.326	0.000
McFadden R-square	0.375		LR statistic (3 df)	21.244
Log likelihood	-131.093		Probability(LR stat)	0.000
Restr. log likelihood	-141.715			
	Do not choose	Choose	Total	
Total	224	57	281	

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[89] Author's calculations using Gas Strategies Online 2005the BP Statistical Review of World Energy 2005

% Correct	81.14	53.05	75.44	
% Incorrect	18.86	46.95	24.56	

Table 7 Results for the Partner Choice Model

In this partner model, because of the low volume of data at hand, the model was estimated collectively, assuming that the three markets behaved similarly. This can be justified by the fact that security of supply is more a pan-European issue –which the EU commission actively works on- than other issues, particularly infrastructure investment which are more commercial driven and therefore a national effect can be envisaged.

The McFadden R-square (which is the equivalent of the R-square for binary regressions) of about 37% shows some good-fit of the data, though Demaris (1992) argues that this indicator is not a good estimator of fit – especially in terms of this model, where the importance of the result does not lie in the absolute value of the Probit model, rather of the relative value of the Probit vis-à-vis other partners. The best-fit test of the model shows that the model performs on 82% correct estimations for *not choosing the wrong partner* and 53% *on choosing the right partner*, overall a correct rate of 75.44%. This is an indicator generated by Eviews that compares, historically, what the model yields, using the cut-off probability shown in Equation 5-2.

From the coefficients point of view, distance was found to be a significant (at 99% confidence level) and negative coefficient, corresponding to economic theory, as the probability of signing an LTC with a particular partner was expected to be negatively related to their distance to the buyer – which is a proxy for the cost, and therefore, a good indication of the price. The distance used was in kilometers, hence the low magnitude of the coefficient. The intercept, in this case, which is not particularly economically meaningful, is found to be positive and significant. The coefficient ensures that different suppliers with exactly the same market shares, distance and political relationship have the same probability of being chosen.

The interesting result from this regression, however, was the negatively signed and statistically significant, at 99% confidence level, coefficient for the market-share (lagged one year) of the partner just before signing the contract, which corresponds to our theory of diversification of partners which states that the higher the market share of a potential partner, ceteris paribus, the lower their probability of being chosen.

5.3.5 Results for infrastructure decisions

The infrastructure model, below, was also estimated collectively for the three countries. Again in this case, the low volume of data can be expected to hinder the quality of the results.

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.375	0.532	0.704	0.482
SPARECAP(-4)	-2.507	0.927	-2.705	0.007
GROWTH(-4)	-0.220	0.136	-1.620	0.105
McFadden R-square	0.423		LR statistic (2 df)	8.045969
Log likelihood	-38.72771		Probability(LR stat)	0.004561
Restr. log likelihood	-42.75069			
	Do not invest	Invest	Total	
Total	88	15	103	
% Correct	86.64	59.03	82.62	
% Incorrect	13.36	40.97	17.38	

The table above displays a relatively high McFadden R-square of 42% and a robust track record for goodness of fit, with 86.64 % correct of *Do not Invest*, 59% of *Invest* and 82%

overall. The spare capacity is significant and negative, as expected. As the lower the spare capacity at time t, the higher the probability of deciding for a plant and having it online in t+4. The growth of gas consumption did not yield significant coefficients (and of the wrong sign).

5.3.6 Use of the model for forecasting

This model will not be used for forecasting actual decisions. It is designed to provide a benchmark of what decisions *would have been taken* if the market was still not liberalized. If in this state, optimal public utility in terms of security of supplies are met, which is an assumption many policy makers agree with.[90]

Market observers argue that there is a structural break that takes shape in the studied market at this time. The EU Commission Gas Directives are being implemented in the market "slowly but surely"[91]. The new structure is expected to end legal monopolies to the profit of other organizations which is expected to bring more liquidity, more competitiveness and more efficiency to the market, as to make companies evolving in the different EU national markets compete on price and quality of service, ultimately –it is hoped- offering a better product for a lower price.

However, discussions held with different market players and observers have shown high skepticism on this, which is comforting for the assumptions of the model. Though the process of liberalization has started and some of the partner and investment decisions do not emanate from a clear long term national level, in the medium term, observers expect an oligopolistic market structure to emerge and the state to play an important role through delivery of construction permits for the regasification terminals, other authorizations for pipelines as well as market regulators. At the EU level, therefore, and still on the medium

[90] Discussion with the Security of Supply Department at the French Ministry of Industry (2005)

[91] Personal Communication, DGTREN, March 2005

term –the horizon at which this model is designed to work- legal and regulatory levers are expected to remain and the strategic roles of companies are also expected to stay important features of the system.

On the issue of long term contracts trade structure, which is another one of the assumptions of the model, most industry observers seem to agree that it will remain an important feature of the market and that it is not expected to change in the medium term.

Neumann and von Hirschhausen (2004), cited above found, running a regression model using LTC length, year of signature, contracted volume, LNG vs Pipeline, share of natural gas in national total primary energy supply and other country specific dummy variables, that while LTC length is decreasing, the structure of the trade relying on LTCs will remain.

In effect, many of the industry observers and players who were approached to discuss the strength of the assumptions seem to agree that the market is not expecting a structural break, but a smooth transition that would only materialize in the long run.

5.4 Conclusions

This chapter provides an attempt to model decision-making processes for "partner choice" and middle-stream infrastructure (regasification) decisions. It is designed to be positioned at the "Recognition Level" of the Mintzberg, Raisinghani and Theoret (1976) model and at the "Feasible Source Level" of the Hayes & Victor (2004) model. Decision-making is assumed to be at the macro level –i.e. from a country perspective- and other assumptions are made with regards to rigid market structure and strategic interest.

Natural Gas market, especially in the studied area –France, Italy and Spain- is a particular commodity with different drivers that, it is believed, justifies a whole new perspective on decision-making determination.

This model is looked at econometrically using dichotomous estimation methods, or discreet choice modeling, (PROBIT) taking into account variables that were identified, through discussions with a number of industry and government players as well as a number of observers, to have a deterministic effect on decision making.

Regressions have comforted *a priori* models in almost all cases. Also, low McFadden R-Squares as well as low significance levels as believed to be the product of the short period of time, and henceforth the low volume of data, used.

5.4.1 Potential for future work

The framework that the present paper proposes offers many opportunities for improvement. On the methodology level, variables thought to have a deterministic impact may be modeled using other techniques –notably game theory or system dynamic, depending on the data involved and the research questions. Unavailability of data being one of the most important impediments encountered, there is strong potential in the improvement of the model by researching, for example, CIF prices, FOB costs, other terms of the contracts and more frequent data. This will offer more degrees of freedom and help lower the missing variables problem.

The next chapter will incorporate the results of both chapter 4 and chapter 5 into a Dynamic Object Oriented System and model a view of potential developments in French, Italian and Spanish infrastructure and partner mix.

6. Modeling LNG trade-flows and infrastructure investment to France, Italy and Spain

In this chapter, a model is constructed using result from previous chapters to model the dynamics of gas trade to France, Italy and Spain.

6.1 Introduction:

Chapter 2 shows the uniqueness of the trans-border natural gas trade in the Mediterranean. This fundamentally different trade structure of the Mediterranean market lies in its infant market liberalization and scarcity of supply and is due to the inherent properties: high capital investment, long term contracts, highly strategic middle-stream infrastructure.

Research relative to the modeling and the forecasting trade flows and infrastructure needs in the west-Mediterranean is gaining importance for policy makers. Many examples of decisions taken using debatably robust modeling techniques have had important repercussions on the market. For example, the Turkish market is believed by the majority of observers to be oversupplied because decision makers failed to capture GDP/Gas Consumption elasticity. Indeed, due to the recent monetary turmoil, GDP growth was lower in Turkey and so was natural gas consumption. Contracted gas, decided on the basis of these forecast meant that Turkey is now buying much more gas that it needs.

Conversely, new geopolitical developments such as EU integration in a common energy policy, which emphasizes the need for environmental friendliness, security of supply and market liberalization, are influencing the way natural gas deals are being conducted: The recent Repsol/Gas Natural bid on the Gassi Touil plant and the BG stake in the Damietta liquefaction terminal in Egypt are examples of this.

Last but not least, there is a growing debate on the necessity for more flexible LTCs (e.g. length and destination clauses), amid the progressive –though slow- formation of a global LNG market. Opportunities for arbitrage are affecting, with a growing significance, the overall market.

This paper addresses the modeling of natural gas demand and trade flows with the perspective of decision-making needs for governments and involved companies. It provides an original, comprehensive, flexible and upgradeable platform for such modeling and forecasting taking into express and explicit consideration the particularities of the market in the Mediterranean. Inspired by different academic and industrial models, it aims to provide a solid modeling methodology that is also industry oriented.

6.2 Literature review:

Modeling systems with capacity constraints and step changes, with legal and political variables such as the natural gas market, can be constructed with a number of tools. Most of the models presented in the literature for natural gas trade are either internal (country level or EU level), micro-level, or downstream models. Important tools presented can be used for middle-stream trade modeling. There is, however, little presented for middle-stream models at the regional and macro levels.

It is worthwhile noting, on the outset, that downstream models cannot be considered appropriate as they disregard the strategic aspect of partners. Internal trade in the EU, either through a complex and mature network of pipelines or, in kind, as electricity, can also not be considered appropriate in a system where LNG accounts for a large proportion of imports. Micro-models are also not appropriate as they place a higher importance on forecasted revenues and interaction between agents.

The methodologies used in the literature can be categorized into: system dynamics, game theory, econometric and other bespoke models.

6.2.1 Game theory

In the context of the present research, where there is a restricted number of sellers each of them knowing the existence and actions of the other and behaving in an oligopolistic manner (i.e. a restricted number of players with a high aggregate market share), Game Theory is a good methodology, particularly tacit collusion (of buyers and sellers).

Tacit Collusion was first introduced by Chamberlain (1929) and stipulates that a market with a restricted number of sellers will act, without an explicit agreement, as an oligopoly; as each of them knows that a price, and thereby profits, would decrease if they behaved competitively and aggressively. Chamberlain suggests that such a principle holds in mature markets where there are established sellers, not in low entry barriers markets.

The Nash-Cournot method, widely used in micro models, was developed by Melvin and Warne (1973) and Markusen (1981). For natural gas, Golombek, Gjelsvik, & Rosendahl (1995) present a numerical model for the long-run impact of a radical liberalization of the West-European natural gas market by studying Cournot producers facing ideal third party access regimes for gas transport. They later analyze how the supply side of the Western European natural gas market may react if the demand side becomes competitive. The paper shows that once the demand side of the market is liberalized, each gas producing country has an incentive to break up its gas sellers. The model therefore suggests that there may be numerous producers in a liberalized natural gas market. Hence, in a liberalized market consumers will not be exploited by suppliers.

Dierker, Dierker & Grodal (2003) examine from the theoretical point of view the Nash-Cournot equilibrium on international trade, assuming constant returns to scale and a two-factor, two-sector and two-country model. In the same fashion as the 'oligopoly' theories introduced above, Boots, Rijkers & Hobbs (2005) model supplies using the Cournot model looking at producers with non-linear production costs. The model presented, GASTALE, attempts to integrate capacity constraints into the numerical method inspired from Greenhut & Ohta (1979), which looks at situations of multiple consumers separated in space and several upstream producers and uses either oligopolistic, or perfectly competitive behaviour in the market.

It is important to note that all research found dedicated to the modeling of supply was estimated at the micro-level (many in the United States where the market is highly deregulated, where a large number of small operators is present and where high frequency data was available for a long time). In the market that the present research is pointing at, there is historically no aspect of the upstream, middle-stream and even downstream deregulation, though the latter is gradually being implemented. A micro-analysis is therefore not appropriate. Although some of the literature listed above may have an importance in the elaboration of the model for the present research, they remain remote to the fundamental supply related modeling factors in the case of the market looked at in the present research.

6.2.2 General and Partial Equilibrium models

One of the major researches conducted on the modeling of natural gas trade on a cross-boundary basis was a paper published in 1987 introducing a General Equilibrium Gas Trade Model, Boucher, J and Smeers, Y (1987), including the market forces in the European natural gas market and the predictions drawn in the short run and the long run. The paper discusses the future of natural gas supply and demand patterns for the internal European market.

An overview of other general and partial equilibrium models is available in Bhattacharyya (1996):

MSG models

Author	Coverage	Details
Hogan and Naughten (1990) ORANI short run	Australia	Base year 1977-78, 112 industrial sectors, to study the economy-wide effects of a 15% decline in production of crude oil
Hall et ai. (1990) ORANI-LF1	Australia	To identify the principal aggregate and structural impacts which result from a substantial switch from crude oil levy revenue to product excise revenue
Mckibbin and Wilcoxen (1993) G-Cubed	Global	A multiregional (six regions), multi-sector (12 sectors in each region), intertemporal model A nested CES function system describes the production process - 1987 data
Bergman (1988) ELIAS	Sweden	Multiperiod model in which the agents had static or adaptive expectations Distinguishes ex ante and ex post technological constraints, as well as different vintages of production
Bergman (1991)	Sweden	Static CGE model of an open economy with 45 sectors, benchmarked with the 1985 data, includes emissions and emission control activities, as well as markets, and market prices for tradable emission permits Distinguishes between old and new production units in some sectors; Considers four types of domestic inter-sectorially mobile factors of production-capital, labour, electricity, and the natural resource base of the production sector
Bergman (1987)	Sweden	Seven producing sectors The ex ante production functions are defined as nested

		CES-Cobb-Douglas-Leontief functions. Ex post labour is the only variable input and labour productivity and energy input coefficients vary according to vintage
Hanson and Alfsen (1986)	Norway	A two-sector model to analyse the impacts of a tax on SO 2 emissions Generalized Leontief cost function with KLEM inputs Consumer's preference is represented by a CES function
Proost and Van Regemorter (1990)	Belgium	A two-period perfect foresight 25-sector model Dynamic input-output framework with constant return to scale and perfect competition describes the production possibilities
OECD (1993) GREEN	Global	12-region, dynamic model 15 producing sector of which 12 are energy related including seven back-stop technologies The model distinguishes between old and new capital goods. A nested system of CES (except fossil fuels) functions describes the production process A simple recursive dynamic structure is used

HHSW

Author	Coverage	Details
Goulder (1982)	USA	Nine sectors of which five are energy producing ones; 18 consumer goods which are connected to nine producer goods through a fixed-coefficient conversion matrix A nested system of cost functions (translog KLEM) is used for each industry 12 categories of households are considered. Consumer

		demands are derived from a nested system of Cobb-Douglas and CES utility functions in which leisure, current consumption and future consumption are the principal arguments Benchmark year: 1973
Borgess and Goulder (1984)	USA	24 industrial sectors, 12 household categories, and 18 consumer goods are considered Three functional forms are tested to analyse the sensitivity of results: (i) fixed coefficient for interindustry transactions combined with a Cobb-Douglas nest for capital and labour; (ii) Cobb-Douglas specification for KLEM; (iii) a multi-nested structure to combine KLEM Consumer demands are derived from a nested system of Cobb-Douglas and CES utility functions in which leisure, current consumption and future consumption are the principal arguments Benchmark year: 1973
Boyd and Uri (1991)	USA	12 sectors, 13 consumer goods, 6 household categories are considered The substitution of capital, labour and land (for agricultural and forestry sector) is incorporated through a CES production function Consumer demands are derived from a nested system of CES utility functions in which leisure and current consumption are the principal arguments Benchmark year: 1984

Boyd and Uri (1993)	The	14 producing sectors, 14 consumer goods, and 3 household The substitution of capital, labour, and land (for agricultural and forestry sector) is incorporated through a CES production function Consumer demands are derived from a nested system of CES Benchmark data: 1983
Whalley and Wigle (1991a)	Philippines categories are considered	3 regions, three types of energy and two types of industrial output are considered. Production is represented by CES functions. Oil, gas and coal are not distinguished
Pezzey (1992) based on Whalley and Wigle (1991b)	Global	Same as Whalley and Wigle (1991a), only exception is there are 6 regions instead of 3 regions

Econometric AGE

Author	Coverage	Details
Hudson and Jorgenson (1974)	USA	Nine industrial sectors, of which five are energy related A two-stage KLEM transiog price possibility frontier is used. Aggregate energy and aggregate material are generated from translog submodels A macroeconomic model provides totals for consumption, investment, government and export demand Data from 1947 to 1971 were used to estimate parameters econometrically The model presents projections of economic activity and

		energy utilization for the period 1975 through 2000
Jorgenson and Wilcoxen (1990a, 1990b, 1993a 1993b) Scherageet a1.(1993)	USA	35 production sectors and 672 types of households are considered This is an intertemporal equilibrium model, the dynamics of which is based on intertemporal optimization by firms and households Data series: 1947-85
Jorgenson, and Wilcoxen (1993c) Jorgenson, Slesnick and Wilcoxen (1992)	USA	Similar to the detail in row 2, with the exception of 1344 households instead of 672 in those studies
Hazill and Kopp (1990)	USA	There are 36 production sectors but relies on a representative household Translog cost functions are used for producing sectors It is also an intertemporal equilibrium model Data series: 1958-74

The National Technical University of Athens, Greece, has developed a number of energy modeling tools for the European market and aimed at the policy making community both at the European level and at national levels. Below are some of the modeling tools available

6.2.2.1 Primes Energy System

The PRIMES model is a static model finding equilibrium by calculating the price allowing supplies and demand to match. It takes into consideration environmental policy, taxation and technological advances. The major assumption of this model is price elasticity of demand and supply (both the empirical evidence provided in the present research and recent IEA reports do not concord with the above assumption). The demand side of this model, which is a bottom-up one (refer to the demand section in chapter 4), looks at the demand patterns of different sectors and sub-sectors with regards to different primary and secondary sources. The model also takes into account different capacities of production, refinery capacities, power plant capacities and the network of distribution both on the internal and external levels.

6.2.2.2 GEM E-3

This is the General Equilibrium Model for Energy, Economics and Environment interactions. It is a structural empirical model and takes into account macro-economic variables, environment issues and energy regulation, trade and taxation. The model treats every country as a separate entity and linking them through endogenous trade. According to its manual, the model determines the optimum balance for energy supply and demand, atmospheric emissions and pollution abatement, simultaneously with the optimizing behavior of agents and the fulfillment of the overall equilibrium conditions.

6.2.2.3 MIDAS

The MIDAS system works in the same fashion as the ones above. It includes an econometric component for demand which works, again, on a bottom-up approach. It looks at a set of important sub-sectors (6 industrial ones, 4 domestic ones and 4 transport ones) and deals with over 18 energy fuels. The supply side is a set of sub-models some of them engineering and others econometric models (these work in the same fashion as the micro-economic approach in the present literature review) for different sources (e.g. electricity and natural gas).

All of the models above concentrate on the dynamics of the energy within the EU and, in the opinion of the author, do not give strong enough consideration to international trade flows and security of supply issues.

6.2.3 Econometric tools

Research on the modeling of supply, demand and prices for natural gas is not predominant in the literature. A noteworthy research is MacAvoy, P.W & Moshkin, N.V. (2000) which aims at predicting long term well-head natural gas prices in the US using simulations and a partial equilibrium model. The system consists of simultaneous equations for production from reserves and for demands for production in the residential, commercial and industrial sectors. A more comprehensive literature review for the consumption and demand can be obtained form chapter 4.

Below is a taxonomy of commodities modeling methodologies proposed in Tamvakis (1997).

Modelling Process Methodologies	What is the purpose of the methodology?	What quantitative method is used?	What economic behaviour is specified?	Examples of commodity applications
Market Model	Demand, supply, inventories interact to produce an equilibrium price in competitive or non-competitive	Dynamic micro econometric system composed of difference or differential equations	Interaction between decision makers in reaching market equilibrium based on demand, supply,	Cobalt, Energy, Lauric Oils, Rubber, Soybeans, Sugar,

Modelling Process Methodologies	What is the purpose of the methodology?	What quantitative method is used?	What economic behaviour is specified?	Examples of commodity applications
	markets		inventories, prices, trade, etc.	Tungsten
Process Model	Demand and production determined within an industry, focusing on transformation from product demand to input requirements	Dynamic micro economic difference equation system suitable for integrating linear programming on production site	Interaction between decision makers in industries, markets, national economies based on demand, inventories, production, investment, capacity utilisation, commodity inputs, prices, etc.	Petroleum, Steel
Systems dynamics model	Demand, supply, inventories interact to produce an equilibrium price	Dynamic micro econometric differential equation system which features	Interaction between decision makers in adjusting rate of production to	Aluminium, Broilers, Cattle, Copper,

Modelling Process Methodologies	What is the purpose of the methodology?	What quantitative method is used?	What economic behaviour is specified?	Examples of commodity applications
	emphasising role of amplifications and feedback delays	lagged feedback relations and variables in rates of change	maintain a desired level of inventory in relationship to rate of consumption	Hogs, Orange Juice
Spatial equilibrium and programming models 1. Linear and quadratic programming	Spatial flows of demand and supply and equilibrium conditions assigned optimally in equilibrium depending on configuration of transportation network	Activity analysis of a spatial and/or temporal form. Degree of complexity depends on endogeneity and method of incorporation of demand and supply functions	Interaction between decision makers in allocating shipments (exports) and consumption (imports) optimised through maximising sectoral revenues or minimising sectoral costs	Bananas, Broilers, Livestock, Oranges, Palm Oil, Wheat
2. Recursive programming	Production conditions and	Activity analysis involving a	Interaction between decision	Coal, Iron, Steel,

Modelling Process Methodologies	What is the purpose of the methodology?	What quantitative method is used?	What economic behaviour is specified?	Examples of commodity applications
	input revenue determined through primal/dual of linear programme. Recursivity introduced through feedback component which includes profit, capital and demand	sequence of constrained maximisation problems in which objective function, limitation coefficients depend on optimal primal/dual solutions attained earlier in the sequence	makers in reaching market equilibrium involves adaptive intertemporal processes related to production, investment and technological change	Wheat, Corn, Soybeans
3. Mixed integer programming	Spatial and temporal equilibrium embodying production-process, transportation, and project	Activity analysis involving spatial and temporal optimisation but also including integer (0/1) variables to represent	Interaction between decision makers in finding minimum discounted costs of meeting specific market requirements, i.e.	Aluminium, Copper, Fertilisers

Modelling Process Methodologies	What is the purpose of the methodology?	What quantitative method is used?	What economic behaviour is specified?	Examples of commodity applications
	investment components	capacity additions	project selection	
Optimisation model	Supply and demand analysed in relation to optimal resource exhaustion over time and cartel behaviour	Dynamic micro econometric system featuring formal cartel-fringe models such as that of monopoly, Stackelberg and Nash-Cournot	Interaction between decision makers in optimising resources allocation and prices over time in non-competitive markets involving bargaining activity	Aluminium, Copper, Oil
Input-output model	System regarded as process that converts raw materials into intermediate and final products via intermediate	Input-output model combined with macro economic framework or disaggregated raw materials	Interaction between non-fuel and fuel commodities and macro markets in reaching materials and	Minerals, Energy, Agriculture

Modelling Process Methodologies	What is the purpose of the methodology?	What quantitative method is used?	What economic behaviour is specified?	Examples of commodity applications
	processes. Investment strategies evaluated in terms of raw material supply and demand	balance framework	energy balance including supply-demand determination	
Systems simulation model	Demand, supply and other major variables and objectives considered as a complete system rather than a single market	Dynamic micro econometric equation system which when formed into a simulation framework is coupled with activity analysis and/or decision rules	Interaction between decision makers belonging to the system environment based on performance variables such as revenues, costs as well as market variables such as demand, supply, prices, etc.	Beef, Energy, Fish, Livestock, Multi-commodity, Rice

6.2.4 Scenarios

In the early eighties, Shell introduced a new modeling philosophy called the "Shell Scenario Analysis". SSA does not have a particular technical tool, though System Dynamics is used regularly, but looks at long term, top-down, scenarios. Shell Scenarios has revolutionized the way decision-makers look at modelling and forecasting especially in the energy sector. In his book "*Crise de la prevision. Essor de la prospective : Exemples et methods* » (Crisis of forecasts, rise of prospective: Examples and methods") Godet (1977) sets the tone for a new way of looking at economic modeling by the use of top-down scenarios and sensitivity analysis in decision making, instead of simple forecasts.

In fact, the scenario analysis has become both in analytical and modeling natural gas related literature a common tool. The IEA and the EU Commission's publications have scenario analysis (base, high, low, and other variable related scenarios). Considine (WiP) uses this approach in an econometric model to estimate production of Russian oil. Hartley & Medlock (2005a) and (2005b) both use this approach.

6.2.5 System dynamics

System dynamics is a powerful methodology and computer simulation modeling technique for framing, understanding, and discussing complex issues and problems. Originally developed in the 1950s to help corporate managers improve their understanding of industrial processes, system dynamics is currently being used throughout the public and private sector for policy analysis and design. Energy related research using systems dynamic is numerous, one of the research looked at is Powell, Stephen G. (1990b) looking at optimal capacity utilization for OPEC countries. The software package usually used is VENSIM (tutorial reference in the bibliography).

Ninios, Vlahos and Bunn (1993) provide a comprehensive overview of the system dynamics methodology from a "strategy support model" perspective. Morecroft and van der Heijden

(1992), Bunn and Larsen (1992a), Morecroft (1992) are quoted to support the view that system dynamics tend to be the preferred technology for industry level simulations. Ninios, Vlahos and Bunn (1993) mention that although this methodology appeals due to the user-friendly graphical design, its core has remained unchanged since the sixties. Issues identified are related to the structure, the focus, the time representation and the reusability. The methodology is, according to Peterson (1992), as quoted in Ninios, Vlahos and Bunn (1993), "abstract and, in many cases, not the natural way for the less proficient modeler to think about system structure"

The systems dynamics approach, though potentially efficient for some components of the model, does not offer enough flexibility to accommodate for the model itself especially through the aforementioned software package.

According to Ninios, Vlahos and Bunn (1993), the Object Oriented method offers strong comparative advantages in that it provides for encapsulation (being able to put variables and functions together under the form of classes), inheritance (the way in which a class can be lower down the hierarchy than another class and would therefore offer flexibility in dealing with such systems, and was suggested in organisation modelling by Blanning (1987).

The Object-Oriented methodology is particularly strong when coupled with a relational database system[92] which optimises the structure of the data and the inheritance structure of the classes.

6.3 Methodology

The methodology proposed in the present paper is referred to as DOOS (Dynamic Object Oriented System). It is a simulation tool whose mechanics are obtained through calibration

[92] Deleany (2000)

to past behavior of variables and that is suitable to economic systems with legal, political and infrastructure constraints. The DOOS methodology also uses a relational database structure, normalized on a top-down basis.

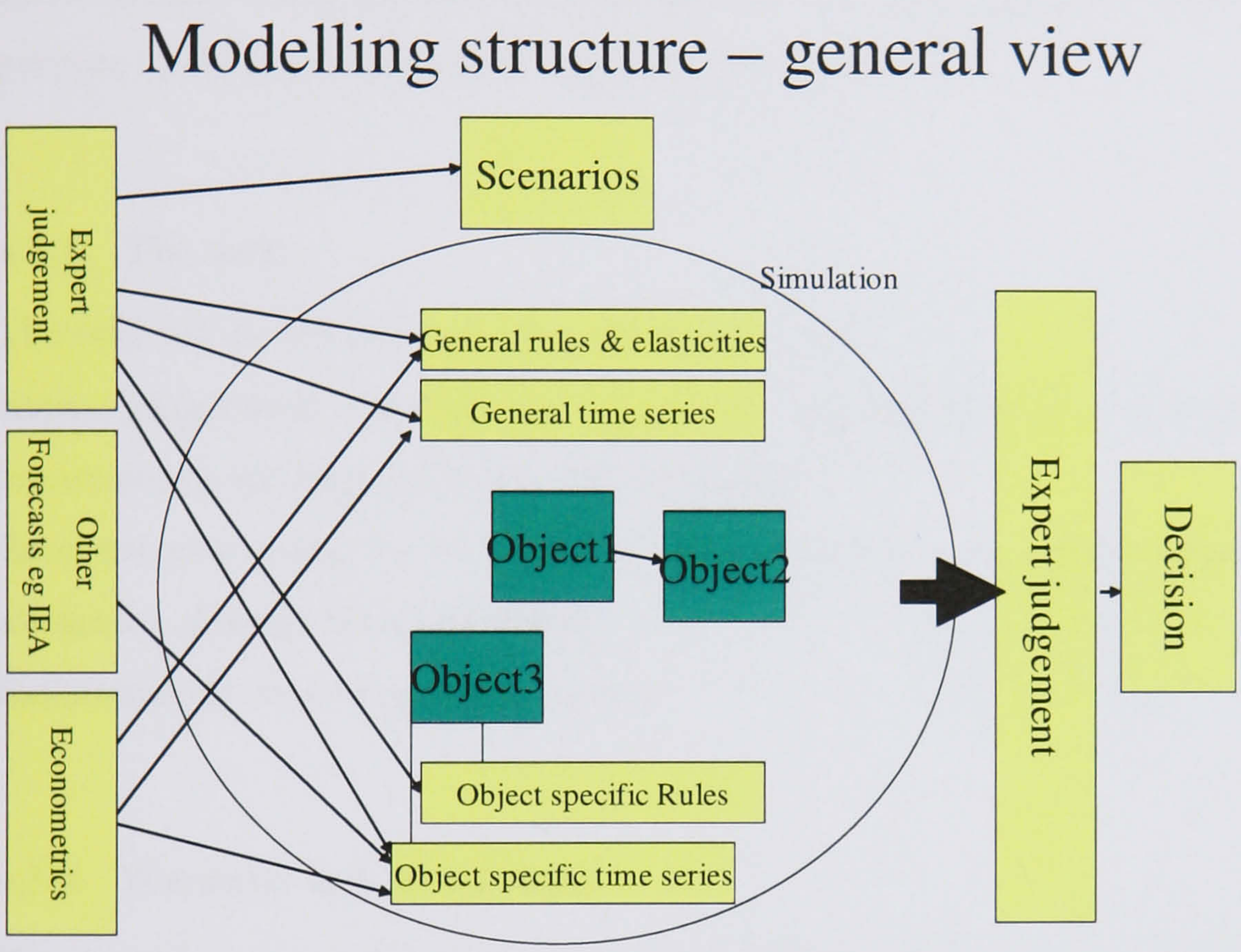

Figure 6-1 Modelling Structure of the Dynamic Object Oriented System

6.3.1 The Objects

The objects are instances within classes. Classes (e.g. pipeline), their variables (e.g. pipeline capacity) and their functions (e.g. enable pipeline) are predefined in the model and cannot be changed during the running though their contents can be amended. Objects however can be edited, added or removed from the system according to a defined **rule**. The system will therefore be dynamically amended.

6.3.2 The Data

The data, or variables, maybe **object specific** or **'global',** they are obtained by different means including:

Expert judgements: forecasts by experts and organisations

Econometrics: using forecasts obtained from econometric models constructed either for the purpose of the present model or for other considerations

6.3.3 The rules

The rules maybe are obtained from different sources:

Expert judgements: forecasts by experts and organisations in terms of policy decisions, infrastructure and legal decisions and other rules

Econometrics: using the LOGIT/PROBIT method or through the inputting of different elasticities, discreet choice modelling

Calibration: by observing past behaviour

6.3.4 Scenarios and simulations

The scenarios are sets of **dynamic data tables**. Each table represents a scenario and includes the set of object specific and global variables and rules. The simulation is run for each scenario according to predefined constant rules (e.g. if the CIF price in the US east coast is higher than the CIF price to Spain plus the shipping cost between Spain and the US, and the destination clause in the contract between any supplier to Spain is not active, then the cargo can be diverted to the US and more cargo will be required by Spain to compensate for that cargo).

As the table includes information, complete or incomplete, until the end of the time-horizon for the simulation, the model runs for period t, and according to the rules, where applicable, fills the information gap in the subsequent time periods according to the rules. When the simulation runs for t+1, it will take into account the information inputted through the scenarios and the information generated by the model and inputted in the information table.

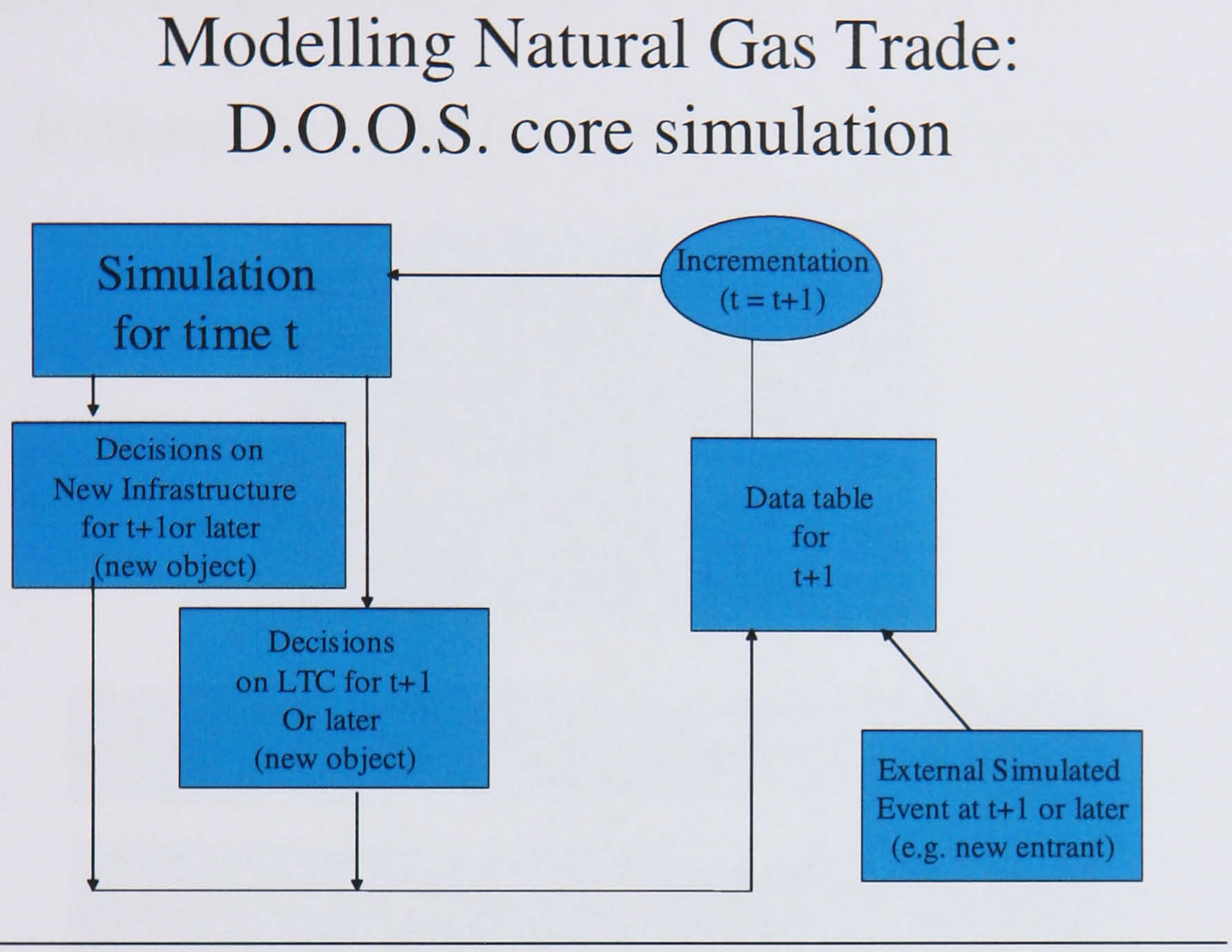

Figure 6-2 DOOS simulation diagramme

The variables for which the model provides forecasts are referred to as **forecastable variables.** When the simulation is run for each scenario, probabilities can be assigned to each scenario for decision making, or such decision can be supported by the decision-maker's belief in such of such scenario.

On top of this, by running a large number of scenarios, the model can also provide sensitivity analysis for, say, a legal variable or other variables.

6.3.5 Integrity of the model

Out-sample forecasting is a potential tool for verifying the integrity of the model. The calibration should be conducted on a sample *t* to *t+n-1* and the simulation run for *t+n* until *t+n+k* using either known information at *t+n+k* or assumed information at *t+n-1*. The model should be run under one scenario and results thereof should be compared to a predefined '**Acceptable Level of Errors**' for each forecastable variable.

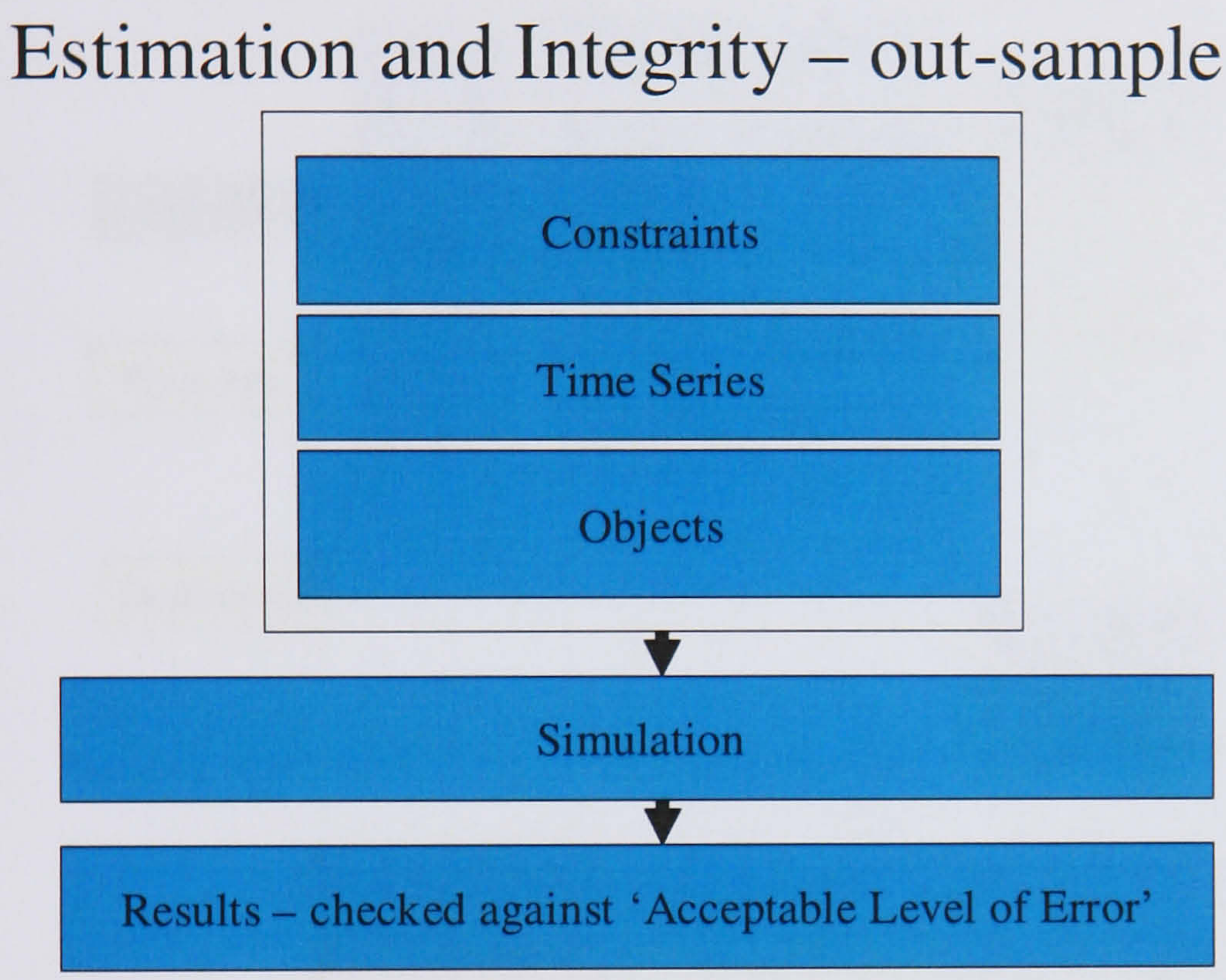

Figure 6-3 Verifying the integrity of the model

6.4 The model

The graphical representation of the model

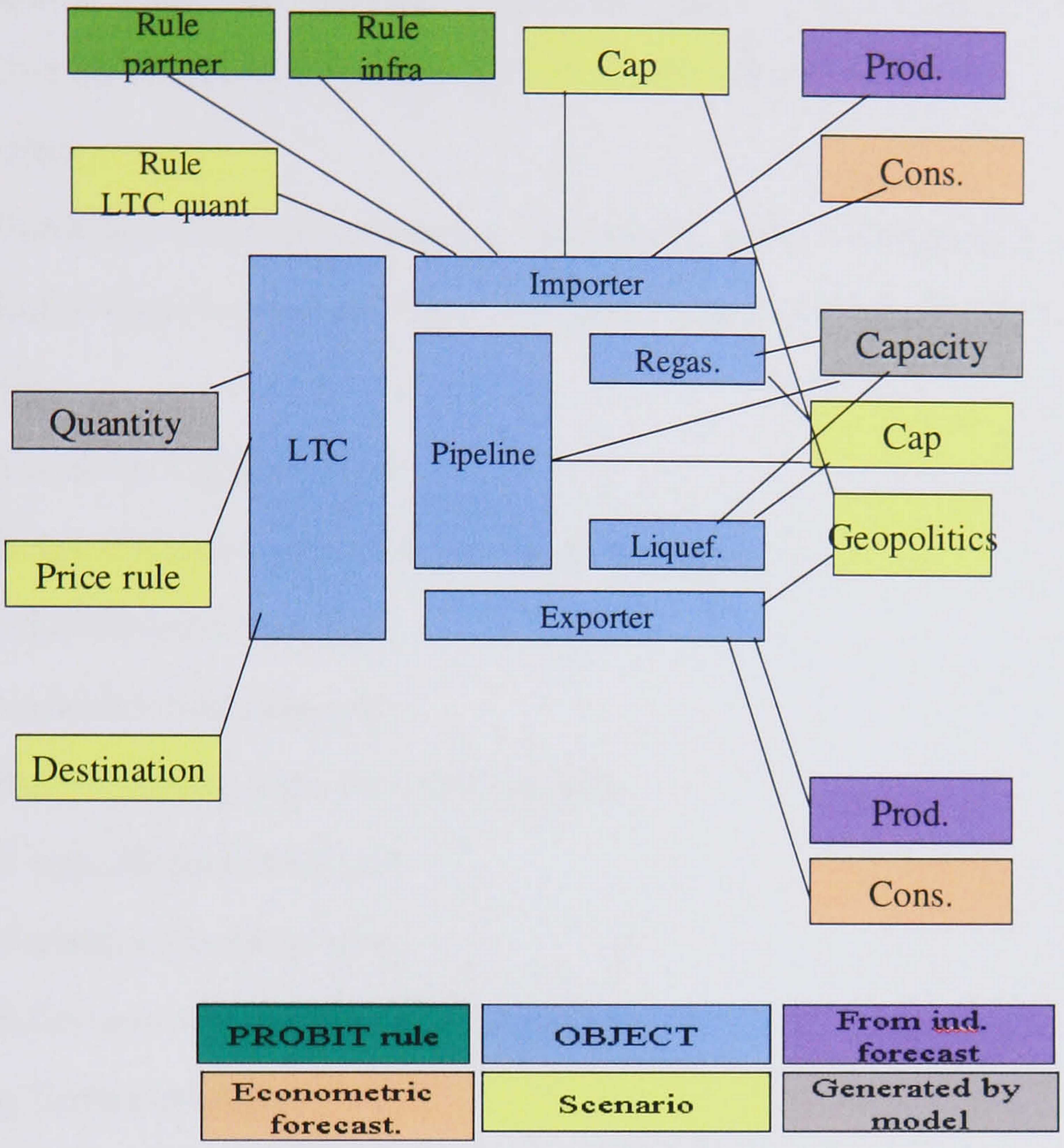

Figure 6-4 DOOS applied to the Mediterranean gas market

6.4.1 Assumptions

- The system is demand led: discussed above
- Abundant shipping supply: This assumption is taken as, at the time of writing, shipping capacity exceeds total demand and a number of ships are on lay-up according to Poten 2004.

6.4.2 Objects

- Importer
  - Variables: Comsuption array, Production array, weather

- Rules: Caps on imports, Caps on spare capacity, threshold for investment in terminal, threshold for negotiation of LTC, partner of LTC

- Exporter
  - Variables: Consumption array, Production array, political relation (dummy)
  - Rules: Caps on exports, Caps on spare capacity, threshold for investment in terminal
- Pipeline
  - Variables: Capacity array
  - Rules: importer, exporter, cap on spare capacity
- LNG liquefaction terminal
  - Variables: Capacity array
  - Rules: country, caps on spare capacity
- LNG regasification terminal
  - Variables: Capacity array
  - Rules: country, caps on spare capacity
- Long Term Contract
  - Variables: quantity array, price array (available in the model, but not used)
  - Rules: importer, exporter, assigned infrastructure, destination clause (dummy)

6.4.3 Rules

The rules or the constraints take into account forecasted and assumed variables to make decisions for infrastructure decisions and partner choice. Different rules can be used, but for this exercise, the PROBIT results of Chapter 5 are incorporated.

6.4.4 Econometric Forecasts

The forecasts obtained from chapter 4 are included as series. This being said, other forecasts and scenario forecasts can also be inputted. Also, results from Honore (2005) power generation model are also added.

6.4.5 Scenarios

The model allows for 3 multiple entries of each value and allows for the separate simulation for each "state of the world". Results in chapter 7 show the base case scenario.

6.4.6 "Generated by Model"

New dynamic objects that the model generates will be assumed to have attributes that are close to the average of that particular country.

6.4.7 Data Structure

Because of the links between the objects of the model, data is stored in a relational database. SQL[93] is used to communicate between the program and the database.

[93] SQL is a scripting language used to communicate with relational databases

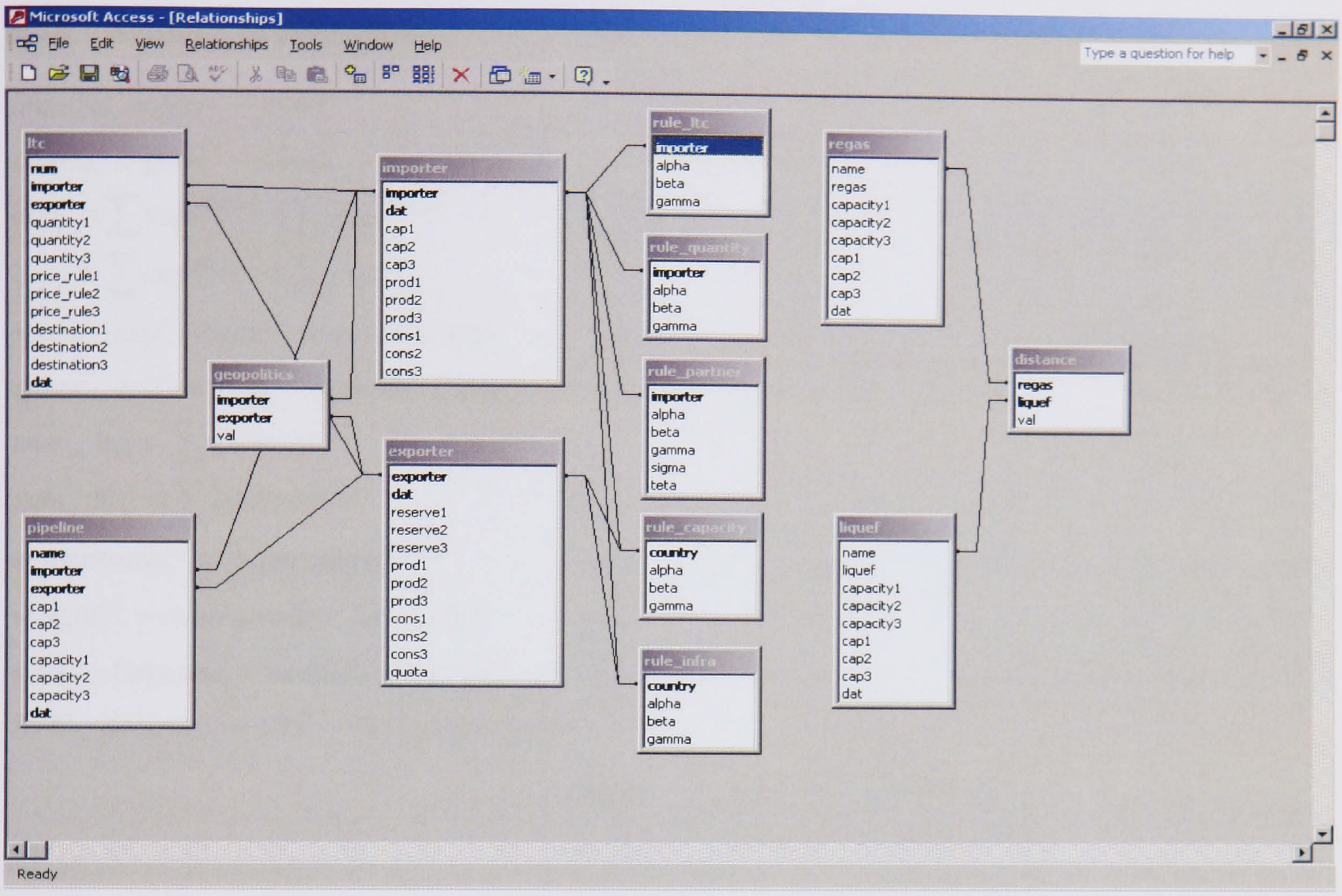

Figure 6-5 Data Structure of the Model

The following relationships are assumed:

Country -> Terminal (one-to-many)

Pipeline-> Country (one-to-two)

Contract->Country (one-to-two)

6.4.8 Running of the model

$$imports_t^i = cons_t^i - prod_t^i$$
$$eports_t^e = prod_t^e - cons_t^e$$
$$cap_t^e = \sum cap_t^{liquf[e]} + \sum cap_t^{pipe[e]}$$
$$cap_t^i = \sum cap_t^{regas[i]} + \sum cap_t^{pipe[i]}$$
$$spare\_cap_t^i = (cap_t^i - imports_t^i) / cap_t^i$$
$$spare\_cap_t^e = (cap_t^e - imports_t^e) / cap_t^e$$
$$sum\_ltc_t^i = \sum quantity_t^{ltc[i]}$$
$$sum\_ltc_t^e = \sum quantity_t^{ltc[e]}$$
$$contratrade_t^{e,i} = \sum quantity_t^{ltc[e][i]}$$
$$weight_t^{i,e} = contratrade_t^{e,i} / sum\_ltc_t^i$$
$$spot_t^i = (imports_t^i - sumltc_t^i) / imports_t^i$$
$$LTC\_decision_t^i = LTC\_RULE(spot_t^i, ...)$$
$$Partner\_choice_t^i = PARTNER\_RULE(\begin{bmatrix} weight_t^{1,i} \\ weight_t^{2,i} \\ weight_t^{3,i} \\ ... \\ ... \\ weight_t^{e,i} \end{bmatrix}, \begin{bmatrix} political^{1,i} \\ political^{2,i} \\ political^{3,i} \\ ... \\ ... \\ political^{e,i} \end{bmatrix}, \begin{bmatrix} distnce^{1,i} \\ distnce^{2,i} \\ distnce^{3,i} \\ ... \\ ... \\ distnse^{e,i} \end{bmatrix}, ...)$$
$$INFRA\_decision_t^i = INFRA\_RULE_i(spare\_cap_t^i, ...)$$
$$INFRA\_decision_e^i = INFRA\_RULE_e(spare\_cap_e^i, ...)$$

Equation 3 Functioning of the DOOS

6.4.9 Integrity of the model

The aim of the present paper was to introduce the DOOS methodology and to give an indication about its reliability and efficiency. An estimation is conducted between 1980 and 1996 to determine some of the rules and an out-sample analysis is conducted from 1996. It is noteworthy that one of the most important features of this methodology, the scenario approach, was not taken as this is an out-sample, not a forecasting exercise. As aforementioned, forecasts for the data were obtained using an in-house econometric model, scenario variables (such as oil prices) were kept inactive –as it is applicable- and forecasts for rules were obtained either through the estimation using the PROBIT/LOGIT method[94].

With hindsight, the market was influenced by many new entrants in this period, new entrants are not forecasted by the model, but are included in the information table as scenarios. This said, the model has however generated interesting results:

Below are the predictions of the model and what actually happened:

Regasification terminals

Actual terminal	Country	Actual Capacity[95]	Actual date of start	Predicted date of start
Bilbao	Spain	2.7	2003	2002
Rovigo	Italy	6	2005	2005*
Brindisi	Italy	4	2007	2006*
Sagunto	Spain	8	2005	2004*

Liquefaction terminals

Actual terminal	Country	Actual Capacity	Actual date of start	Predicted date of start
Bnny Island	Nigeria	10.9	2005	2005*
Ras Laffan	Qatar	9.0	1999	2000

[94] Refer to previous chapter

[95] BCM (Billion Cubic Feet)

The next chapter will put together results of chapter 4, 5 and 6 and produce foreasts for discussion.

7. Putting it all together: Example model result

This chapter will use the models proposed in this thesis to discuss the current supply profiles for France, Italy and Spain. Section 1 of this chapter will discuss the infrastructure for these countries. Section 2 will propose a benchmark for the partner portfolios.

7.1 The Import Infrastructure

7.1.1 Consumption

7.1.1.1 Assumptions

The following assumptions are made:

- The industrial production growth between 2005-2013 is **2%** for the three countries (normalised assumptions from various sources)
- The weather is assumed to be constant at year 2004 (the weather affects growth either way and is important in terms of sensitivity, as discussed in chapter 4, rather than level).
- The production in Italy is assumed to reduce at a rate of **6%** (current depletion rate)
- As mentioned in chapter 4, Honore (2005) is used for the power generation forecasts
- Other gas consumption is taken from the IEA (2005) with a growth rate of **1% per year**
- The conversion factor from BCM to MTOE is **0.9**[96]

7.1.1.2 Results for France

[96] BP Statistical Review of World Energy (2005)

Consumption (mtoe)	Source	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Industrial	Generated by Model, Chapter 4	16.08	16.29	16.58	16.91	17.25	17.61	17.97	18.34	18.72	19.11
Resid-Comm	Generated by Model, Chapter 4	19.99	20.47	21.12	21.84	22.61	23.42	24.25	25.12	26.01	26.94
Power Generation	Honore (2005)	1.97	2.00	2.04	2.07	2.10	2.14	2.18	2.21	2.25	2.29
Other	IEA and author's assumptions	1.00	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09
Total	Calculated	39.04	39.77	40.76	41.85	43.01	44.22	45.46	46.74	48.07	49.43

Table 8 Forecasted Consumption for France

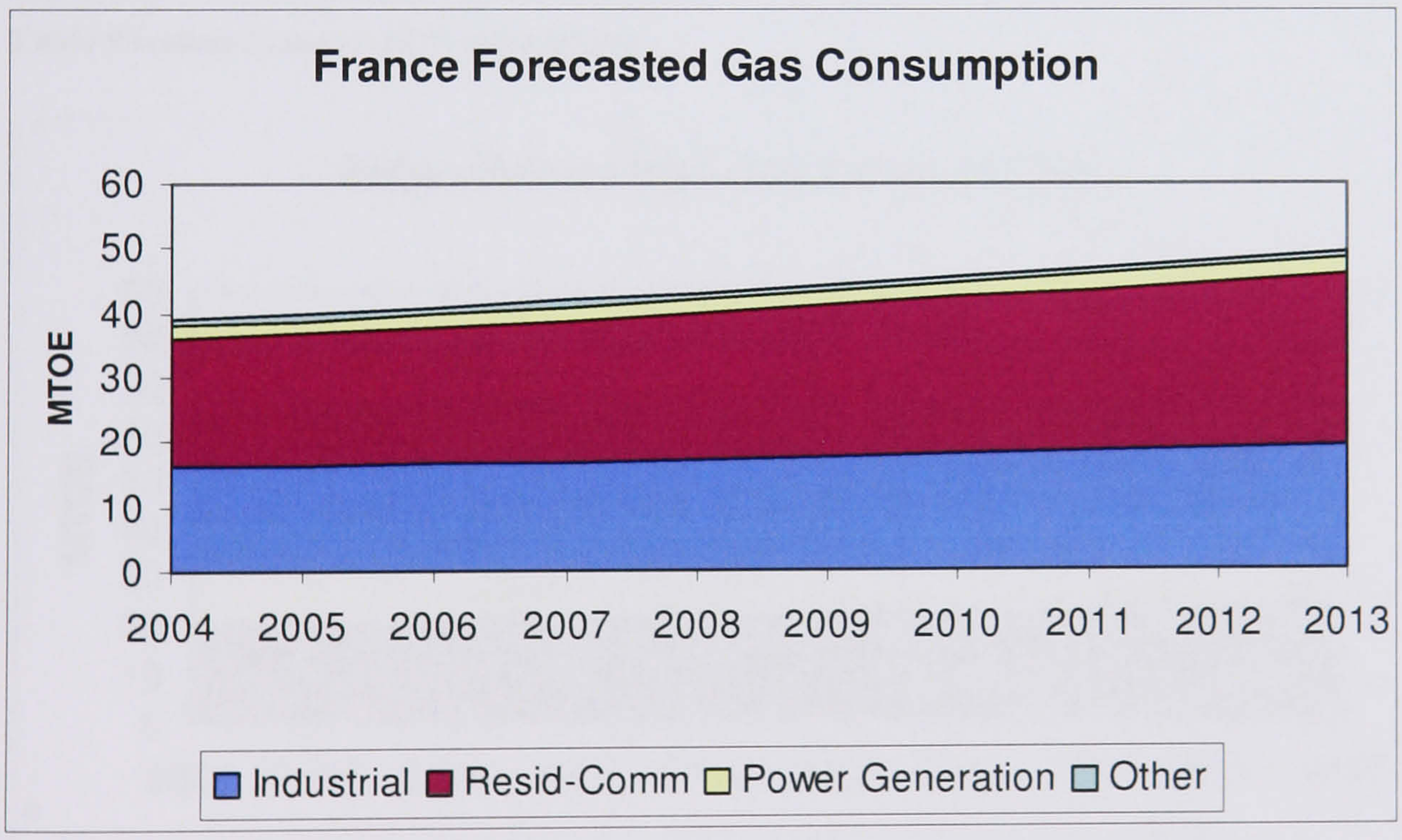

Figure 7-1 French Forecasted Consumption

7.1.1.3 Results for Italy

Consumption (mtoe)	Source	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Industrial	Generated by Model, Chapter 4	19.49	19.82	20.27	20.78	21.31	21.87	22.44	23.033	23.639	24.26
Resid-Comm	Generated by Model, Chapter 4	22.75	23.41	24.33	25.35	26.45	27.6	28.8	30.061	31.375	32.75
Power Generation	Honore (2005)	20.7	21.2	21.2	21.2	21.2	21.2	21.2	21.201	21.201	21.2
Other	IEA and author's assumptions	1	1.01	1.02	1.03	1.041	1.051	1.062	1.0721	1.0829	1.094
Total	Calculated	63.94	65.44	66.82	68.36	70	71.72	73.51	75.368	77.297	79.3

Table 9 Italian Forecasted Consumption

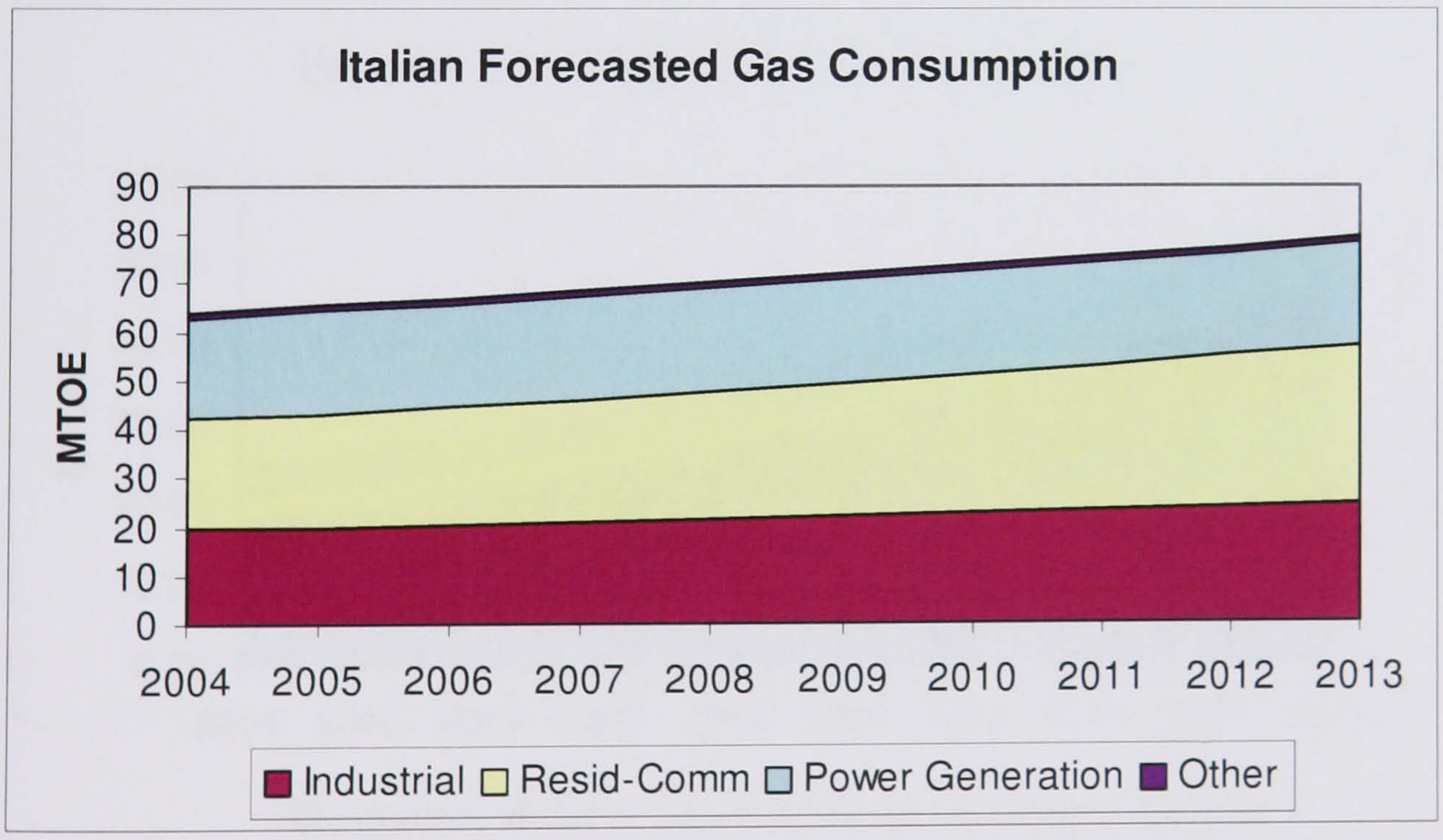

Figure 7-2 Italian Forecasted Consumption

7.1.1.4 Results for Spain

Consumption (mtoe)	Source	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Industrial	Generated by Model, Chapter 4	13.21	14.21	15.66	17.41	19.40	21.64	24.15	26.94	30.07	33.55
Resid-Comm	Generated by Model, Chapter 4	4.50	4.92	5.54	6.28	7.14	8.12	9.24	10.51	11.96	13.61
Power Generation	Honore (2005)	3.70	3.83	3.97	4.12	4.27	4.42	4.59	4.75	4.93	5.11
Other	IEA and author's assumptions	3.00	3.03	3.06	3.09	3.12	3.15	3.18	3.22	3.25	3.28
Total	Calculated	24.41	26.00	28.24	30.90	33.93	37.34	41.15	45.42	50.20	55.55

Table 10 Spanish Forecasted Consumption

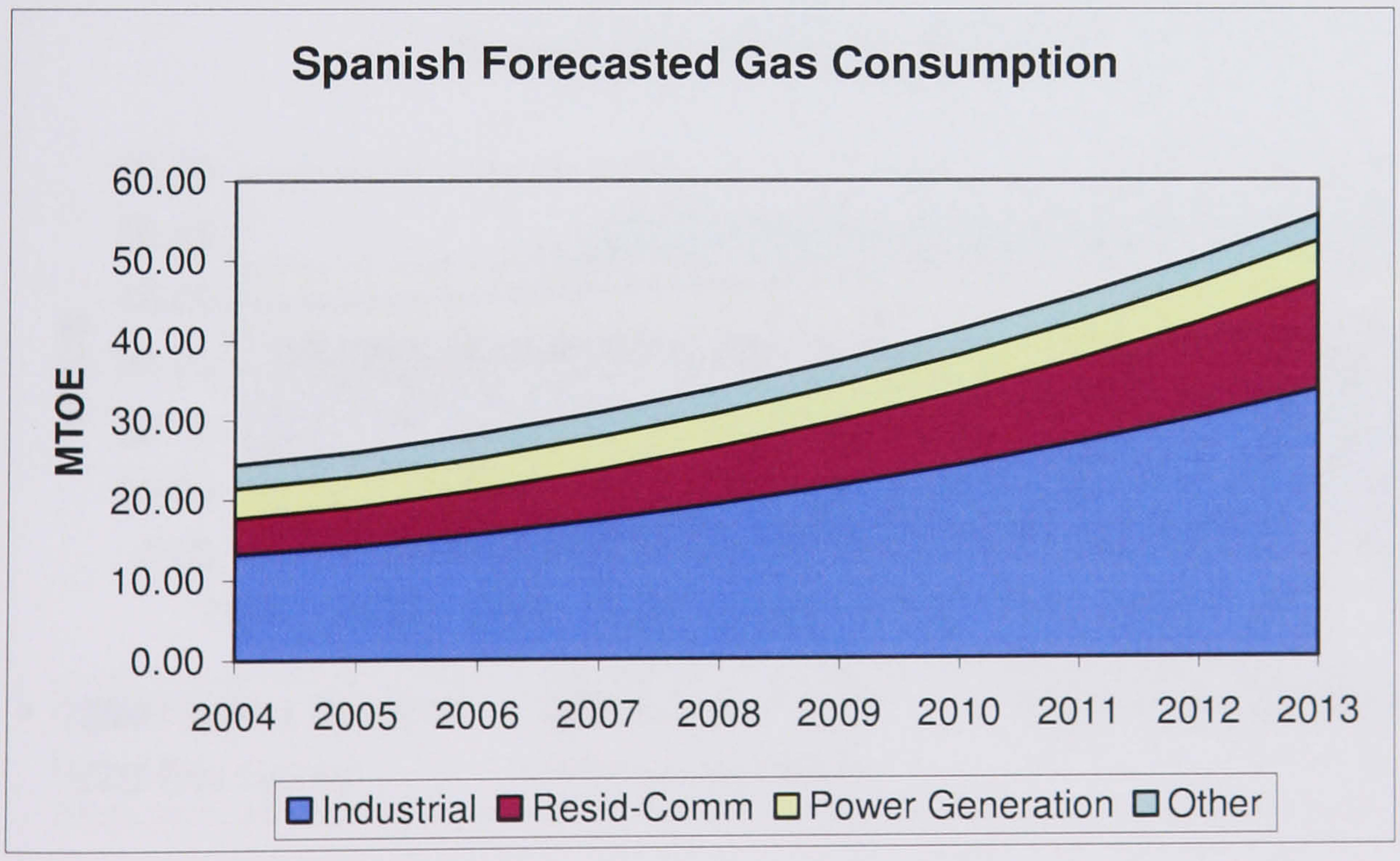

Figure 7-3 Spanish Forecasted Consumption

7.1.2 Infrastructure – Actual

7.1.2.1 France

Supply	Source	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Existing Pipelines	BP Statistical Review 2005	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
Fos Sur Mer	Gas Strategies Online 2006	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93
Montoir De Bretagne		11.34	11.34	11.34	11.34	11.34	11.34	11.34	11.34	11.34	11.34
Fos Cavou					7.46	7.46	7.46	7.46	7.46	7.46	7.46
Consumption	As above	39.04	39.77	40.76	41.85	43.01	44.22	45.46	46.74	48.07	49.43

Table 11 French Consumption with Current Infrastructure

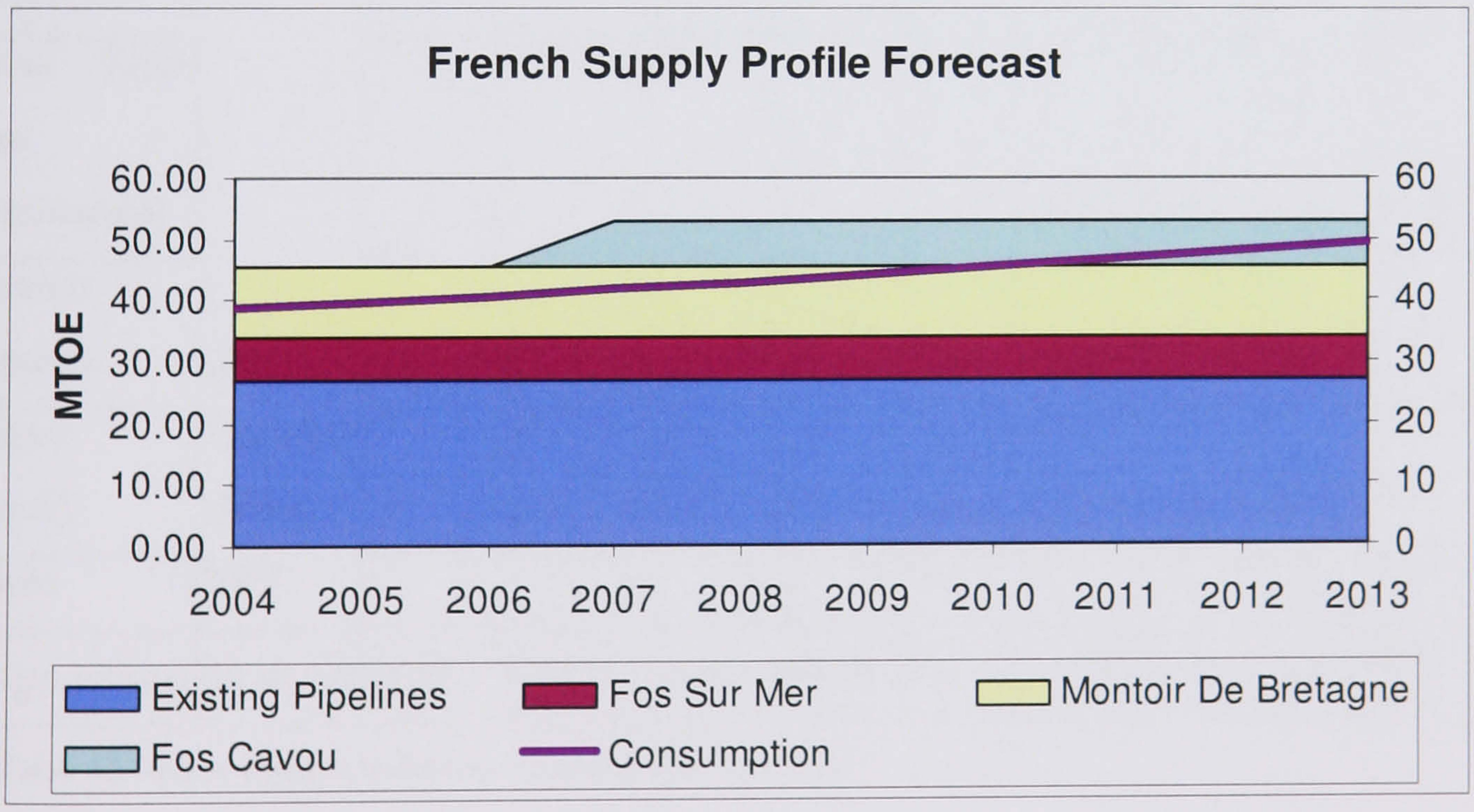

Figure 7-4 French Consumption and Infrastructure

7.1.2.2 Italy

Profile	Source	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Production	BP	11.70	11.00	10.34	9.72	9.13	8.59	8.07	7.59	7.13	6.70
Existing Pipelines	Statistical Review 2005	53.20	53.20	53.20	53.20	53.20	53.20	53.20	53.20	53.20	53.20
Galsi pipeline	Algerian Ministry of Energy							9.00	9.00	9.00	9.00
La Spazia		3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47
Adriatic LNG						7.2	7.2	7.2	7.2	7.2	7.2
Brindisi						7.2	7.2	7.2	7.2	7.2	7.2
Livorno offshore						3.6	3.6	3.6	3.6	3.6	3.6
Gioia Tauro (San Ferdinando)							10.8	10.8	10.8	10.8	10.8
Taranto (Apuila)	Gas						7.2	7.2	7.2	7.2	7.2
Trieste (Friuli)	Strategies Online						7.2	7.2	7.2	7.2	7.2
Priolo	2006							7.2	7.2	7.2	7.2
Consumption	As above	63.94	65.441	66.82	68.36	70	71.72	73.51	75.37	77.3	79.3

Table 12 Italian Consumption and current infrastructure

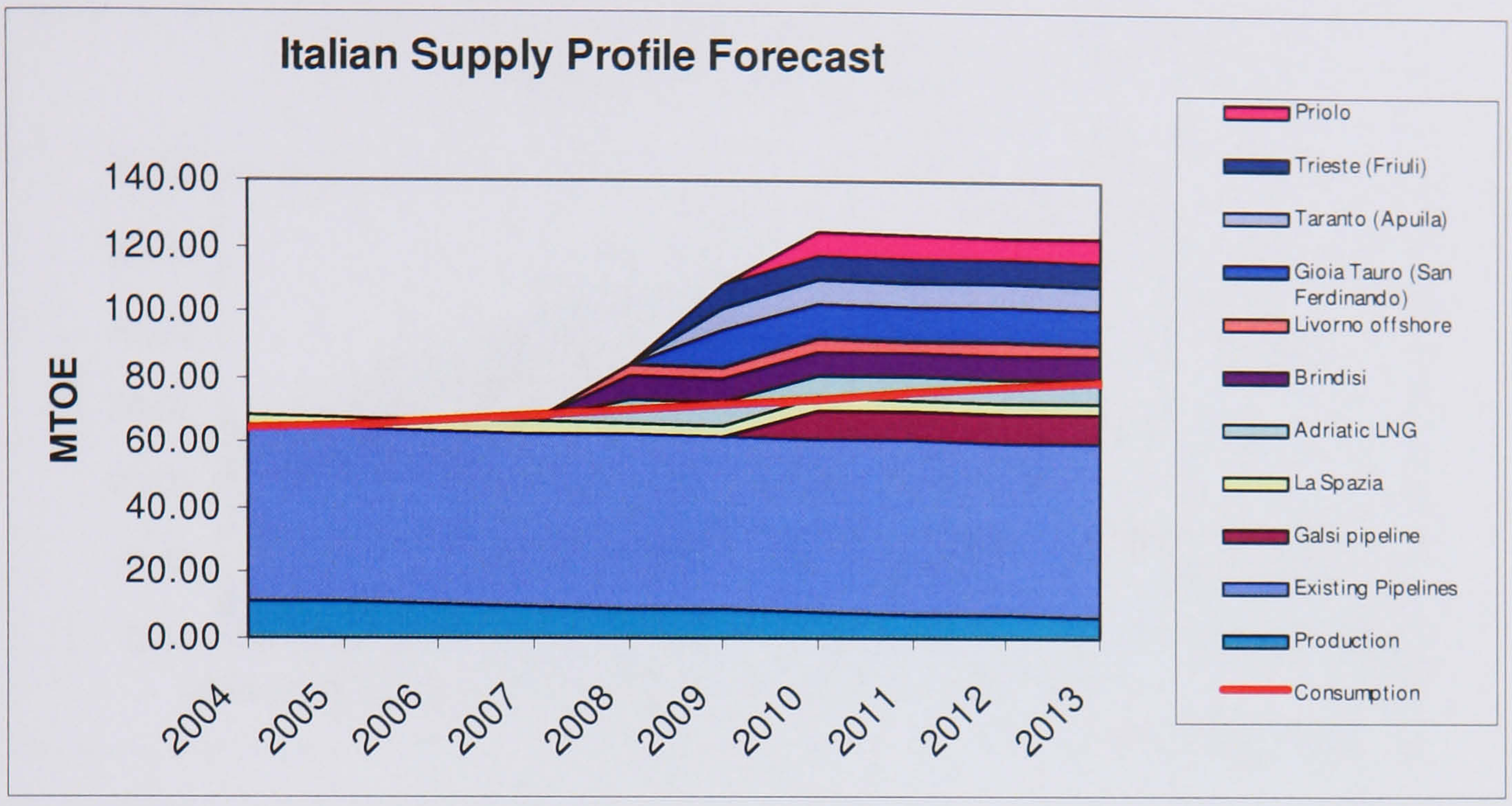

Figure 7-5 Italian Consumption and Planned Infrastructure

7.1.2.3 Spain

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Pipeline imports	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76
New pipelines (MEDGAS)					9.00	9.00	9.00	9.00	9.00	9.00
Bilbao	5.454	5.454	5.454	5.454	5.454	5.454	5.454	5.454	5.454	5.454
Cartagena	7.092	7.092	7.092	7.092	7.092	7.092	7.092	7.092	7.092	7.092
Huelva	7.092	7.092	7.092	7.092	7.092	7.092	7.092	7.092	7.092	7.092
El Ferrol			2.259	2.259	2.259	2.259	2.259	2.259	2.259	2.259
Sagunto			5.913	5.913	5.913	5.913	5.913	5.913	5.913	5.913
Consumption	24.41	26.00	28.24	30.90	33.93	37.34	41.15	45.42	50.20	55.55

Table 7-13 Consumption and Planned Infrastructure

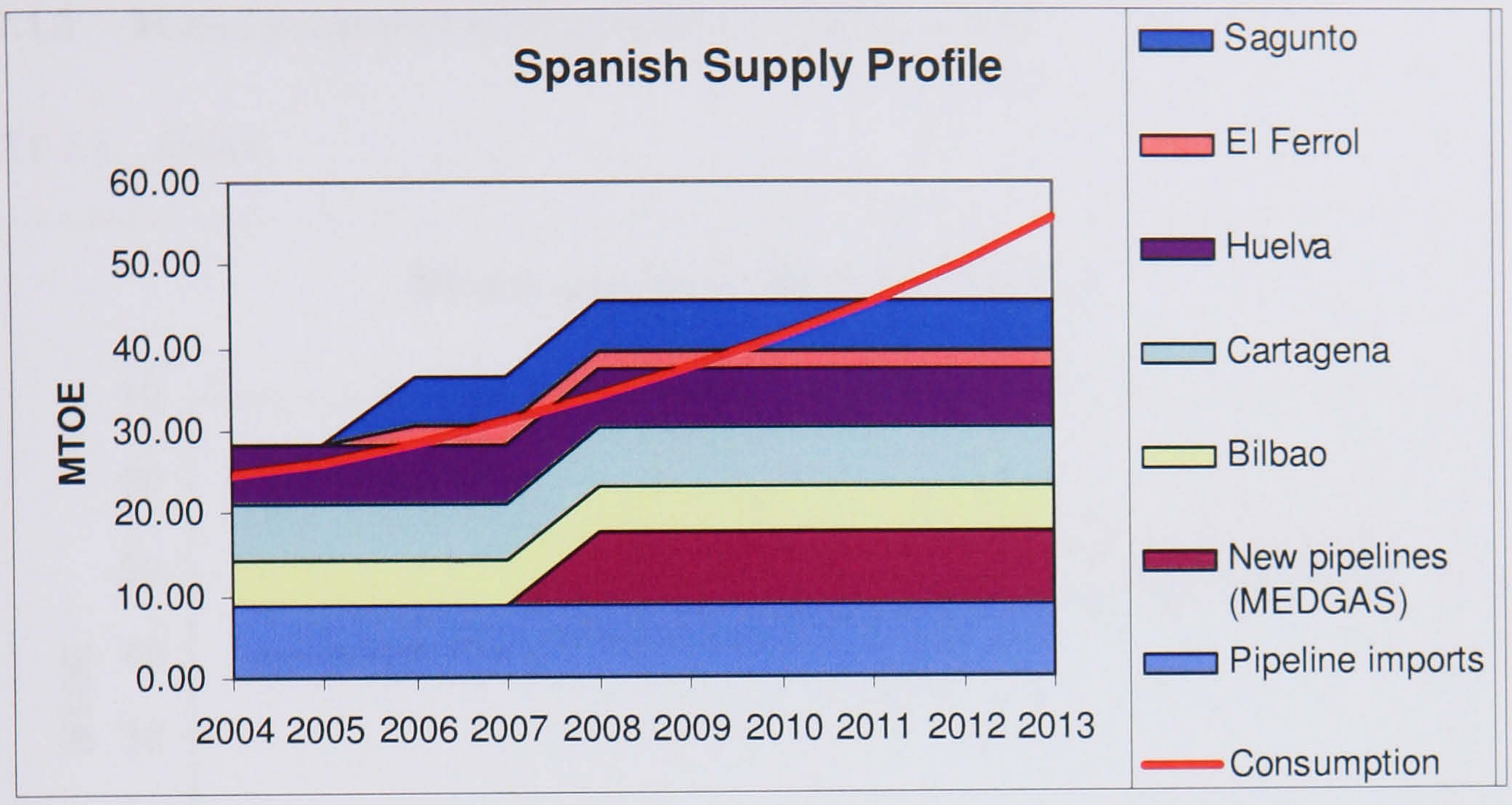

Figure 7-6 Consumption and Planned Infrastructure

7.1.3 Model generated infrastructure, example results

7.1.3.1 France

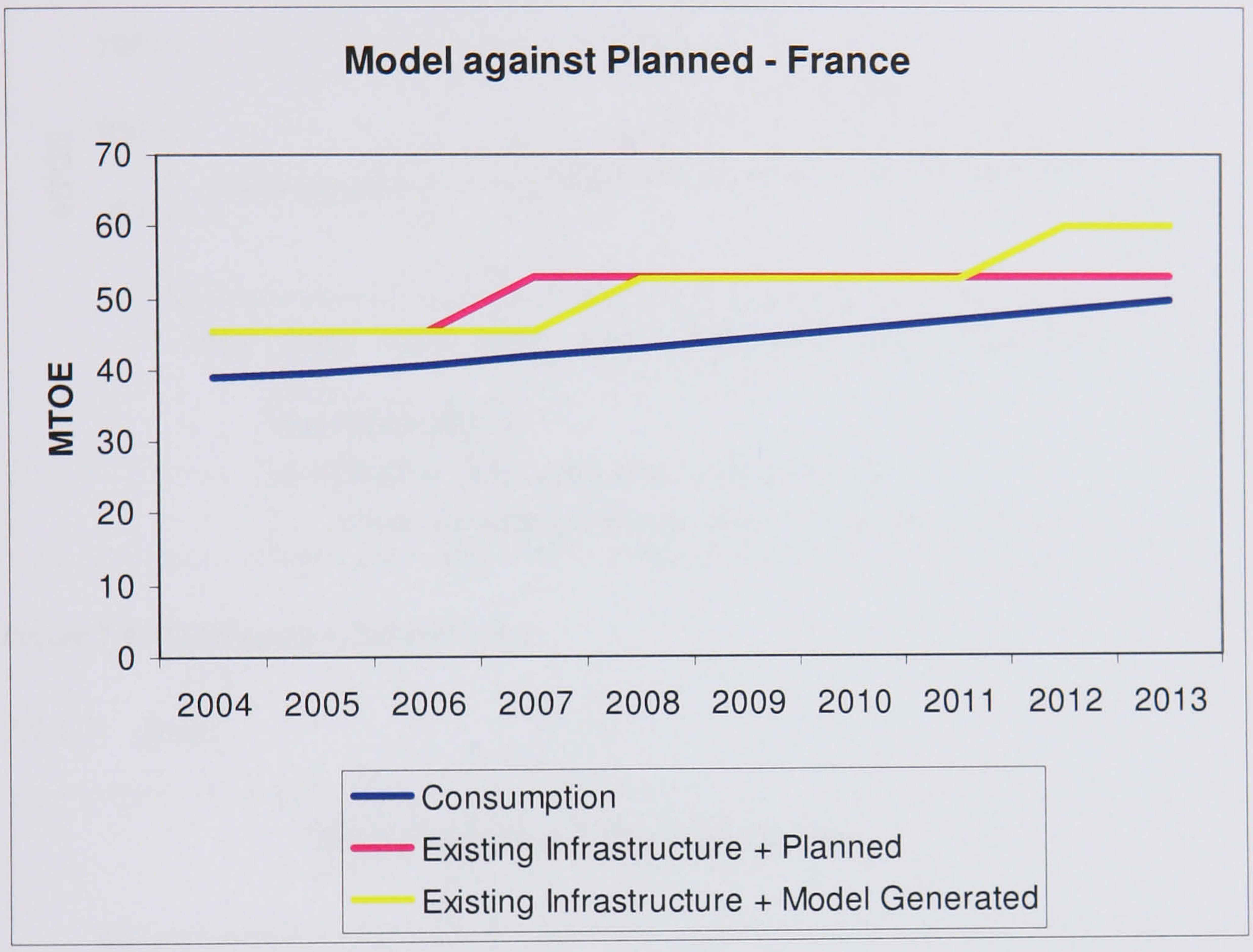

Figure 7-7 Model against Planned - France

7.1.3.2 Italy

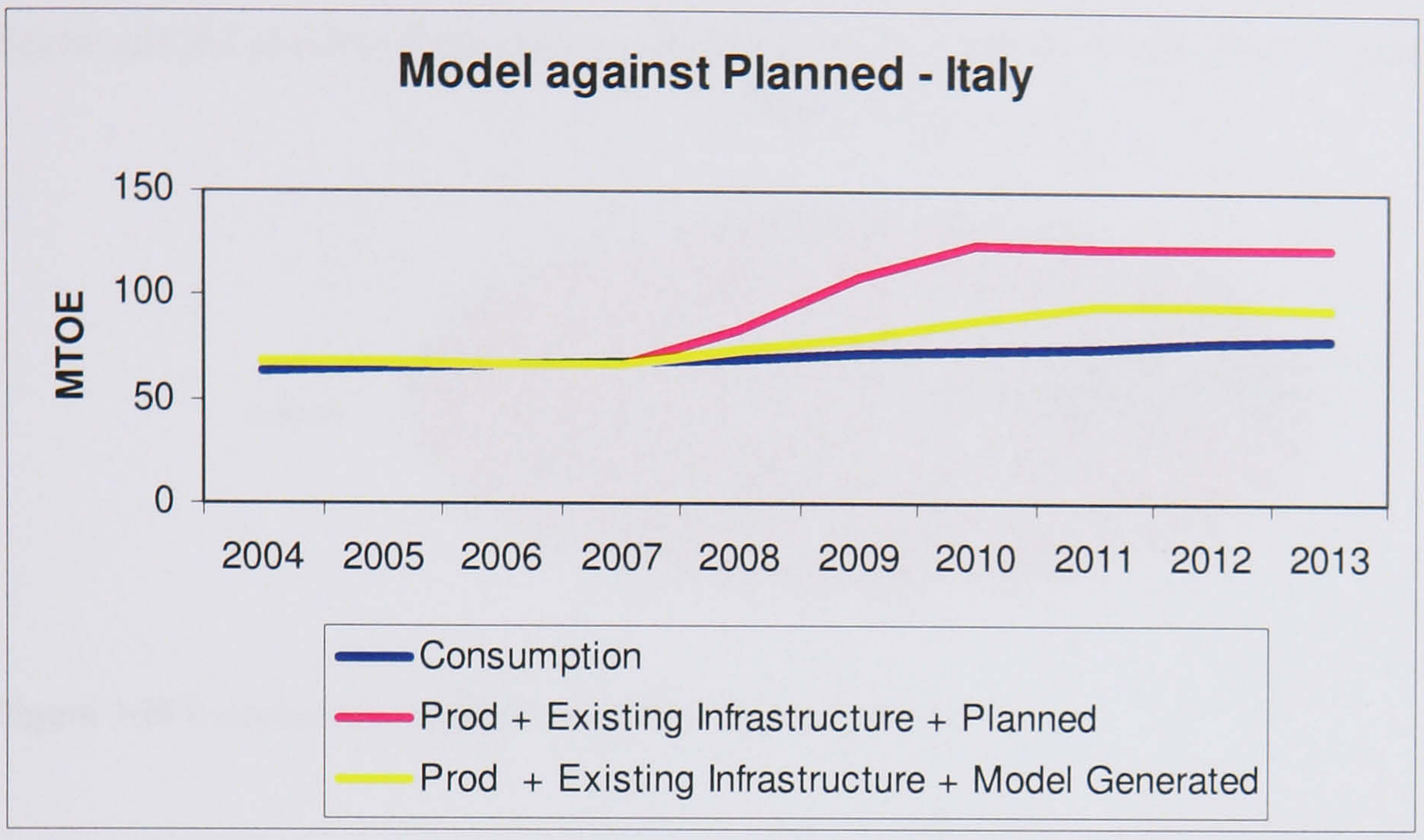

Figure 7-8 Model against Planned - Italy

7.1.3.3 Spain

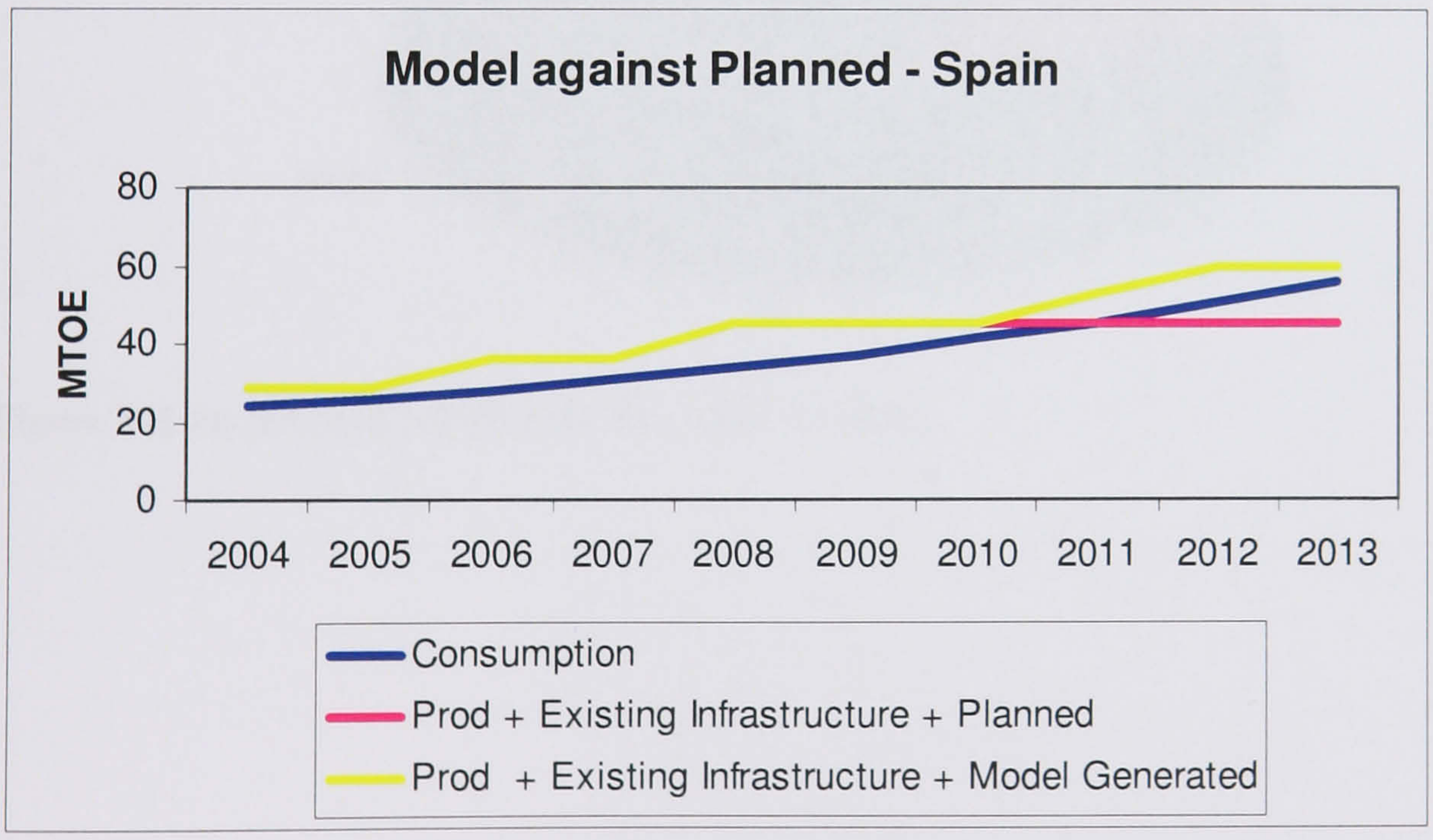

Figure 7-9 Model against Planned - Spain

7.2 Partner choice

Below are the results of the partner choice model, using the assumptions listed above.

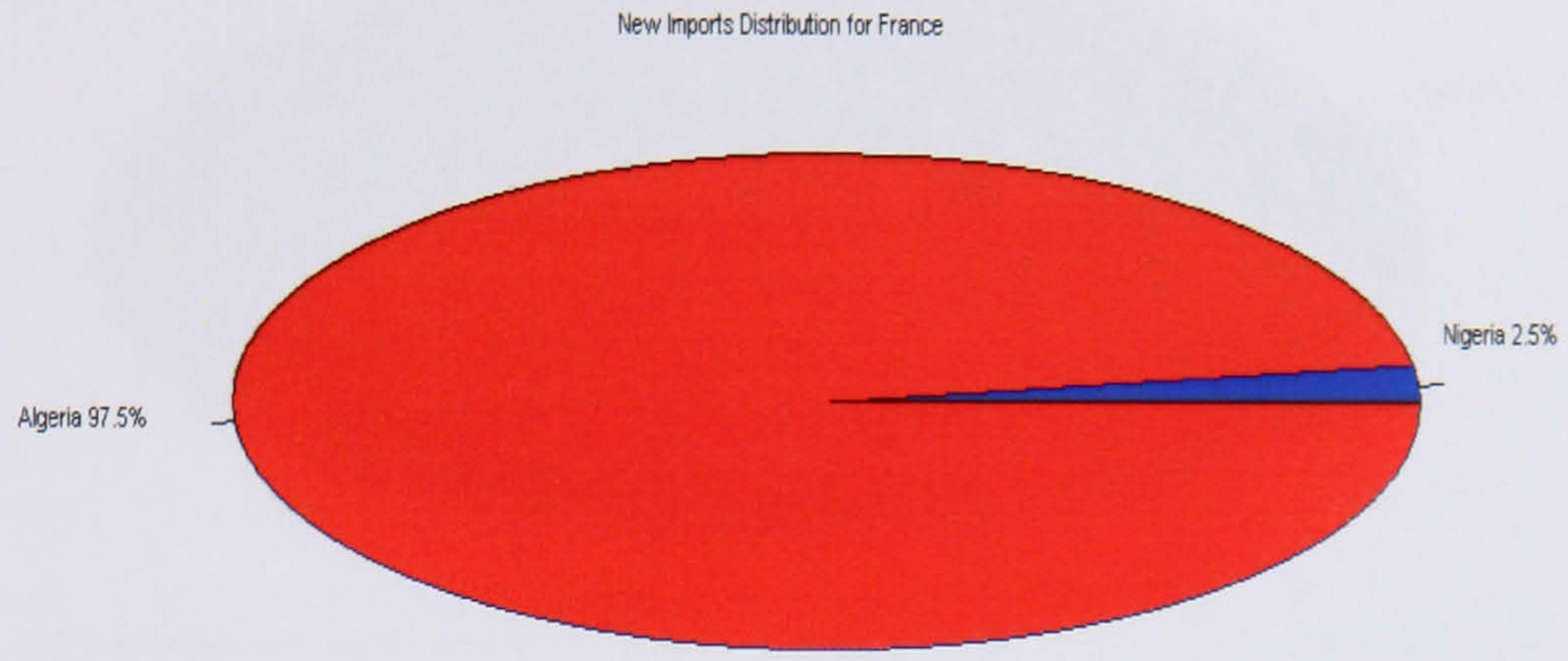

Figure 7-10 Incremental portfolio for France (2013 horizon)

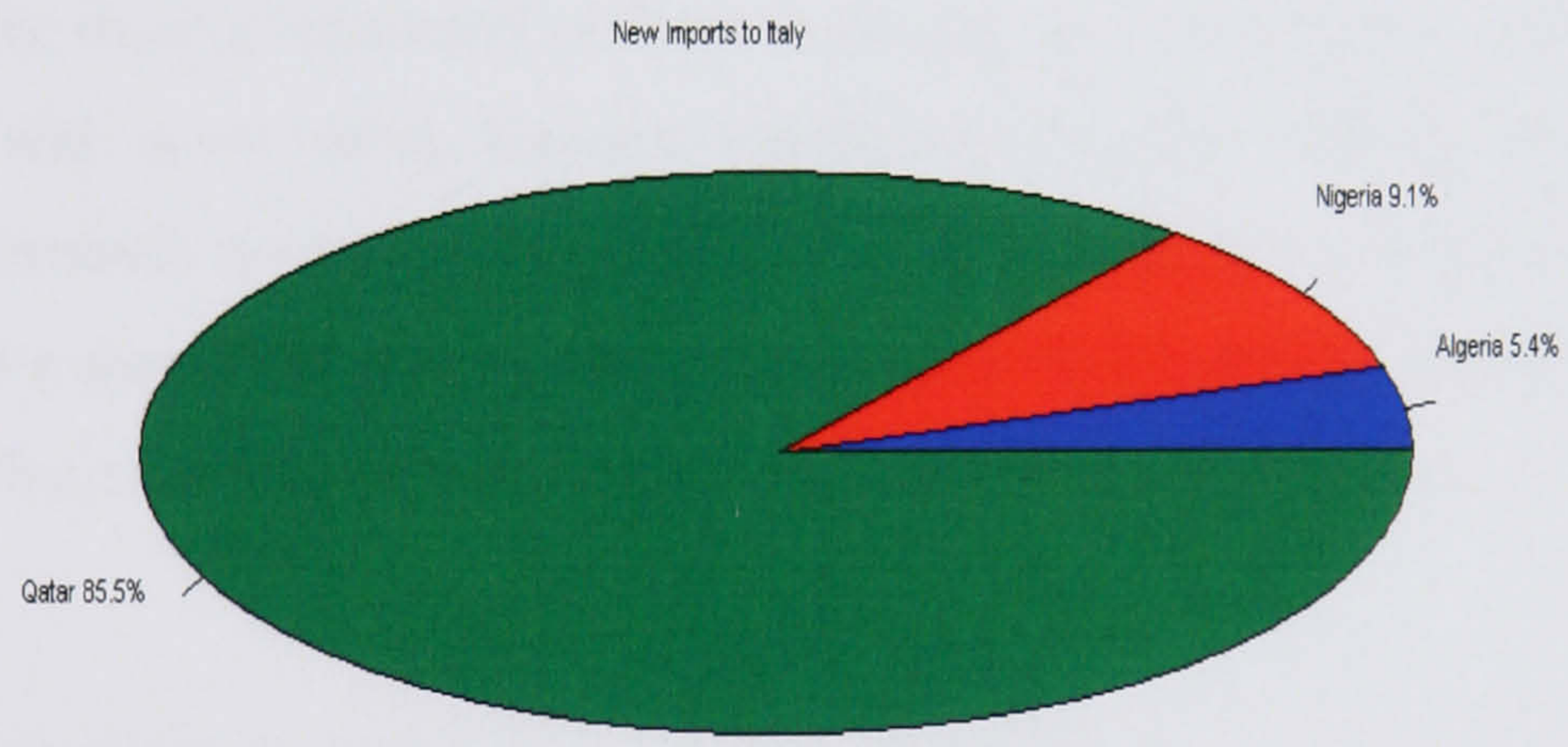

Figure 7-11 Incremental portfolio for Italy (2013 horizon)

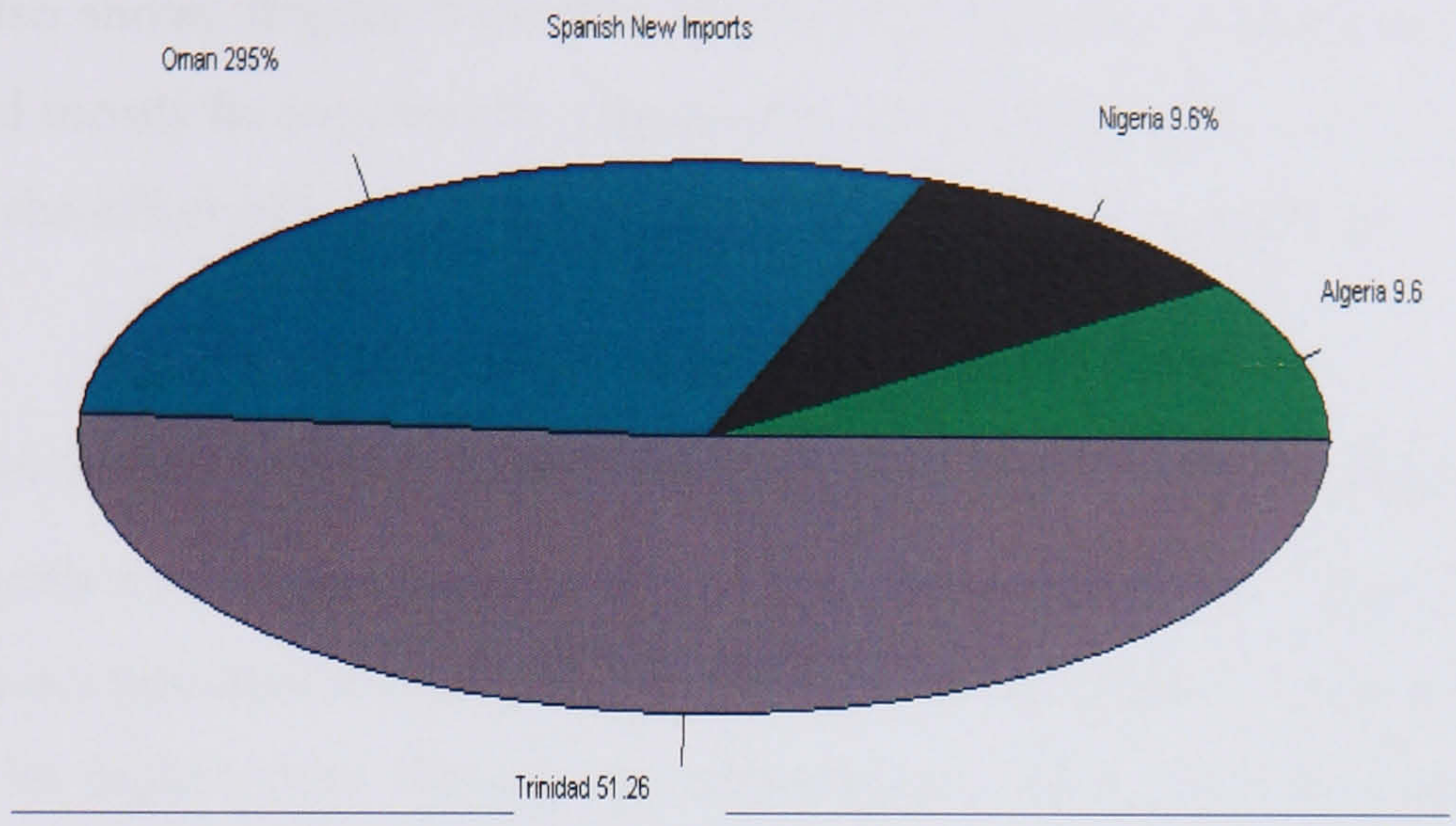

Figure 7-12 Spanish Incremental Portfolio (2013 horizon)

7.3 Discussion & Challenges

The results above show a continued increase in natural gas consumption in France, Italy and Spain, in line with most other forecasts, including the IEA (2004). An investment in regasification terminals is expected (and documented in section 7.1.2). This thesis observes whether there is a significant mis-match between the current plans to invest in regasification terminals and what they should have been under a non-liberalized system.

7.3.1.1 French market well supplied: because of lag in liberalization?

The French market is expected to grow as shows Figure 7-1. Chapter 3 discusses the state of the French gas liberalization, which stands as one of the slow ones in Europe. Figure 7-4 and Figure 7-7 show that the capacity of import in France is ample, with a steady spare capacity, roughly until the end of the period. The model generates one more terminal (8 BCM capacity) by 2012. In view of this, France is a well-supplied market, which could be a result of the lagged liberalization.

The model also shows (Figure 7-10) that the incremental gas consumption for the French market should mostly be supplied by Algeria (the effect of diversification of supply is over-shadowed by the effect of lower cost because of lower distance to market).

7.3.1.2 Italian market over-supplied: towards Italy becoming a gas hub in the Mediterranean?

Figure 7-2 shows a steady increase for Italian gas consumption also. One of the interesting results shown is a potential tension point in 2007, as shows Figure 7-5, when consumption is expected to be higher than the export infrastructure. This could be due to optimistic consumption forecasts from the model in chapter 4 or to the assumptions for decrease in reserves to be too high. What can also be observed from Figure 7-5, at the post-2008 horizon, with a number of plants expected to come online, the Italian market will be over-supplied. Figure 7-8, shows that the DOOS model also misses the 2007 supply tension (model assumes a 3-4 years time lag for investment decisions to materialize and starts in 2004). However, the forecasts less capacity at the 2013 horizon, reinforcing the point that Italy will be over-supplied.

This over-supply is high in magnitude even disregarding other pipeline projects (Bluestream from Russia, other Iranian and Azerbaijani piped gas). However, this over-supply is not necessarily negative for the Italian market. It may create a more cyclical pricing profile but, given the right investment in re-export infrastructure (pipelines to France and other neighboring countries), Italy would position itself as a gas hub and potentially where prices for South Europe could start being set.

The Italian new supply portfolio (Figure 7-11) shows a strong import from Qatar (this is validated with current projects with Exxon Mobil and Qatar Petroleum in the Berindisi terminal). Italy is closest, in terms of distance to market, to Qatar and farthest from Nigeria. Algeria's share remains low due to the diversification effect.

7.3.1.3 Spanish market under-supplied, or would demand tail-off?

Growth in the Spanish gas market has been high and the model expects this robust growth to continue, as shows Figure 7-3, a strong demand for Spain is expected by many market observers (IEA 2005). However, there is doubt on whether this growth would be at the proportions of the late 1990s where gas consumption was growing with double digit rates. Figure 7-6 shows the Spanish market to be well-supplied until 2011 where, as Figure 7-9 shows, the model expects new capacity to be added. However, this under-supply status strongly depends on the consumption at the 2011 horizon: if consumption growth slows down (below what the model in chapter 4 predicts) the status of under-supply might not be realistic.

Subject to the challenge below, the Spanish market should receive more gas from Trinidad & Tobago (again due to the distance to market relative to other market) and from Oman (this is validated by current plans for Oman LNG and Union Fenosa). Less gas is expected to come from Niger and Algeria because of the diversification effect and the legal constraint.

7.3.1.4 Other challenges to the models

Since the time where the model started to be developed and where initial discussions where engaged, new developments in the LNG markets, documented in Hallouche & Tamvakis (2005), have reshaped the Atlantic LNG market. The US market became an increasingly important LNG outlet and deliveries to the EU, even those under long term contracts, were diverted to the US where prices where higher. The phase out of the destination clause in the EU made these diversions easier.

The supply constraint experience in 2005-2006 in the UK and similar situations in Spain have shown that it is the availability of supply, not the capacity, that could be the issue (the UK's Isle of Grain was up and running, but not utilized because of scarcity of supply, prompting prices to reach unprecedented peaks). This is particularly true if the market is competitive and if buyers have to compete for cargoes.

One of the other constraints that the model fails to capture is the capacity pressure that EPC companies (service companies building terminals and other infrastructure). With a strong growth in demand for their service and a resource constraint, particularly human resources, costs of procurement of terminals and, more importantly, lag times between decision to invest and first cargo regasified, could be higher, with more impact on the local market.

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8.2 Personal communications

- Mr Iyyad Awwad, Egyptian Mission to the United Nations, New York (2003)
- Mr Ali Benbouzid, Sonatrach London (2003, 2005)
- Ms. Fatma Zohra Benoughlis, Executive Director of Strategy, Prospective and Economics, Sonatrach and Mr Mazari-Boufares, Director of Srategy (2005)
- Prof. Sadek Boussenna, Associate Professor, IEPE, University Pierre Mendes France, Grenoble, France - (former Minister of Energy and Mines, Algeria) (2004)
- Mr Thierry Bros, Security of Supply, French Ministry of Energy (2005)
- Mr Johannes Enzmann, Security of Supply, DGTREN, EU Commission (2005)
- H.E. Sameh Fahmi, Egyptian Minister of Petroleum (brief communication in London 2005)
- Mr Manfred Hafner, scientific director, Observatoir Meditteraneen de l'Energie (the meeting also included a number of researchers and modellers within OME) (2004)
- H.E. Chakib Khelil, Algerian Minister of Energy and Mines (brief communication in Algiers, Algeria 2005)
- Dr Andre Plourde. , Departement of Economics, University of Alberta, Canada, (2005)
- Dr David Ryan, Department of Economics, University of Alberta, Canada, (2003)

- Mr Mohammed Sultan, Qatar Representation to the United Nations (2003)
- Mr Chris Walters, Head of Consulting, Gas Strategies London, (numerous discussions and presentations) (2003-2005)
- H.E. Erik Williams, Trinidad & Tobago Minister of Energy (brief communication in Port of Spain, Trinidad & Tobago, 2005)
- Mr Aziz Yahiai, Short Term Energy Markets, OPEC (2004)
- Other personal communications with GDF, Total, EDF were held on the margins of the Mediterranean Gas Conference, held in Algiers in September 2003. Other communications were held with a number of gas exporters on the margins of the Gas Exporters Forum meeting in Port of Spain, April 2005

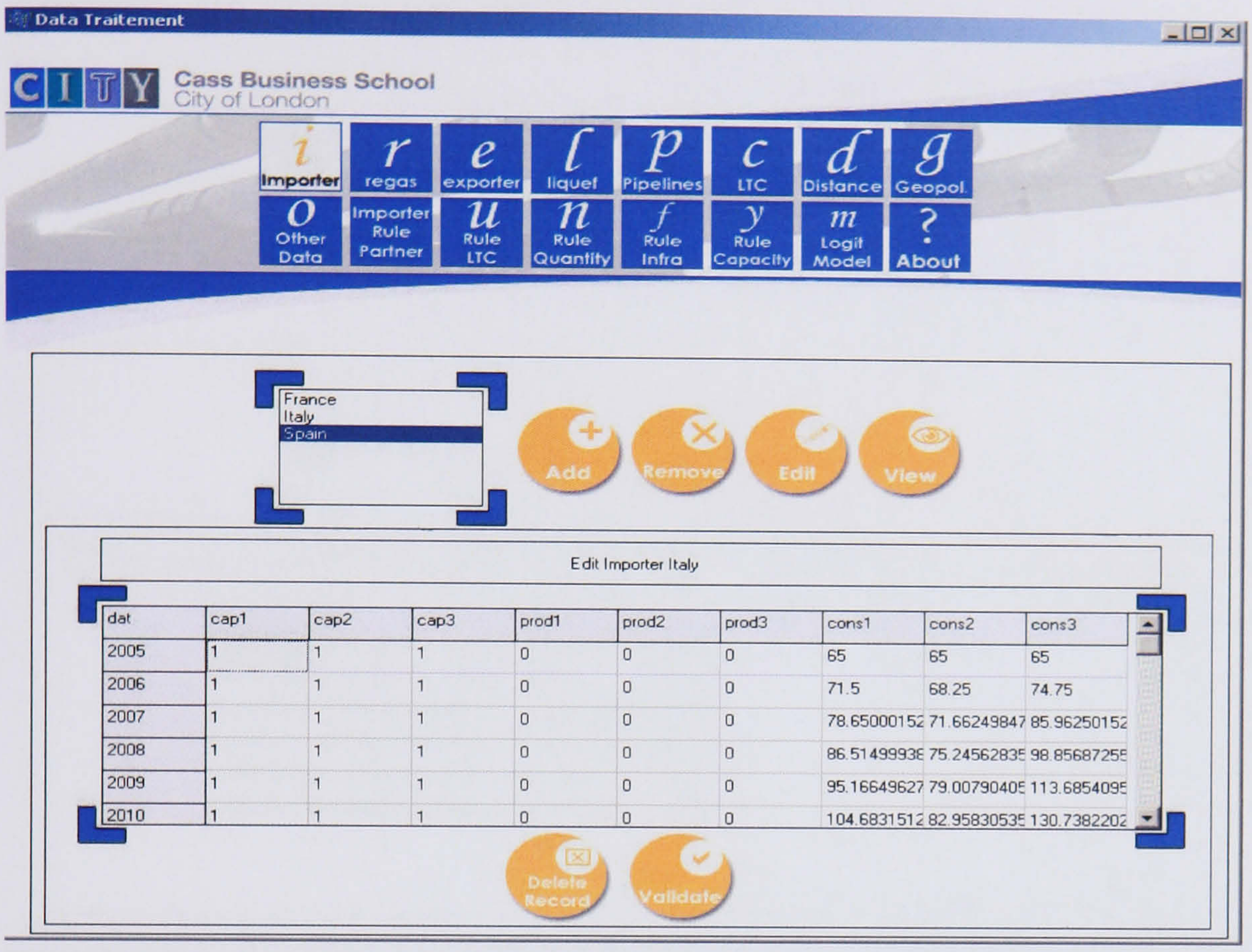
8.3 Data sources

- Cedigaz, Natural Gas in the World (2004)
- BP Statistical Review of World Energy (2005)
- IEA OECD Energy Statistics (2003)
- IEA OECD Energy Prices and Taxes (2003)
- Gas Strategies Online (2005, 2006)
- Drewry LNG OneWorld Database (2005)
- Datastream, Thomson Multimedia (2003, 2004, 2005)
- IMF International Financial Statistics, (2003, 2004)

9. Appendices

Appendix 1: User Friendly Version of the Model

Below are snapshots of a user-friendly graphical interface that was built for this model using C++ Builder and a MS ACCESS database.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2006 1 1 1 0 0 0 71.5 68.25 74.75
2007 1 1 1 0 0 0 78.65000152 71.66249847 85.96250152
2008 1 1 1 0 0 0 86.51499938 75.24562835 98.85687255
2009 1 1 1 0 0 0 95.16649627 79.00790405 113.6854095
2010 1 1 1 0 0 0 104.6831512 82.95830535 130.7382202
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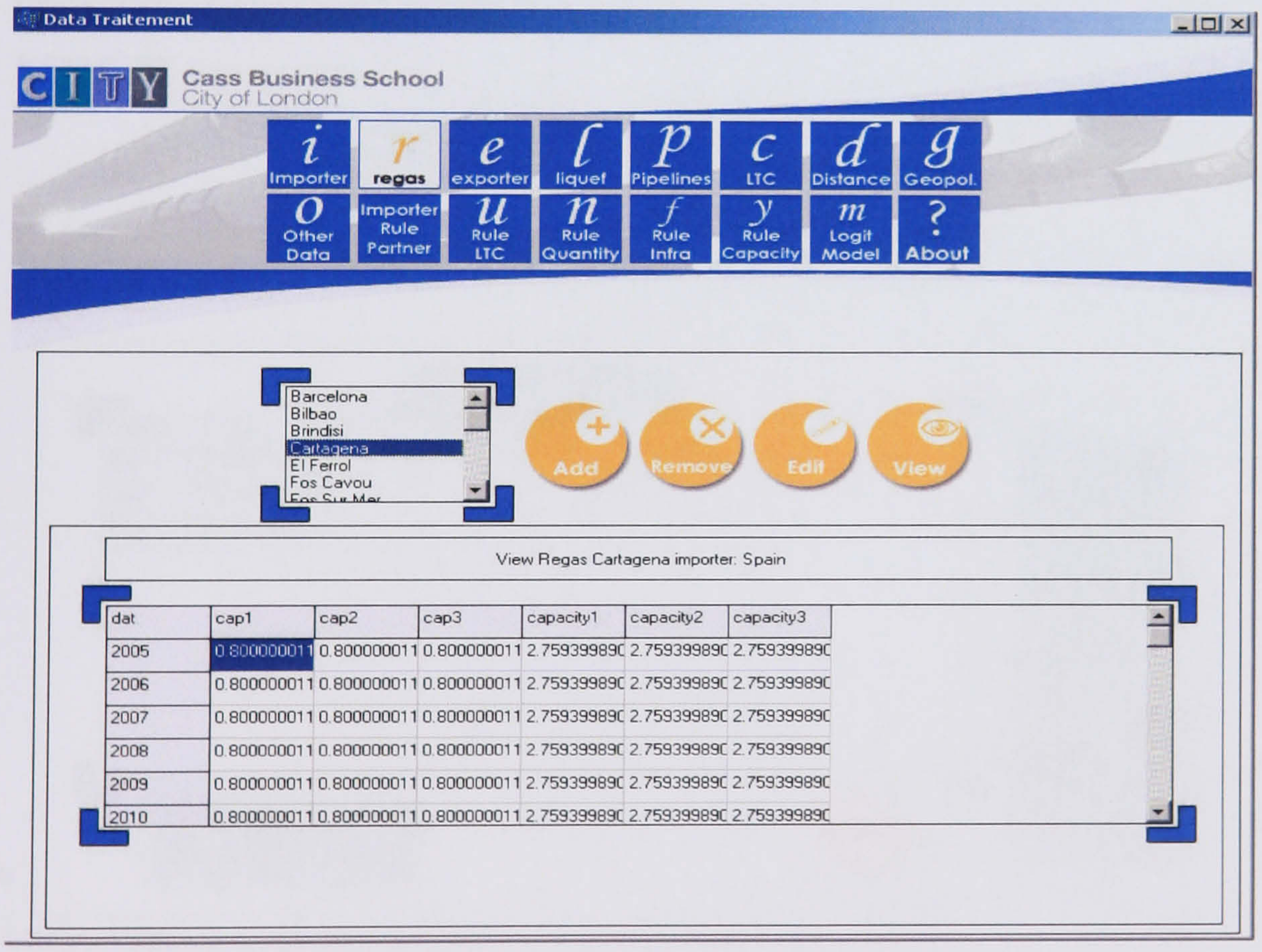
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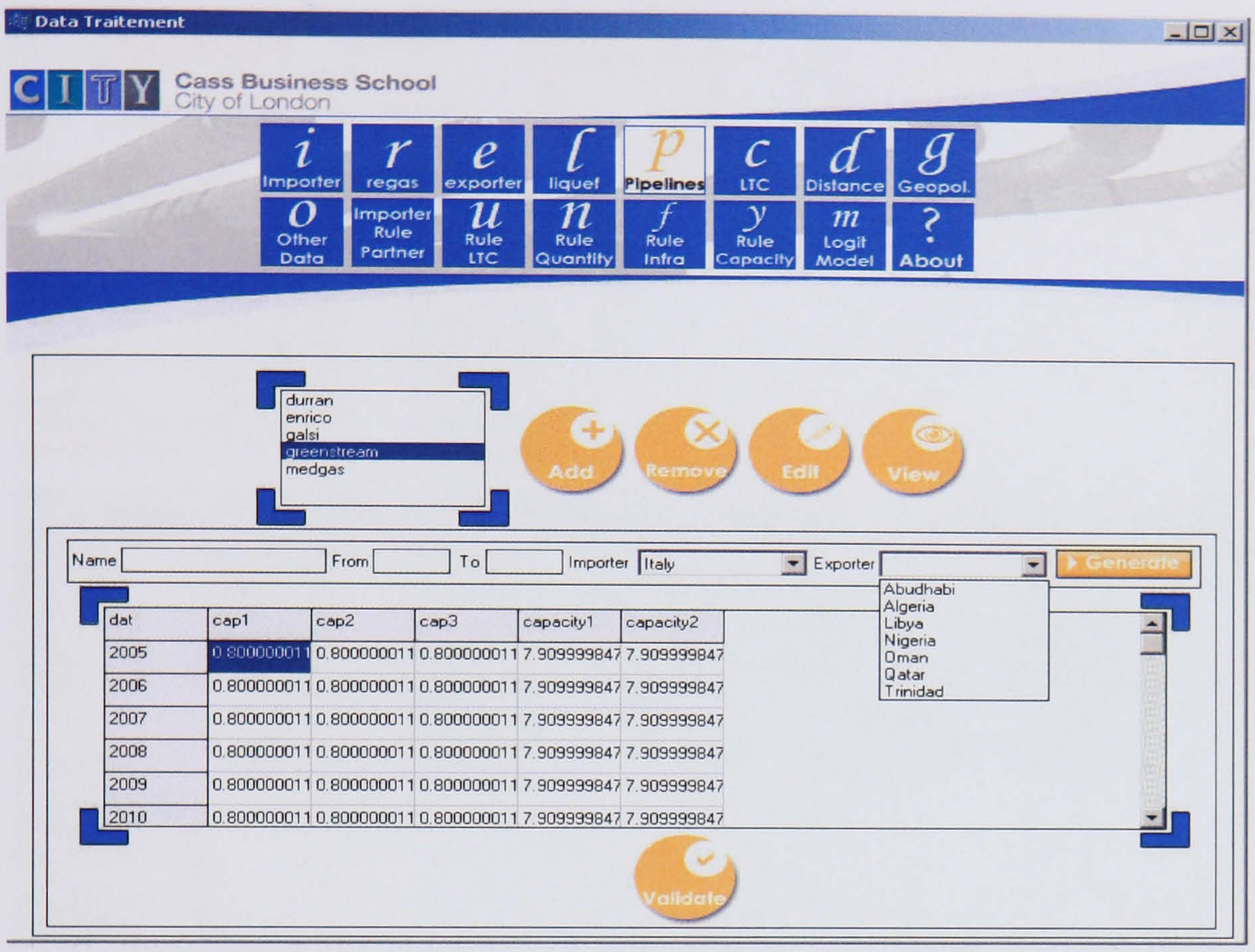
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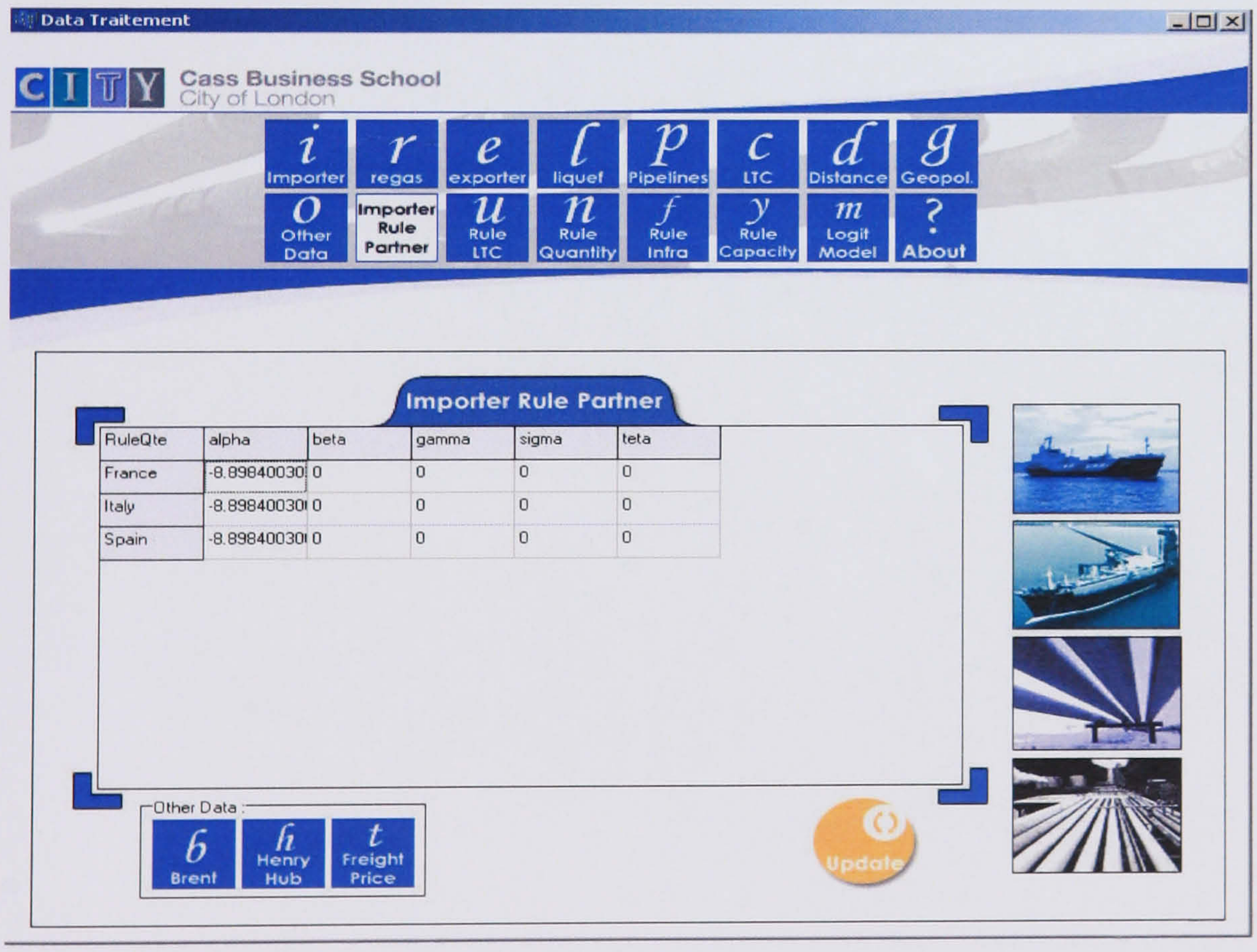
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Freight Price
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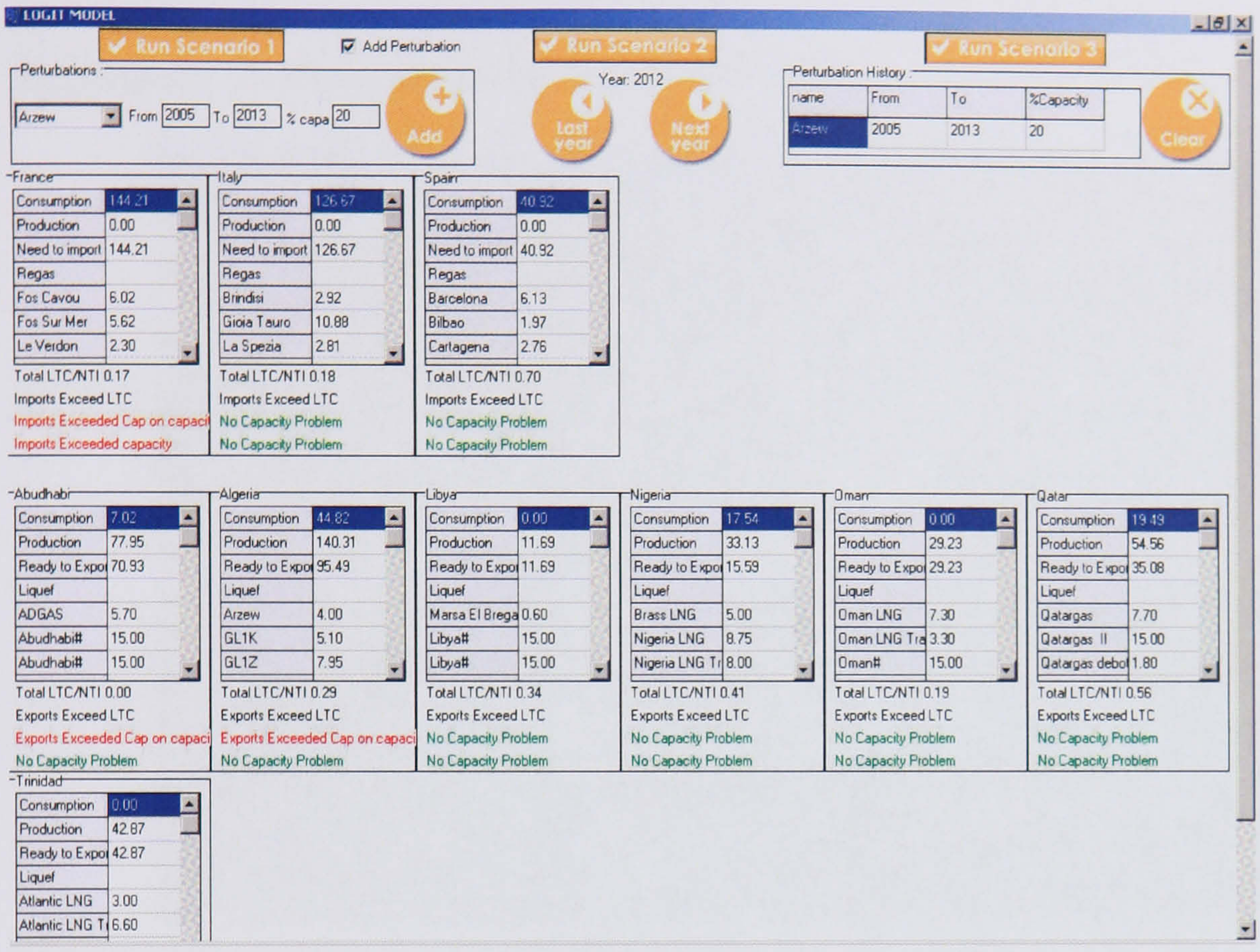
LOGIT MODEL
Run Scenario 1
Add Perturbation
Run Scenario 2
Run Scenario 3
Perturbations :
Arzew
From 2005 To 2013 % capa 20
Add
Year: 2012
Last year
Next year
Perturbation History :
name From To %Capacity
Arzew 2005 2013 20
Clear
France
Consumption 144.21
Production 0.00
Need to import 144.21
Regas
Fos Cavou 6.02
Fos Sur Mer 5.62
Le Verdon 2.30
Total LTC/NTI 0.17
Imports Exceed LTC
Imports Exceeded Cap on capaci
Imports Exceeded capacity
Italy
Consumption 126.67
Production 0.00
Need to import 126.67
Regas
Brindisi 2.92
Gioia Tauro 10.88
La Spezia 2.81
Total LTC/NTI 0.18
Imports Exceed LTC
No Capacity Problem
No Capacity Problem
Spain
Consumption 40.92
Production 0.00
Need to import 40.92
Regas
Barcelona 6.13
Bilbao 1.97
Cartagena 2.76
Total LTC/NTI 0.70
Imports Exceed LTC
No Capacity Problem
No Capacity Problem
Abudhabi
Consumption 7.02
Production 77.95
Ready to Expo 70.93
Liquef
ADGAS 5.70
Abudhabi# 15.00
Abudhabi# 15.00
Total LTC/NTI 0.00
Exports Exceed LTC
Exports Exceeded Cap on capaci
No Capacity Problem
Algeria
Consumption 44.82
Production 140.31
Ready to Expo 95.49
Liquef
Arzew 4.00
GL1K 5.10
GL1Z 7.95
Total LTC/NTI 0.29
Exports Exceed LTC
Exports Exceeded Cap on capaci
No Capacity Problem
Libya
Consumption 0.00
Production 11.69
Ready to Expo 11.69
Liquef
Marsa El Brega 0.60
Libya# 15.00
Libya# 15.00
Total LTC/NTI 0.34
Exports Exceed LTC
No Capacity Problem
No Capacity Problem
Nigeria
Consumption 17.54
Production 33.13
Ready to Expo 15.59
Liquef
Brass LNG 5.00
Nigeria LNG 8.75
Nigeria LNG Tr 8.00
Total LTC/NTI 0.41
Exports Exceed LTC
No Capacity Problem
No Capacity Problem
Oman
Consumption 0.00
Production 29.23
Ready to Expo 29.23
Liquef
Oman LNG 7.30
Oman LNG Tra 3.30
Oman# 15.00
Total LTC/NTI 0.19
Exports Exceed LTC
No Capacity Problem
No Capacity Problem
Qatar
Consumption 19.49
Production 54.56
Ready to Expo 35.08
Liquef
Qatargas 7.70
Qatargas II 15.00
Qatargas debo 1.80
Total LTC/NTI 0.56
Exports Exceed LTC
No Capacity Problem
No Capacity Problem
Trinidad
Consumption 0.00
Production 42.87
Ready to Expo 42.87
Liquef
Atlantic LNG 3.00
Atlantic LNG T 6.60

Appendix 2: Pictures of LNG terminals

Picture of an LNG Liquefaction plant in Oman[97]

Picture of an LNG regasification terminal in Belgium[98]

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[97] Source: Total Presentation, the Energy Risk Management Seminar, 2004

[98] Idem