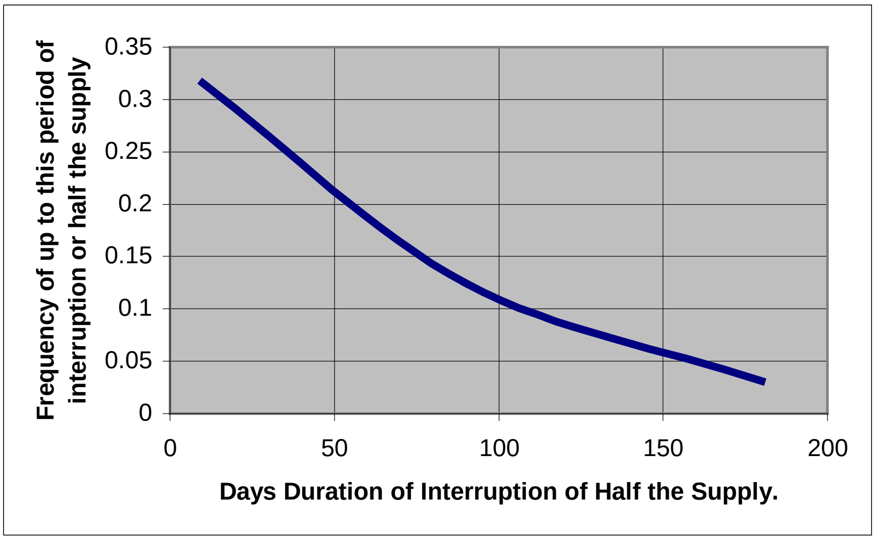
Liquid Natural Gas: Security of Supply to the UK, 2003 to 2020

Prepared By
Professor John H Gittus. F R Eng. D Sc. D Tech.
Consultant.

July 1`8th 2003



PROFESSOR JOHN H GITTUS.

John Gittus was elected Regents' Professor at the University of California in Los Angeles in 1990. He is Visiting Professor of Nuclear Engineering at the University of Plymouth, England. He was a Director of the United Kingdom Atomic Energy Authority (later AEA Technology) and is now a Consultant to Governments and private industry on nuclear matters world-wide. His recent clients include BNFL Plc, The UK Government's Department of Trade and Industry, Serco Plc, The Sumitomo Corporation, the French nuclear company COGEMA, Amersham Plc the radio pharmaceutical company, Cox Insurance Plc, the world's largest commercial insurer of nuclear risks, Chaucer Insurance Holdings and ESKOM, the South African utility.

Professor Gittus is a Fellow of the Royal Academy of Engineering (Britain's top 1,000 engineers) and has Doctor of Science degrees from the Universities of London and Stockholm. He has held over 30 patents and published over 100 papers in learned Journals describing his personal research. He invented Nimonic 115, the strongest of the early creep-resistant alloys used for the hottest turbine blades in jet engines and went on to develop a theory of creep that forms the basis of many of his papers to the Royal Society and the Philosophical Magazine. He used this theory to develop one of the world's first computer models of nuclear fuel elements, with which he forecast that some of the fuel element designs then extant would fail as their lives were extended in a quest for cheaper power. He was able to model the failure processes and deduced remedies that have been applied throughout the world. Fuel element failures are now rare, due in part to this early work.

He held a series of senior posts in the UKAEA, where he headed the late Lord Marshall's Task Force at Harwell and produced the UK's first nuclear-reactor Probabilistic Risk Assessment, for Sizewell B. He became Director of the R&D programme that underpinned the design details of Sizewell B, then Director of Safety and Director of Communications. He left the UKAEA to become the first Director General of the British Nuclear Industry Forum, where he helped with the restructuring of the UK nuclear industry, a process that is still going on. When his term of office there was complete he became a consultant, first to his successor and then, quickly, to other nuclear companies at home and overseas. On the death of Lord Marshall of Goring, Professor Gittus was appointed to succeed him at Cox Insurance Holdings Plc, advising on the insurance of the world's nuclear power stations and other nuclear installations.

Since January 2003 Professor Gittus and Mr Michael Dawson have led Syndicate 1176, the biggest commercial nuclear insurer in the world and Lloyds of London's most profitable syndicate..

Amongst his published papers are two communicated to the Royal Society by P.A.M. Dirac and describing Professor Gittus's solution of a problem with the structure of matter which Dirac said he himself had been unable to solve.

Entry From Who's Who

Name
GITTUS, John Henry.

Awards
DSc. DTech; FREng 1989.

Positions
Consultant, Amersham Plc, since 1999. Consultant, Cox Power Holdings, since 1997; Consultant, Serco Plc (formerly AEA Technology) since 1993; Senior Partner, NUSYS Consultants, Paris.

Personal Details
Born 25 July 1930; *son* of Henry Gittus and Amy Gittus; *married* 1953, Rosemary Ann Geeves; one *son* two *daughters*.

Education
BSc 1st Honours Mathematics London 1952; DSc Phys London 1976. DTech Metall Stockholm 1975. CEng, FIMechE, FIS, FIM.FREng

Work
British Cast Iron Res. Assoc., 1947-1955; Mond Nickel Co., R&D Labs, Birmingham, 1955-1960 (develt Nimonic series high temp. super alloys for aircraft gas turbine engines); United Kingdom Atomic Energy Authority, 1960-1989: Research Manager, Springfields; Head, Water Reactor fuel develt; Head, Atomic Energy Tech. Br., Harwell; Director: Water Reactor Safety Research; Safety and Reliability Directorate, Culcheth; Communication and Information; Dir Gen., British Nuclear Forum, 1990-1993. Consultant: Argonne Nat. Lab., USA, 1968; Oak Ridge Nat. Lab., 1969. Visiting Professor: Ecole Polytechnique Fédérale, Lausanne, 1976; Univ. de Nancy, 1984; Regents' Prof., UCLA, 1990-1991; Prof. of Risk Mgt, Plymouth Univ., 1997-. Editor-in-Chief, Res Mechanica, 1980-1991.

Publications
Uranium, 1962; Creep, Viscoelasticity and Creep-fracture in Solids, 1979; Irradiation Effects in Crystalline Solids, 1979; (with W. Crosbie) Medical Response to Effects of Ionizing Radiation, 1989; numerous articles in learned jls.

Recreations
Old houses, old motor cars, old friends.

Address
(office) 22 Buckingham Gate, SW1E 6LB. *Telephone:* +44 7775 898 449.

Clubs
Royal Society of Medicine, Institute of Directors.

Contents.

INTRODUCTION....16

BASIC FACTS ABOUT LNG....16

Liquefied natural gas: an international growth market....17

MAIN MARKETS....17

MANY INSTALLATIONS ACROSS THE WORLD:....18

THE TYPES OF RISK PRESENTED BY LNG....18

Gas transportation: 135 Ships in 2003, 270 Ships in 2010....19

Risk assessment programmes....19

Bigger ship evolution....20

New technology....21

LNG SHIPS AND THEIR ROUTES....22

SHIPPERS COULD CHALLENGE UK'S LNG SUPPLIES....24

POSSIBLE CHANGES IN THE LNG SHIPPING CHAIN THAT WILL IMPROVE SECURITY OF SUPPLY FOR EUROPE....26

US CONSIDERS LNG TANKERS MOVING NEAR CITIES AS TERRORIST TARGETS....26

COST OF A LNG TANKER SHIP....26

LNG IMPORTS AND EXPORTS....27

SUPPLIERS OF LNG....28

SOURCES FROM WHICH UK IS LIKELY TO IMPORT LNG....28

GAZ DE FRANCE, A LIKELY SUPPLIER OF REGASIFIED LNG TO THE UK....28

Algeria....28

Nigeria....28

Qatar....29

A complete maritime hub....29

Chartering....29

Operation....29

Equipment, maintenance and management....29

Design....29

Two LNG terminals:....30

Gaz de France LNG Safety Research:....30

Montoir-de-Bretagne : Europe's largest LNG terminal....30

Fos-sur-Mer: France's second LNG terminal....31

SOURCES OF POTENTIAL DIRECT SUPPLY OF LNG TO THE UK....32

Qatar,....32

Norway....33

Canada....33

Alaska's markets for natural gas Do Not include Europe....33

Algeria....33

Algeria, Home to Terrorists....34

A "Second Algerian War"....35

Egypt....35

Nigeria....36

Angola....37

Namibia......37
Russia......38
LNG STORAGE IN THE UK. 38
PROPOSED LNG TERMINAL AT MILFORD HAVEN. 38
NEW UK LNG TERMINAL PLANNED FOR RIVER MEDWAY......39
QATAR PETROLEUM AND EXXONMOBIL CORPORATION SIGN AGREEMENT FOR THE SUPPLY OF LNG FROM QATAR TO THE UK......39
GAS STORAGE, INCLUDING LNG, IN THE UK......40
LIQUEFACTION. 41
Liquefaction Plant: Example in Nigeria, 9.8million m^3 / day Train 1,2,3 43
REGAS CAPACITY, 2000 TO 2006. 43
MARKET AND COSTS. 44
COMMERCIAL STRUCTURE. 44
INTEGRATED PROJECT. 45
TRANSFER PRICING. 45
THROUGHPUT ARRANGEMENTS. 45
WORLD LNG IMPORTS AND EXPORTS. 46
FORECAST PRICE OF GAS AND LNG......47
LNG Pricing Systems.......47
Volatility of LNG Price.......49
PRICE OF LNG SHIPS AND TRANSIT. 51
SPOT MARKET TRADING. 51
LNG MARKET TO 2020: FORECASTS. 52
Buyers' Market has Emerged......52
Competition in the Market for LNG Rising. 53
EUROPEAN GAS CONSUMPTION. 53
NATURAL GAS WILL MEET 28% OF EUROPE'S PRIMARY ENERGY NEEDS BY 2020. .55
EUROPE IMPORTS LNG BY TANKER-SHIPS, MOSTLY FROM ALGERIA. 55
SAFETY PROVISIONS. 56
USA LNG ANTI TERRORISM PROVISION UNDER 33 CFR PART 165 56
DESIGN OF TYPICAL LNG ABOVE-GROUND STORAGE TANK. 57
DESIGN OF TYPICAL LNG IN-GROUND STORAGE TANK......61
AUTOMATED SYSTEMS THAT HELP TO AVOID LNG ACCIDENTS TO SHIPPING. 62
LNG ACCIDENTS......62
NO BLEVE EVENTS HAVE BEEN PRODUCED WITH LNG. 63
NO CARGO EXPLOSIONS HAVE OCCURRED WITH LNG. 63
LLOYDS REGISTER REPORT. 63
RISK ANALYSIS FOR LNG. 64
Hazard Identification......65
Example of identified Hazards:......65
Risk Assessment......66

Examples of Incidents Identified and for which the Risk has been Assessed. 66
The Events Constituting the Majority of the Risk....67
COST OF TERRORIST INCIDENTS 67

CHANGES TO INSURANCE POLICY COVER. 68

POOL RE OFFERS TERRORISM COVER FROM 23/07/2002) 69
Pool Re Extended to Cover Nuclear and Biological Warfare. 70
Employer's liability 71
Public liability. 71
Motor 71
Marine Cargo 71
War Risk. 71
Summary. 71

SCENARIO: UK OBTAINS LNG FROM ALGERIA, THROUGH FRANCE. .72

Adequacy of Algeria's Reserves and R/P Ratio. 72
Trade Movements. 72
Political Risks and Insurance Premiums for Algeria, France and the UK. 73
Incidents that Could Interrupt the UK's LNG Supplies for this the "Algerian" Scenario. 73
Political Interruption of LNG Supplies by Algeria. 73
Political Interruption of UK's LNG Supplies, from Algeria, en Route through France. 74
Political Interruption in the UK of UK's LNG Supplies, from Algeria. 75
Interruption of LNG Tankers in Transit from Algeria to France. 75
Political or Strike Action by Ship Owners or Crew. 76
Tanker Accident. 76
Accidental Interruption of LNG Supplies from Algeria. 77
Accidental Interruption of LNG Supplies from Algeria in France. 78
Terrorist Interruption of LNG Supplies by Algeria. 79

SCENARIO: UK OBTAINS LNG FROM QATAR. 81

Political Risks. 81
Political or Strike Action by Ship Owners or Crew. 81

SUMMARY TABLE FOR RESULTS OF PRESENT ANALYSIS. 83

ADEQUACY OF THE INTERCONNECTORS. 84

ANNEX: CATALOGUE OF DISASTERS BY CATEGORY 85

Information Sources 99
Inclusion Criteria 100

ANNEX: USA.FEDERAL TERRORISM INSURANCE LEGISLATION: QUESTIONS AND ANSWERS 101

ANNEX: LNG INCIDENTS AND ACCIDENTS THAT HAVE OCCURRED IN THE PERIOD UP TO DECEMBER 2002. 104

INTRODUCTION. 104
LAND-BASED LNG FACILITIES. 105
LNG SHIPS. 106
Lloyd's List. 106

APPENDIX A CHRONOLOGICAL SUMMARY OF INCIDENTS INVOLVING LAND-BASED LNG FACILITIES 107
LNG Peakshaving Facility 107
APPENDIX B CHRONOLOGICAL SUMMARY OF INCIDENTS INVOLVING LNG SHIPS 111

Table of Figures.

Figure 2 Shipping Routes and Terminals for LNG..11
Figure 3 Shipping Routes for LNG..22
Figure 4; LNG New Ship Supply, to 2005..23
Figure 5; Total Global Fleet of LNG Tankers..23
Figure 6; LNG Operators by Fleet Capacity. 24
Figure 7; European LNG Supplies Constrained by Shipping Bottlenecks. 25
Figure 8; LNG Market is Becoming Less Inflexible. 25
Figure 9; Free Yard Capacity for LNG Ships in the year 2000.....................................25
Figure 10 LNG Imports and Exports, Year 2000. 27
Figure 11: The Two Gaz de France LNG Terminals...30
Figure 13 Liquefaction Projects..41
Figure 14. Existing Liquefaction Capacity...42
Figure 15: Example of Liquefaction Plant. 42
Figure 16. Regas Capacity, 2000 to 2006. 43
Figure 17: Strength of LNG Market. 44
Figure 18: World Imports and Exports of LNG, 1995 to 2020. 46
Figure 19..48
Figure 20: LNG Imports and Total Gas Consumption for European Countries, 1995 to 2000. 54
Figure 21. LNG Imported by European Countries, 1995 to 2000. 54
Figure 22 Design of typical Above-ground LNG Storage Tank. 57
Figure 23; TongYoung-140,000cubic meter LNG Aboveground Storage Tanks at the Anjung CCGT Power Station. (TK-201/202/203)..59
Figure 24; Inchon-200,000 cubic meter LNG Inground Storage Tank (TK-213~218) 61
Figure 25: Algeria's Gas Reserves and Ratio of Reserves to Production, R/P. 72
Figure 26: Trade Movements of LNG Between Algeria and France...........................73
Figure 27: Political Risks and Political Risk Insurance Premiums are taken, for Algeria, France and the UK. 73
Figure 28: Risk Parameters for LNG Supplies for UK from Algeria to France...........74
Figure 29: The Two Gaz de France LNG Terminals...78
Figure 30: Political Risk Indices and Insurance Premiums for Qatar, with comparative values for UK and Algeria. 81
Figure 31: Political Risk Parameters for LNG Supplies for UK from Qatar to UK....81
Figure 32: Summary Table of Results for LNG. 83

SUMMARY

Liquid Natural Gas: Security of Supply

Prepared By

Professor John H Gittus. F R Eng. D Sc. D Tech.
Consultant.

Thursday, August 12, 2004

The amount of proven gas reserves has risen year on year since 1980. Since 1990, for every million cubic feet of gas consumed three million have been found and in the last couple of years, that figure has been closer to five million. Global reserves of natural gas recently surpassed oil reserves and gas is still being discovered in large quantities. By 2020 it is expected that the world consumption of gas will exceed that of oil.

Liquefied Natural Gas (LNG) is obtained by liquefaction of natural gas at 160°C. For an equivalent amount of energy, the volume of LNG is 600 times smaller than that of natural gas in gaseous form. LNG is composed of around 90% Methane, along with small quantities of ethane, propane, butane and less than 1% nitrogen.

The reduction in volume resulting from natural gas liquefaction means that natural gas can be transported by sea in LNG carriers to receiving points known as LNG terminals. At these terminals, located close to consumption zones, the LNG is regasified and injected into the natural gas transmission system.

In 2001, world LNG exports totalled an estimated 143 billion cu.m of natural gas in gaseous form, almost 21% of world natural gas exports (around 680 billion cu.m).

The market concerns 23 countries, of which 12 are exporters.

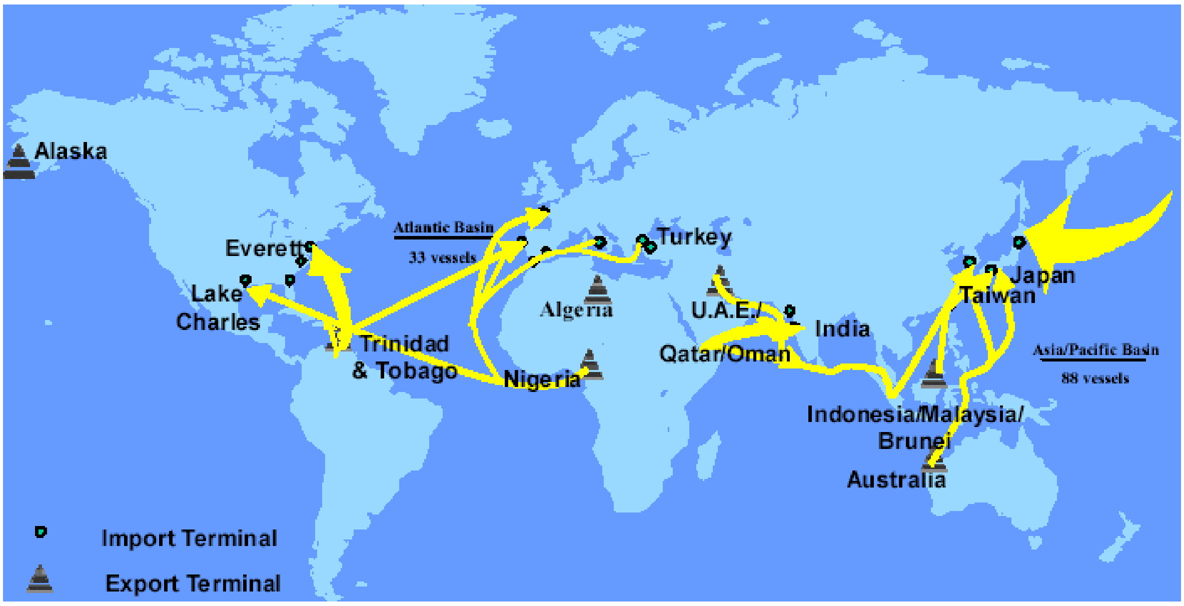
In France, the share of LNG is proportionally larger, representing 27% of the country's gas supplies in 2001.

Experts are forecasting continued growth, boosted by the entry into service of new liquefaction processes and facilities and by more efficient use of export capacities. The LNG market could reach 200 billion cu.m by 2010 and involve around 30 countries.

Between Europe, Africa and the Middle East the LNG trade is based primarily on sales from Algeria, the world's second largest producer (18.2%), with around one-third of gas volumes going to France (which imports around 8.5% of world production) and the remaining volumes going mainly to Spain, Belgium, Turkey, Italy and Greece.

LNG ships have been the most successful in the marine industry in terms of safety and reliability. However, in the wake of the September 11th 2001 WTC terrorist attacks, Quest Consultants, working for Bechtel- and Lloyds Register of London performed studies on the consequences of a breach of a single tank of an LNG Carrier. These two studies form part of the input to the analysis in the present Report. The study carried out by Lloyd's Register helped in 2002 in re-establishing LNG shipments to terminals in the US and other studies have been carried out by Lloyd's Register in support of proposals for siting new terminals, and reactivating and expanding existing terminals around the world.

Figure 1 Shipping Routes and Terminals for LNG



Gaz de France, A likely Supplier of Regasified LNG to the UK.

The largest European LNG importer Gaz de France, which has the most diversified supply portfolio in Europe, imported 11.1 billion cu.m of natural gas in the form of LNG in 2001, mainly from Algeria which accounts for 25.5% of gas supplies to France. Gaz de France is the largest European LNG importer (around one-third of imports) and number three in the world (8.5% of world production), behind Japan (almost 69 billion cu.m) and Korea (more than 20 billion cu.m).

In 2001, Gaz de France imported around 8.1 billion cu.m of natural gas in the form of LNG from Algeria. Sonatrach delivered it from liquefaction facilities at Arzew, Bethioua and Skikda. The corresponding purchase and sale agreements are long-term contracts that expire in 2013. Further to the dismantling of the Le Havre terminal which, from 1965 to 1989, sent out half a billion cu.m of gas each year, Gaz de France now has two LNG terminals, one at Fos-sur-Mer and the other at Montoir-de-Bretagne.

Montoir-de-Bretagne : Europe's largest LNG terminal

Since it came into service in 1980, the Montoir-de-Bretagne LNG terminal has supplied western France with natural gas, imported in the form of liquefied natural gas (LNG) from the Arzew et Bethioua liquefaction plants in Algeria, from the Bonny plant in Nigeria and, on an occasional basis, from plants in Qatar and Abu Dhabi. The contractual volumes correspond to an annual capacity of around 8.5 billion cu.m of gas. This is one of the terminals where Algerian LNG is likely to be received, destined for regasification to be piped to the UK. This scenario is one of two analysed in the present Report from the standpoint of security of gas supplies to the UK. It takes three days on average for an LNG carrier to sail from Arzew to Montoir and more than eight days from Nigeria (one day from Skikda to Fos-sur-Mer).

Fos-sur-Mer: France's second LNG terminal

Commissioned in 1972, the Fos-sur-Mer LNG terminal supplies southern France with natural gas imported in the form of liquefied natural gas (LNG) from the Skikda, Arzew and Bethioua liquefaction plants in Algeria. The contractual volumes correspond to an annual capacity of around 4.5 billion cu.m of gas. The terminal was refurbished between 1995 and 1999. In 2001, 212 cargoes of LNG carried by five LNG tankers were received at Fos-sur-Mer, representing 13 % of total French natural gas supplies. A tanker voyage between Skikda and Fos-sur-Mer takes one day on average (three days from Bethioua to Montoir-de-Bretagne).

Qatar,

Qatar Petroleum and ExxonMobil Corporation have signed a Heads of Agreement for the supply of Liquefied Natural Gas from Qatar to the United Kingdom. This is the second scenario whose security of supply is analysed in detail in the present Report. The HOA covers the development of two LNG trains that are expected to be the largest ever built by industry. The feed gas for these trains will be sourced from Qatar's giant North Field, which has proven natural gas reserves in excess of 900 trillion cubic feet (tcf). Qatar Petroleum will have a 70% equity interest in the LNG trains, and ExxonMobil 30%.

The LNG trains will be built at the Ras Laffan Industrial City in Qatar.

LNG shipments to the UK are scheduled to begin in the 2006/7 timeframe and extend over 25 years.

ExxonMobil is currently investigating a number of potential sites in the UK for the import facility that will receive the LNG.

Proposed LNG terminal at Milford Haven.

Petroplus is planning to develop a terminal for the importation and storage of Liquefied Natural Gas at its site at Waterston, Milford Haven. The Waterston site was formerly the Gulf Oil Refinery which operated from the mid 1960’s until 1997, when refining operations ceased. Petroplus acquired the site in 1998, when it purchased Gulf Oil Refining Ltd. UK from Chevron. In the second scenario analysed in this Report, and thought to be equally likely with the first “Algerian scenario”, we consider importation of LNG from Qatar to Milford Haven or another similar, new UK LNG Terminal. Two full containment storage tanks each of 165,000m^3 nominal capacity would be constructed, providing the terminal with a total of 330,000m^3 nominal capacity of LNG storage.

New UK LNG Terminal Planned for River Medway

Mersey Docks & Harbour will submit plans for a major liquid natural gas terminal and production plant on the River Medway. The Port Authority, which is part of the Mersey Docks, has agreed to transfer a 10-hectare stretch of the river bed to Lattice Group PLC, which will develop the site. This also could therefore be used to receive direct LNG imports from Qatar or one of the other sources considered in the present paper.

LNG Accidents

The LNG industry has an almost accident-free record for the last 33-years.

Since 1970, there have been only sixteen LNG-related accidents world-wide;

Since 1980, there have been two LNG-related fatalities world-wide.

All prior accident-causes have been incorporated into existing regulatory standards.

Of only 20 LNG-vehicle accidents since 1971, none were fatal, only 6 released LNG, and only 3 resulted LNG-related fires.

From a review of marine incidents involving LNG carriers, a new Lloyd's Register report concludes that there have been no recorded incidents of collision, grounding, fire, explosion or hull failure which have resulted in cargo spillage. Also, no fatalities have occurred, nor has there ever been damage to land-based property or the environment as a result of a LNG release from a vessel. Further, the report indicated that if a ship was attacked, the likely consequence would probably involve a fire, not an explosion.

The Lloyds Register Report draws from many sources, historical, experimental, and modelling. It concludes that, historically for all types of LNG accident, the inherent strength of LNG carrier-ships has prevented loss of containment.

Risk Analysis for LNG.

Risk analysis methods have been applied to LNG and the findings are used in the present analysis. In a study presented by Det Norske Veritas, six events stands out in the respect they enter either into ALARP or unacceptable level for nearly all the consequence classes and operational modes. These are

- sabotage,
- war action,
- collision, A fire or explosion in the engine room has been assessed to give collision as a secondary effect when sailing in port or close to shore. This latter situation is considered unlikely.
- ignited release from a cargo tank
- overfilling during loading operation and
- structural damage to hull.

Changes to Insurance Policy cover.

World insurance markets have seen the curtailment of terrorism cover across most classes of risk which has impacted particularly hard on industries such as aviation causing a number of governments to step in to provide some terrorism cover. The US property market is the largest in the world and therefore US events have a disproportionate effect on the global insurance market.

The rules for terrorism insurance are altering for commercial Policies incepting or renewing on or after 1st January 2003. This is in accordance with market agreement and these rules apply - regardless of Insurer - in respect of material damage and business interruption:-

- There is now no 'free' cover.
- Policies will either have no cover for terrorism, or will have been extended to provide full cover to match the sums insured provided by the existing material damage and business interruption cover.
- Terrorism cover is not automatically provided. Each individual Policyholder must apply for, and be accepted for, and pay the additional premium due.
- The terrorism cover will be on an 'All Risks' basis, regardless of the scope of the main Policy and will include nuclear, chemical and biological radiation.
- Unlike previously, a separate Policy will not be issued. Cover will be added by Endorsement to the main Policy.

Traditionally US property insurance cover did not exclude terrorism cover from the 'all risks' wording, but insurers never rated, nor had the expertise to rate, the terrorism risk. This has resulted in the reticence to provide cover now.

In mainland Great Britain, terrorism fire and explosion cover was excluded from property and business interruption insurance contracts in December 1993 following terrorist attacks in the City of London. (Cover was withdrawn for Northern Ireland in 1975).

The UK government became reinsurer of last resort to a market mutual reinsurer called Pool Re, which was set up to guarantee the fire and explosion cover. Its voluntary membership comprises most of the recognised retail insurers and Lloyd's syndicates.

Terrorism exclusions have now been extended and applied to insurances of transportation e.g. transit static marine and motor and to liability insurances.

<u>Scenario: UK Obtains LNG From Algeria, through France.</u>

In this the first of the two Scenarios analyzed in the present Report, the UK obtains supplies of LNG as regasified LNG from France. France obtains its LNG from Algeria, regasifies it and supplies gas through an Interconnector to the UK.

<u>Scenario: UK Obtains LNG From Qatar.</u>

In this second scenario the case is considered where the UK receives imports of LNG from Qatar. From the information given in the body of this Report, this is judged equally likely with the case where the UK receives LNG from Algeria through France.

LNG from Qatar would dock at a modern Terminal, such as that planned for Milford Haven and described above.

Summary Table for Results of Present Analysis.

The forecasts arrived at above have been tabulated in worksheet RESULTS and that Table is given below:

Summary Table of Forecasts for Security of Supply of LNG.

Source of Interruption.	Days: Duration	Per Year: Likelihood	$ Maximum Insurable Amount	Loss, bcm/day
Political Risk in France and Algeria	90	0.02	100,000,000	0.026849
Political Risk in Algeria	180	0.002	100,000,000	0.026849
Political Risk in UK: Algeria supplies.	90	0.0008	100,000,000	0.026849
Algeria Tanker Strike Action	10	0.002	100,000,000	0.026849
Algeria Tanker Accident	10	0.049	100,000,000	0.026849
Algeria Port Accident	10	0.0065	200,000,000	0.026849
French Port Accident	10	0.0065	200,000,000	0.026849
Algeria Port Terrorist Attack.	180	0.0059	10,000,000	0.026849
Political Risk in Qatar	90	0.072	100,000,000	0.026849
Political Risk in UK: Qatar supplies.	90	0.0008	100,000,000	0.026849
Qatar Tanker Strike Action	10	0.0032	100,000,000	0.026849
Qatar Tanker Accident	10	0.098	100000000	0.026849
Qatar Port Accident	10	0.0130	200,000,000	0.026849
UK Port Accident	10	0.0130	200,000,000	0.026849
UK Port Terrorist Attack.	180	0.0117	10,000,000	0.026849
Qatar Port Terrorist Attack.	180	0.0117	10,000,000	0.026849

Introduction.

The amount of proven gas reserves has risen year on year since 1980. Since 1990, for every million cubic feet of gas consumed three million have been found and in the last couple of years, that figure has been closer to five million. Global reserves of natural gas recently surpassed oil reserves and gas is still being discovered in large quantities. By 2020 it is expected that the world consumption of gas will exceed that of oil.

Basic Facts About LNG.

Liquefied Natural Gas (LNG) is obtained by liquefaction of natural gas at 160°C. For an equivalent amount of energy, the volume of LNG is 600 times smaller than that of natural gas in gaseous form. LNG is composed of around 90% Methane, along with small quantities of ethane, propane, butane and less than 1% nitrogen.

The reduction in volume resulting from natural gas liquefaction means that natural gas can be transported by sea in LNG carriers to receiving points known as LNG terminals. At these terminals, located close to consumption zones, the LNG is regasified and injected into the natural gas transmission system.

An LNG chain liquefaction plant, transportation by LNG carrier, LNG terminal is generally set up when pipeline transmission is too expensive due to the long distances involved or the technical difficulties of pipeline construction.

The most widely used natural gas liquefaction technique is the "mixed refrigerant cascade" (MRC) which involves a series of high-pressure gas condensation stages, each followed by low-pressure vaporization. A liquefaction plant is made up of specific natural gas treatment installations, several MRC liquefaction units and various auxiliary installations for steam production, seawater pumping, etc. along with LNG storage and loading facilities. On average, 12% of the gas delivered to a liquefaction plant is used to fuel the liquefaction process.

LNG carriers are large double-hulled ships, several hundred metres in length, which travel at an average speed of 18 knots (33 km/h). It take around ten hours to fill an LNG tanker with a capacity of 120,000 cu.m.

The LNG terminals comprise unloading and storage facilities, along with LNG regasification installations. The regasification process generally uses seawater or hot water as a heat source.

Liquefied natural gas: an international growth market

On the LNG markets, buyers and sellers are generally linked by long-term contracts for predefined quantities of LNG produced in a liquefaction plant and received at an LNG terminal specified in the contract.

In 2001, world LNG exports totalled an estimated 143 billion cu.m of natural gas in gaseous form, almost 21% of world natural gas exports (around 680 billion cu.m).

The market concerns 23 countries, of which 12 are exporters.

In France, the share of LNG is proportionally larger, representing 27% of the country's gas supplies in 2001.

The LNG spot market is growing steadily. The volume of LNG spot purchases totalled around 11 billion cu.m in 2001, i.e., 8% of the international LNG trade, of which 4 billion cu.m were destined for western Europe.

With growing world demand for natural gas and ever increasing distances between consumer and producer regions, LNG trade is expanding rapidly. It grew by 4.2% in 2001, 0.7 percentage points more than that of pipeline gas.

Experts are forecasting continued growth, boosted by the entry into service of new liquefaction processes and facilities and by more efficient use of export capacities. The LNG market could reach 200 billion cu.m by 2010 and involve around 30 countries.

Main Markets[1]

There are three independent import markets: the Far East, Europe and America.
In the Far East: Three importer countries Japan, the world's largest, buying 51.6% of world production, South Korea (15.1% of world imports) and Taiwan (4.4%) receive LNG produced in four countries: Indonesia (the world's leading exporter with almost 23% of world production), Malaysia (14.5%), Australia (6.9%) and Brunei (6.3%). Far East countries also receive LNG produced in the Middle East, in Abu-Dhabi, Qatar and Oman.

Between western Europe, Africa and the Middle East the LNG trade is based primarily on sales from Algeria, the world's second largest producer (18.2%), with around one-third of gas volumes going to France (which imports around 8.5% of world production) and the remaining volumes going mainly to Spain, Belgium, Turkey, Italy and Greece.

---

[1] Source : Cedigaz, Natural Gas Statistics for 2001, first estimates
GII - GNL, the LNG industry in 2001

Nigeria, Trinidad and Libya also produce and export LNG to Europe. And in 2001, several cargoes were received from the Middle East (Qatar and Oman).

In America: The USA exports LNG from Alaska (1.3%) and imports LNG to the east coast (4.8%) from Trinidad and Tobago, Algeria and Nigeria. Porto Rico also started importing LNG in 2000.

Many installations across the world:

There are 15 production sites across the world in 12 different Countries . The Qalhat liquefaction plant in Oman was brought into service in 2000. Liquefaction capacities vary from 1.1 billion cu.m to 20 billion cu.m.

The world LNG carrier fleet totals 128 ships. The volume of LNG carried by an LNG carrier depends on the vessel size, ranging from 19,000 cu.m for the smallest to 138,000 cu.m for the largest.

40 LNG terminals are currently in service, 24 in Japan, 9 in Europe, 3 in the USA , 2 in Korea, 1 in Porto-Rico and 1 in Taiwan.

The Types of Risk Presented by LNG.

The major risks of LNG are:

- Accidental or terrorist-caused release of LNG
- Pooling of spilled LNG
- Formation of a vapour cloud that can travel 2-4 miles
- Ignition of LNG pool or vapour cloud causing massive, intense fire and thermal radiation that can burn people and property thousands of yard away

In the wake of the September 11th terrorist attacks, Quest Consultants, working for Bechtel- and Lloyds Register of London performed studies on the consequences of a breach of a single tank of an LNG Carrier.

The Quest study found that if one tank of an LNG carrier were breached and 25,000 cubic meters of LNG (6,604,301 gallons) leaked out, the resulting flammable vapour cloud could drift up to 2.5 miles before it was no longer flammable.

The Lloyd’s study found that the flammable vapour cloud could drift two to four miles before it could no longer catch on fire.

Quest further found that if 25,000 cubic meters of LNG formed a pool on the water and ignited, heat radiation from the fire would burn a human being up to 1,800 feet away, and it would take up to an hour for the gas to burn out.

Gas transportation: 135 Ships in 2003, 270 Ships in 2010.

The problem facing the gas industry is not finding the gas, but getting that gas to the market. This can be done in several ways either using gas pipelines, gas to liquid technology, “gas by wire” or as liquefied natural gas (LNG).

The pipeline has been and will continue to be the biggest competition to the LNG shipping industry. However miles of pipeline stretched out over open terrain with limited ability to ensure its security might lead suppliers across the world to return to traditional methods of transporting the gas by sea to ensure security of supply. The heightened awareness over security issues could boost the demand for LNG carriers.

The first ship given the classification 'liquefied gas carrier' was the ship, Methane Pioneer, classed by Lloyd's Register, in 1958. The world LNG fleet today still only numbers 135 vessels (February 2003). But the 'dash for gas' is now moving the industry forward at a hitherto unseen pace. The global fleet is now growing at approximately 10% per annum and by the end of this decade the world fleet of LNG carriers will have doubled.

For a long time, the capability to design and build LNG ships was restricted to a few shipyards. However, the demand for LNG ships is now so great that there are yards all over the world gearing up to take a share of the LNG market. In the next few months it is expected that China will enter the arena when the order for LNG carriers required to supply the Guangdong terminal is confirmed. China now has several yards that have developed the skills and approvals necessary to build LNG ships. Many of these yards have achieved this through partnerships with European yards with proven capability in the design and construction of LNG ships. China's entry into the LNG shipbuilding industry will be a significant step for China and for the LNG industry as a whole.

The LNG market is becoming increasingly competitive with the monopolies of old disappearing and new entrants appearing all the time. As the number of yards with the ability to build LNG carriers increases, the competition to secure new build contracts intensifies and prices drop as a consequence. The need to reduce the price and remain competitive is forcing yards to look for advances in technology that improve production schedules whilst retaining the quality, safety and reliability required by the LNG shipping industry.

Risk assessment programmes

LNG ships have been the most successful in the marine industry in terms of safety and reliability. This position has been maintained by close attention to detail in the development of new ideas and concepts and procedures used in the industry. These have been mainly driven by the public perception of potential disasters associated with the spillage of LNG and the possible loss of property and life if such a spillage were to occur either at sea or at a LNG terminal.

To help mitigate the risks and ease concerns raised by the public post September 11, Lloyd's Register has been involved with the industry in the provision of solutions to both safety and security issues. A study carried out by Lloyd's Register helped last year in re-establishing LNG shipments to terminals in the US and other studies have been carried out by Lloyd's Register in support of proposals for siting new terminals, and reactivating and expanding existing terminals around the world.

Owners are continually looking to increase the service life of their vessels and some have already entered into charters that will take their older vessels beyond 40 years of operation. Traditionally LNG ships have been ordered and traded on fixed routes between the same loading and discharge terminal. However owners are now eyeing the spot market as a means to increase income and several cargoes have been traded into the US where the rate has been much higher than the European market at the time. The number of spot cargoes has increased and some of the recent new builds have been ordered on speculation in an effort to take advantage of the developing spot market. When the trading pattern is not known, it is difficult to predict the sea states that the ship might encounter.

This however presents the designers with an entirely new problem particularly as many owners are now specifying a 40-year fatigue life as a part of the specification. Designers are now defining a percentage of operation on the various known routes to predict the sea states. But some detail of intended routes are required, for instance, the North Atlantic is huge so merely declaring an operating area as the North Atlantic does not adequately define the trading pattern. Ships designed and assessed without adequate definition could suffer if they encounter conditions more severe than for which they were designed. There are not many fatigue assessment programs which allow for these options to be entered however Lloyd's Register's ShipRight FDA procedure does allow a greater degree of route specification.

Bigger ship evolution

The size of LNG ships is slowly increasing. Current vessels have capacities around 138 - 145,000 m3, but designs are now on the table for capacities of 165,000 and 200,000 m3 and over. The designs are however limited by the draught, length and air draught available at the loading and discharge ports. These limiting factors may not be so important as new 'green-field' terminals and the offshore floating production and re-gasification terminals are developed over the next few years. However these terminals will present the LNG industry with a whole new range of problems associated with their development. The single biggest factor for floating terminals is the partial filling of LNG containment systems that will occur as the terminals and ships load and discharge their cargo.

These new concepts in the production, transportation and storage of LNG have driven the industry to look towards partial filling of LNG tanks. The Moss system of containment has already gained approval for partial filling however there is now a drive to extend the partial filling approval to the membrane containment system. The subject of partial filling of membrane LNG ships has become a high profile one within the industry and is being debated at length by owners, shipyards and classification societies.

To date partial filling of membrane ships has been approved by two classification societies based on a study by Gaztransport & Technigaz (GTT). However, because of the complexity of the subject, and the need for a high degree of confidence that the integrity the containment system will not be compromised, both Lloyd's Register and DNV have yet to approve partial filling. Lloyd's Register has commissioned an independent study to establish a greater confidence in the scaling factors used previously and to determine whether the dynamic pressures likely to be experienced in partially filled LNG tanks will exceed the maximum acceptable values for the containment system.

New technology

The installation of liquefaction equipment into a gas field increases the production cost of the LNG and for certain fields the use of LNG as a means of transporting the gas makes the operation uneconomic. New proposals are being tabled by some ship owners to transport the gas as compressed natural gas (CNG) or as pressurised liquid natural gas (PLNG). These methods of shipping reduce the cost of the supply chain by removing the need for expensive liquefaction trains. The disadvantages of these systems is that the ships are estimated to be far more expensive than ordinary LNG ships and they are only economically useful for transporting gas over relatively short distances (around 1,000 miles) to a processing facility and long term energy market. The other disadvantages of this new technology lie in the impurities in the gas that may effect the welding or cause corrosion of the containment system. The vessels also do not fall easily into the IGC code and the approach to approving these vessels will need to be considered carefully with a possible risk-based approach being employed.

LNG Ships and Their Routes.

Figure 2 shows the main shipping routes for LNG Tankers.

Golar LNG Ltd is the World's largest independent LNG ship owner (10 ships).

Figure 2 Shipping Routes for LNG

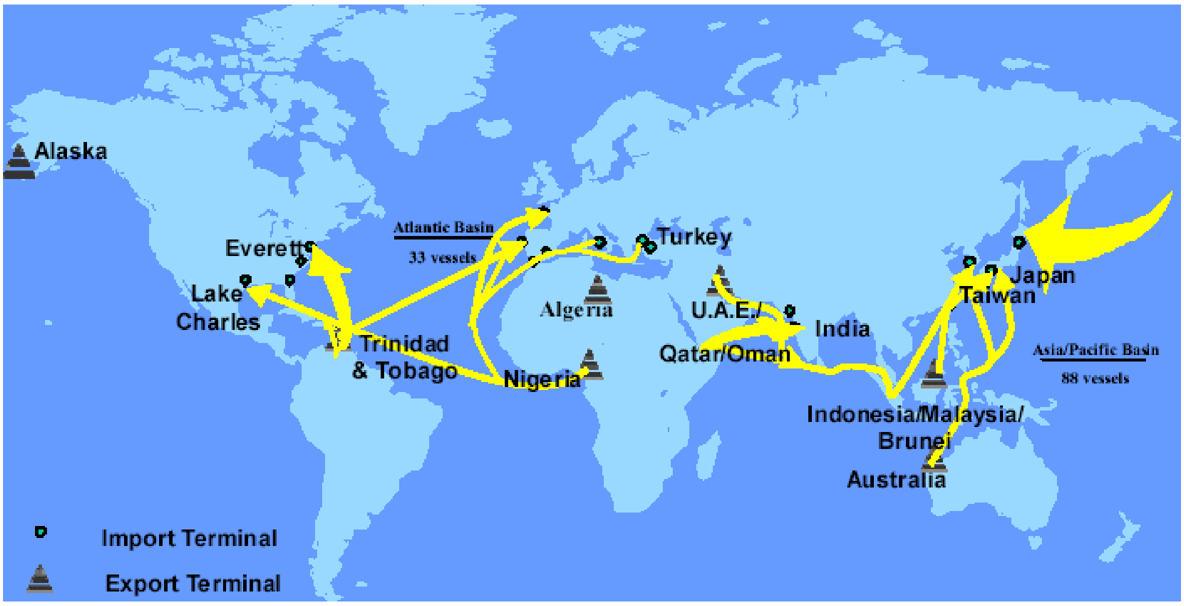
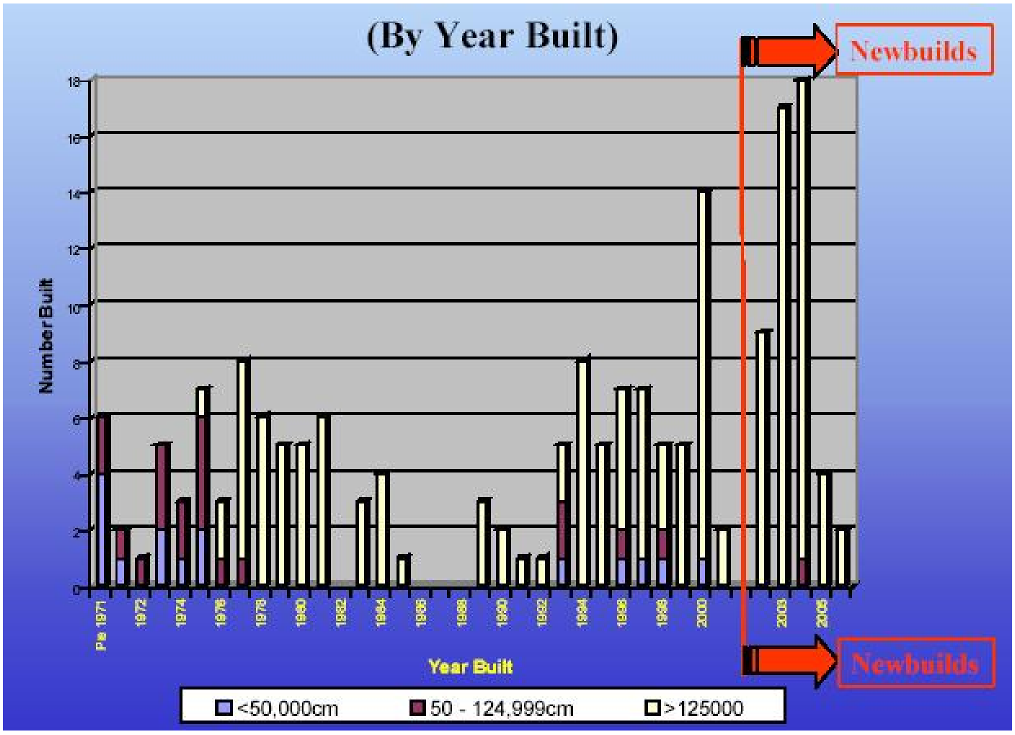


Figure 3 shows that 47 new ships were ordered in the five years from 2000 to 2005. Figure 8 shows that in 2000 there was free yard capacity for 23 LNG ships per year, globally.

Figure 3; LNG New Ship Supply, to 2005.

Figure 4 shows the total global fleet of LNG Tankers up to 2002 and the forecast for the years up to 2006.

Figure 4; Total Global Fleet of LNG Tankers.



Shippers Could Challenge UK's LNG Supplies.

Figure 5 shows that there are 32 operators of LNG tankers. Of these, five have the majority of the market. This means that if one of the largest fleets refused to transport LNG to France (if the UK obtained its supplies from France) or the UK, if the UK builds a terminal, then this could reduce supplies of LNG to UK customers including power stations. Indeed as Figure 6 summarizes, supplies to Europe have been the subject of long term, inflexible contracts with shippers and suppliers. Long term contracts are seen as constraining trades whilst shipping constraints are seen as a bottleneck, causing suppliers to seek new markets such as the USA, where these constraints are not so pressing. Figure 7 shows that these constraints are expected to ease in future, however, as the European market for LNG develops and expands.

Figure 5; LNG Operators by Fleet Capacity.

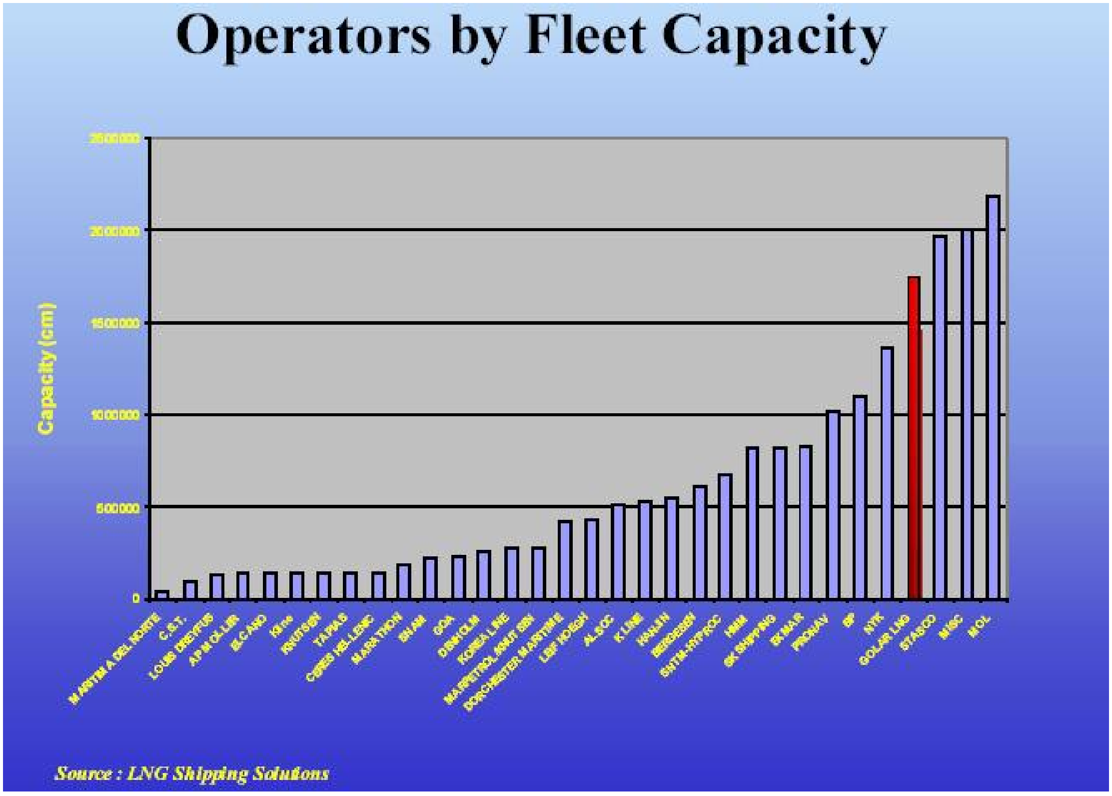


Figure 6; European LNG Supplies Constrained by Shipping Bottlenecks.

Europe	USA
Long Term Bilateral trades with shipping capacity constraining trades. Shipping constraints seen as bottleneck linking upstream expansion to promising new markets.	Entering Dynamic Growth Period bringing greater geographic diversity of Buyers and Sellers More flexible Innovative sales arrangements Orders now placed for uncommitted capacity Trading patterns become less static with supply contracts tailored to a number of small buyers in a spread of locations Large Buyers – to buy from various sources on fob basis using due to emerging destination flexibility

Figure 7; LNG Market is Becoming Less Inflexible.

Historic Structure	Future Structure
• Supply Push • E & P Dominated • Long-term contracts • Dedicated ships and routees • Crude Oil index supplies • High costs	• Downstream market pull • End-market influence • Emerging Merchant deals • More flexible shipping options • Changing mix of supplies • Cost reductions

Figure 8; Free Yard Capacity for LNG Ships in the year 2000.

Free Yard Capacity - Major Yards

Yard	Capacity per year (ships)	Earliest Delivery
Daewoo	6	Q1 2005
Hyundai	4	Q2 2005 (Moss)
Samsung	4	Nov. 2004
Kawasaki	3	Mid 2005
Mitsubishi	2.5	1st. Half 2005
Mitsui	1.5	1st Half 2005
Hanjin	2	Q1 2005

Possible Changes in the LNG Shipping Chain that will Improve Security of Supply for Europe.

• Increase of Supply Sources and Markets (Variety of routes and flexibility of destinations)
• Increase in non-traditional trading
– Combination of Short and Long term contracts
– Spot, swaps and arbitrage trading
• Increase in Buyers involvement in LNG trades (FOB trading)
• Increase in non-dedicated vessels leading to LNG trading opportunities

US Considers LNG Tankers Moving Near Cities as Terrorist Targets

LNG tankers that move on waterways through cities are considered by the US federal government and emergency personnel to be moving terrorist targets. As Boston Fire Chief Paul Christian said about the LNG plant in Everett, Massachusetts, "The transit of LNG through any urban area is extremely hazardous…particularly in light of the terrorist potential."

Currently, U.S. Coast Guard safety zones for LNG tankers are as two miles ahead, one mile behind, and 1,000 yards on either side of the tanker.

Former Deputy Defense Secretary John J. Hamre, head of the Center for Strategic and International Studies, testified before Congress in June 2002 on the topic of Homeland Security. He raised concerns about attacks on so-called "soft" energy targets, including LNG terminals, and noted that the scale of such aggression could rival the September 11th terrorist attracts.(New Vision Urged for Homeland Security, Aviation Week & Space Technology, July 8, 2002, Paul Mann)

Bechtel-Shell say that the new tankers have double hulls and are virtually impossible to breach. This "virtual impossibility" happened on October 6, 2002 when a small terrorist boat in Yemen rammed a double-hulled French oil tanker, piercing the double hull, causing a massive fire and spilling approximately 90,000 barrels of oil. However this was an oil tanker, not an LNG tanker, which may be more resistant to collision damage.

Cost of a LNG Tanker Ship.

A LNG tanker typically costs $200 million, or three times the cost of a crude oil carrier of similar tonnage. The high cost and complexity of LNG tankers is a result of the advanced containment systems necessary to transport liquefied natural gas. The system must control the temperature of the cargo as well as the amount of natural gas that is allowed to "boil off" during transport. This gas is collected and used to power the ship.

Of The four systems currently used in LNG tanker construction, the Kvaerner-Moss Spherical system is the most widely used, equipping approximately half the world's LNG tanker fleet.

LNG Imports and Exports.

Figure 9 shows the main imports and exports of LNG in the year 2000.

Figure 9 LNG Imports and Exports, Year 2000.

LNG Imports in 2000		
	Million tonnes	% Change from 1999
Japan	53.32	5
Korea	14.31	12
Taiwan	4.37	11
Asia	72	7
France	8.58	16
Spain	6.82	26
Belgium	3.11	6
Turkey	3.213	47
Italy	2.63	27
Greece	0.38	
Europe	24.74	24
USA	4.82	40
Puerto Rico	0.26	
Americas	5.08	47
TOTAL	101.81	12

Sources of LNG Imports in 2000		
	Million tonnes	% Change form 1999
Indonesia	26.73	-6
Malaysia	15.03	2
Australia	7.18	-1
Brunei	6.58	8
Asia Pacific	55.53	-2
Algeria	9.75	3
Abu Dhabi	5.00	-2
Qatar	10.24	62
Libya	0.58	-17
Nigeria	4.43	2648
Oman	2.04	34
Mideast/Africa	42.04	88
Trinidad	2.90	3
USA (Alaska)	1.34	49
TOTAL	4.24	12

By 2020 US imports OF LNG will increase by 52 million tons per year. Asian demand will increase by 127 millions per year.

Suppliers of LNG.

Sources From Which UK is Likely to Import LNG..[2]

The following are the sources from which the UK is most likely to import LNG in future:

Gaz de France, A likely Supplier of Regasified LNG to the UK.

The largest European LNG importer Gaz de France, which has the most diversified supply portfolio in Europe, imported 11.1 billion cu.m of natural gas in the form of LNG in 2001, mainly from Algeria which accounts for 25.5% of gas supplies to France. Gaz de France is the largest European LNG importer (around one-third of imports) and number three in the world (8.5% of world production), behind Japan (almost 69 billion cu.m) and Korea (more than 20 billion cu.m).

Algeria

In 2001, Gaz de France imported around 8.1 billion cu.m of natural gas in the form of LNG from Algeria. It was delivered by Sonatrach from liquefaction facilities at Arzew, Bethioua and Skikda. The corresponding purchase and sale agreements are long-term contracts which expire in 2013.

Nigeria

In 1992, Gaz de France signed a long-term LNG purchase agreement with the Nigerian company NLNG. In 1997, a more than 20-year contract was signed with the Italian company Enel under which Gaz de France receives at Montoir-de-Bretagne an annual volume of 3.5 billion cu.m of natural gas purchased by Enel from NLNG. Gaz de France delivers equivalent quantities of energy to Enel via the Italian company Snam in the form of Russian gas transiting via Baumgarten in Austria and LNG from Algeria delivered to the Panigaglia terminal in Italy.

The Gaz de France and Enel purchase contracts generate additional traffic of 50 to 60 ships per year at the Montoir-de-Bretagne terminal, i.e., one extra ship per week.
In 2001, 2.9 billion cu.m of natural gas from the Bonny liquefaction plant were received at the Montoir-de-Bretagne terminal.

[2] Information supplied by Roger Roue, SIGTTO, 17 St Helens Place, London EC3A 7DG, February 25th 2003. Tel: 0207 628 1124. email: techa1@sigtto.org

Qatar

In 2001, the Montoir-de-Bretagne LNG terminal also received two cargoes of 120,000 cu.m of natural gas from Qatar.

A complete maritime hub

Directly, or via its subsidiaries, Gaz de France has acquired more than 35 years' experience in the design, chartering, operation, equipment, maintenance and management of LNG tankers.
*

Chartering

At present, the Gaz de France group owns: via Messigaz (a wholly-owned Gaz de France subsidiary): the Tellier (capacity 40,000 cu.m) and Descartes (capacity 50,000 cu.m) LNG carriers which dock at the Fos-sur-Mer LNG terminal via Methane Transport (50%-owned subsidiary of Gaz de France): the Edouard LD LNG carrier (capacity 129,300 cu.m) which docks at the Montoir-de-Bretagne LNG terminal

Operation

Gaz de France charters six LNG carriers In addition to Descartes and Edouard LD, it also charters: Ramdane Albane (owned by Sonatrach), with a capacity of 126,000 cu.m, which carries LNG between Algeria and France Lerici (capacity above 65,000 cu.m) and Elba (capacity above 40,000 cu.m) owned by the Italian company LNG Shipping Spa The Tellier, Descartes and Edouard LD LNG tankers are operated by French crews.

Equipment, maintenance and management

Since 1958, these functions have been handled by a 75%-owned subsidiary of Gaz de France, Gazocéan Armement, an integrated company specialized in LNG carrier management and maintenance.

Design

Gaztransport & Technigaz, a 40%-owned subsidiary of Gaz de France, has developed a system of membrane tanks built into the ship's hull. The cryogenic tank lining, capable of withstanding extremely low temperatures, is made of stainless steel or invar.

Two LNG terminals:

Further to the dismantling of the Le Havre terminal which, from 1965 to 1989, sent out half a billion cu.m of gas each year, Gaz de France now has two LNG terminals, one at Fos-sur-Mer and the other at Montoir-de-Bretagne:

Figure 10: The Two Gaz de France LNG Terminals

	Fos-sur-Mer	Montoir-de-Bretagne
Entry into service	1972	1982
LNG storage capacity	150,000 cu.m	360,000 cu.m
Annual gas send out capacity	above 4.5 billion cu.m	10 billion cu.m

These LNG terminals form part of the onshore infrastructures which place Gaz de France at the heart of European natural gas supply:

- a transmission system measuring 30,470 kilometres in length (including 300 km laid in 2000)
- a distribution network 158,200 kilometres in length
- 14 underground storage sites with a working volume of 9.4 billion cu.m
- 46 compression stations totalling almost 500,000 MW

Gaz de France LNG Safety Research:

The Gaz de France research centre conducts advanced research in the field of

- LNG: Equipment safety,
- Physical properties:
- LNG spillage and vaporization on water or land,
- LNG behaviour in tanks,
- LNG vapour cloud dispersion,
- Reduction in the cost of the LNG chain through the development of new liquefaction processes and
- New types of LNG carrier.

Montoir-de-Bretagne : Europe's largest LNG terminal

Since it came into service in 1980, the Montoir-de-Bretagne LNG terminal has supplied western France with natural gas, imported in the form of liquefied natural gas (LNG) from the Arzew et Bethioua liquefaction plants in Algeria, from the Bonny plant in Nigeria and, on an occasional basis, from plants in Qatar and Abu Dhabi. The contractual volumes correspond to an annual capacity of around 8.5 billion cu.m of gas.

The terminal was renovated in 1995 and improvement work was completedin the autumn of 2002.

In 2001, ten LNG tankers unloaded 85 cargoes of LNG at Montoir-de-Bretagne, delivering a full 14% of annual natural gas supplies to France. With the extension of the Montoir terminal, annual capacity will be increased to 120 cargoes over the next few years. It takes three days on average for an LNG carrier to sail from Arzew to Montoir and more than eight days from Nigeria (one day from Skikda to Fos-sur-Mer).

The natural gas sent out from Montoir is consumed in Brittany and Pays de Loire. It is also sent to neighbouring regions and to underground storage sites in Sologne and the Paris region.

The terminal installations have four main functions:

- LNG carrier receiving and unloading: The LNG is pumped out of the carriers moored at the unloading quay. The LNG is sent to the storage tanks via five unloading arms and a large diameter pipe.
- LNG storage in three cryogenic tanks for continuous gas reception and sendout.
- Compression to 80 bars and LNG regasification, depending on network requirements and carrier unloading schedules. The LNG is removed from the tanks and compressed in liquid phase by pumps before being regasified in heat exchangers using water from the Loire river or hot water. The 43 MW cogeneration unit installed in 2000 provides a cost-effective heat source for LNG regasification.
- Metering and sendout to the French natural gas transmission system at a pressure of around 80 bars. Two 800 mm pipelines take the gas to the Nozay interconnection station 50 kilometres from the terminal, after odorization with THT (tetrahydrothiophene, a synthetic gas used to odorize natural gas).

The Montoir-de Bretagne terminal occupies an area of 67 hectares on the northern bank of the Loire estuary. It can receive the largest LNG carriers.

Fos-sur-Mer: France's second LNG terminal

Commissioned in 1972, the Fos-sur-Mer LNG terminal supplies southern France with natural gas imported in the form of liquefied natural gas (LNG) from the Skikda, Arzew and Bethioua liquefaction plants in Algeria. The contractual volumes correspond to an annual capacity of around 4.5 billion cu.m of gas. The terminal was refurbished between 1995 and 1999. In 2001, 212 cargoes of LNG carried by five LNG tankers were received at Fos-sur-Mer, representing 13 % of total French natural gas supplies. A tanker voyage between Skikda and Fos-sur-Mer takes one day on average (three days from Bethioua to Montoir-de-Bretagne).

Around half of the natural gas sent out from this terminal is consumed in the Mediterranean region and the other half in the Rhônes-Alpes region. The terminal installations have four main functions:

- LNG carrier receiving and unloading: The LNG is pumped out of the tankers moored at the unloading quay. The LNG is sent to the storage tanks via three unloading arms and a large diameter pipe.
- LNG storage in three cryogenic tanks for continuous gas reception and sendout
- Compression to 67 bars and LNG regasification, depending on network requirements and tanker unloading schedules. The LNG is removed from the tanks and compressed in liquid phase by pumps before being reheated in heat exchangers and regasified using heat from seawater or hot water.
- Metering and sendout to the French natural gas transmission system at a pressure of around 68 bars. Two 600 mm pipelines take the gas to the Saint Martin de Crau interconnection station 24 kilometres from the terminal, after odorization with THT.

The Fos-sur-Mer terminal occupies an area of 17.5 hectares north of an artificial wet dock and along the banks of the Canal du Rhône at Fos. LNG tankers carrying up 70,000 cu.m of LNG reach the terminal via a 4-kilometre channel built by the Port Autonome de Marseille from the Fos roads.

Sources of Potential Direct Supply of LNG to the UK

If the UK builds its own modern, large domestic LNG terminal, then it will be able to import LNG directly, without it passing through French hands. The following are possible sources, according to SIGTTO:

Qatar,

Here there is already discussion of a deal to supply the UK. The deal is being struck by Qatar Gas and RasGas.

Edison Gas of Italy and Ras Laffan Liquefied Natural Gas Company Limited in 2002 signed a Sale and Purchase Agreement (SPA) detailing the terms under which RasGas will supply liquefied natural gas (LNG) from Qatar to Edison in Italy. The SPA covers the supply of 3.5 million metric tonnes (7.6 million cubic meters) per annum of LNG for 25 years with deliveries to begin in 2005. The gas for this project will be sourced from Qatar’s giant North Field, which has recoverable reserves of more than 500 trillion cubic feet of gas. To supply Edison, RasGas will expand its LNG facilities at Ras Laffan Industrial City in Qatar by adding a fourth train bringing total capacity at this facility to approximately 16 million tonnes per annum. RasGas will also be responsible for securing 4 ships to transport the LNG to Italy. Edison will construct a new LNG receiving/regasification terminal in the North Adriatic 15-km off the coast of Italy. “This event marks the beginning of a new era for the state of Qatar. While we have enjoyed much success in becoming the premier LNG supplier to Asia, today we became the first Middle East supplier to capture a major long-term sale to Europe." said H. E. Abdullah Bin Hamad Al Attiyah, Minister of Energy and Industry and Chairman of Qatar Petroleum.

Norway.

Here discussions are taking place with the Norwegian firm Snowvit ("Snow-white")

Canada.

Although this is being discussed, there is no export terminal in Canada at present.

Alaska's markets for natural gas Do Not include Europe.

Alaska sees its markets for gas as:

- The "Lower 48" North American states, via a 4,000 mile gas pipeline.
- The Lower 48 via a 800 mile pipeline plus liquefaction toLNG
- LNG to Asia.
- LNG to Mexico.
- Alaskan in-state use.

Algeria.

Although this is being discussed and the UK Energy Minister was in Algiers for some discussions in the week ended February 22nd 2003, it seems unlikely at present, since France, Spain and the USA are currently taking all the LNG that Algeria can export. However it is believed that the situation could change in the next 5 years and that one source of UK gas could be regasified Algerian LNG from France.

Algeria has been identified as a high priority market for the oil and gas sector. This priority is a result $20 billion investment in the hydrocarbon sector. The investment will take place in the upstream sector (increasing production from existing fields and developing new oil and gas fields), in refining and the fertiliser sector. Sustained activity may be expected since Algeria has the largest reserves of gas in Africa (146.5Tcf) and third largest oil reserves (15.4 billion bbl) in Africa, whilst its proximity to Europe guarantees the country a market for oil and gas production.

Algeria has been the focus of oil and gas activities in North Africa whilst Libya has been isolated from the international community. Through 1998, in contrast with the rest of the world, Algeria, showed a significant increase in new field discoveries which emphasised its prospectivity, and companies such as BP and Anadarko have announced large-scale gas field and oil field developments.

For the last forty years, Algeria has been at the forefront of the development of natural gas. In 1964, Algeria launched the first commercial LNG chain between Arzew and Canvey Island in the UK, a route that opened the giant Hassi R'Mel gas field to consumers outside Algeria. Through the rapid expansion of its LNG capacity and pipeline network to southern Europe, Algeria has been a reliable supplier of natural gas for decades.

Algeria was, until 2001 the only LNG supplier to the US. The US LNG infrastructure, in large part, was built to receive Algerian LNG.

In the North African/Middle East region, Algeria is now the United States' third most active commercial trading partner. In terms of US investment, Algeria ranks second in the region. The foundation of this remarkable increase in trade and investment is, of course, oil and gas.

Algeria was the world's first LNG producer in 1964. It now boasts four LNG plants owned by Sonatrach, the Algerian oil and gas company. Algeria was the second-largest exporter, behind Indonesia, in 2000 with 19% exported to Europe and the US. In 2001, Algeria was again the second-largest exporter, behind Indonesia, with 25.54 Bcm. Most of its exports were to Europe and the US. Algeria's liquefaction plants, two in Bethioua, one in Arzew and one in Skikda, produce 30.5 Bcm per year of LNG.

Increasing competition from Asia and competitive alternative energy prices have slowed Algeria's run as a leading LNG exporter. To reduce operating costs Sonatrach has completed refurbishments of its LNG facilities. The improvements will also keep its oldest facility in Arzew – now at 260 Mmcf/d – operating until 2003. It also has signed a memorandum of understanding with an Australian firm on a feasibility study for another LNG plant and terminal in the Arzew region.

Algeria, Home to Terrorists.

On Jan. 28th 2003, Italian President, Azeglio Ciampi, said in a visit to Algeria:

"Your nation has suffered and continues to suffer due to violence and terrorism. The fight against terrorism is a common cause. I wish to renew to you - he added - and the Algerian people you represent, the solidarity that I have personally expressed to President Bouteflika on behalf of Italy and our condolences for those who have died at the hands of terrorism, especially the civilian population. We must firmly condemn terrorist activities no justification or extenuating factor can be claimed; we must be equally committed to fighting the causes of such events. You must not be discouraged by economic and political obstacles nor must these factors hold you back. Half a century ago Europe was divided and obstacles seemed insurmountable. We have overcome them".

On February 24th 2003, the two Algerian dailies Le Mattin and Le Soir D'Algieres said that 42 people were killed in an ambush at a fake check point in al-Bweira (al-Qabayel area, 120 Km to the east of the capital). The papers also reported a massacre which targeted two families and resulted in 13 killings near al-Bleida town (50 Km to the south of the capital).

The Algerian army will shortly receive American weapons and is preparing to carry out a new plan to chase the armed Islamist groups.

The army arrested less than one month ago a member in ***al-Qaida*** organization, which is led by Osama Bin Laden, and admitted that other fighters of al-Qaida members sneaked into the country.

A "Second Algerian War".

The oil-production zone in the Sahara, the source of $12 billion in annual export earnings, has been cordoned off by the army. Algerians need special passes to enter the area. Omar Bellouchet, the editor of the Algiers daily El Watan, says

*"We went through a war of liberation to fight off French colonization that was unbelievable in its savagery," Bellouchet said. "One million dead to be free. But after the war, the military power simply dilapidated the strength of the country and its resources through waste and corruption. And there was a revolt. That is what the Islamic Salvation Front was: a revolt. There is no way the 3 million Algerians who voted for the front wanted a fundamentalist state. And that in turn produced this tragedy, this **second Algerian war**."*

The Algerian army chief of staff Lt. Gen. Muhammad al-Ammari, in an interview with the French magazine Le Point, replying to a question to the possibility of the Iraqi president will seek the assistance of Algeria, said

"…if he decided that, we will agree."

Egypt.

Egypt has been working with a consortium to develop its LNG market. Egyptian LNG (ELNG) includes BG Group (35.5%), Edison International S.p.A. (35.5%), the Egyptian Natural Gas Holding Co (EGAS) (12%), the Egyptian General Petroleum Corp (EGPC) (12%) and Gas de France (GdF) (5%) to build and operate a $900-mil LNG plant at Idku, east of Alexandria.

BG expects Train 1 – the first large-scale LNG processing plant – to be in place by 2005 with supplies from Simian Sienna in the West Delta Deep Marine (WDDM). This plant will have a production capacity of 3.6-mil tonnes of LNG per year over a 20-year contract. Train 2 is targeted for 2006 with supplies from other WDDM discoveries, though the make up of future train ownerships beyond the first one may be different. The cost of the second plant is expected to be about half the development and construction costs of the first plant.

An LNG Export Project Agreement (LEPA) was signed Apr 5, 2001. The agreement leads the way for the project to be underway once the Gas Sales Agreement and Front End Engineering and Design (FEED) have been finalized. The agreement also provides the facility to be built in a tax-free zone and allows cost recovery for natural gas supplies.

Early permits have been approved and the remaining permits are expected to be approved by the end of 2003. If the project gains full approval the consortium can expect to have the two plants on-line by mid-2005 and mid-2006.

Nigeria.

With proven gas reserves of more than 180-trillion cubic meters, Nigeria is the seventh-largest gas producer in the world. The reserves are largely unexploited, reflecting a history of under-investment, low domestic demand and the dominant preference for oil. With these abundant gas reserves and a need to end gas flaring, the government has sought opportunities to convert its vast gas potential into a source of income. The most high-profile example of a change in approach is the Nigeria Liquefied Natural Gas (NLNG) project at Bonny Island in the Niger Delta, which is in the process of expanding to become one of the largest LNG exporters in the world. It is, however, only one among several projects being proposed by other multinational companies that could see Nigeria turn its gas resources into a welcome revenue spinner.

The NLNG initiative is a joint venture between the state-owned Nigerian National Petroleum Corp and the oil multinationals Shell, TotalFinaElf of France and Italy's Eni. The planned expansion of the plant from three to five trains, for which the contract has already been awarded, is expected to utilize 25% of the associated gas being flared. Since the commencement of commercial operations, at least 230 cargoes of LNG and 14 cargoes of condensates, have been delivered to various European customers and other parts of the world. Exports of LNG earned the country $1.2-bil in 2002. A third train is under construction and will add a further 3.1-mil mt/yr when brought onstream, bringing the installed capacity to approximately 9.1-mil mt/yr.

Although total investment so far on the three trains has been set at about $5-bil, it seems investors are confident that their spending is worth it and have given the go-ahead to construct trains four and five, each with a capacity of about 4-mil mt/yr. The two new trains, due for completion in 2005, will cost $2.7-bil and will give the NLNG a 13% share in the world's LNG market, placing the country as one of the top four LNG producers in the world. The expansion, known as NLNG Plus, when completed will bring the Bonny Island operation to an overall production capacity of 17.3-mil mt/yr of LNG, 2.5-mil mt/yr of LPG and 1-mil mt/yr (200,000 b/d) of condensates.

Marketing arrangements have already been made, including revisions to the off-take arrangements in order to compensate for the loss of Enron as a potential customer. Enron had been scheduled to take 4-bil cu m/yr of gas from trains four and five, but other companies agreed to take these quantities. NLNG has already made agreements for 6.5-bil cu m of LNG from the new trains to Spain's Iberdrola, Portugal's Transgas, Shell and TotalFinaElf.

The fact that shareholders of NLNG are promoting work on the sixth LNG train, and the government is considering four more trains, is indicative that diversifying away from oil as the backbone of the Nigerian economy is yielding huge dividends.

Other projects include the construction of a second, third and possibly a fourth LNG plant involving international companies such as Conoco, Phillips Petroleum, ExxonMobil, ChevronTexaco, Agip and Statoil.

Angola.

ChevronTexaco and Angolan state-owned Sonangol have agreed to develop Angola's flagship LNG project to convert natural gas from offshore oil fields to LNG for export. The facility will process natural gas from offshore Blocks 1, 2, 3, 4, 15, 16, 17 and 18. The facility, which will be located in Luanda adjacent to the existing refinery, will initially consist of one LNG train with a capacity to process 4-mil mt/yr. The site is sufficiently sized for the plant to expand to additional LNG trains. The estimated $2-bil project – crucial for Angola's plans to end gas flaring at its new deep-water developments – was initially planned to start in 2005, but like several other major oil projects it has been delayed several times

In March 2002, ChevronTexaco and Angolan state oil company Sonangol enlisted four other partners – TotalfinaElf, Norsk Hydro, BP and ExxonMobil – which will contribute gas produced from their deep-water fields. Each has 12% equity in the project, while Sonangol holds 20% and ChevronTexaco 32%. The LNG project could spur the development of other gas-related projects including, gas-fired generation facilities in the Luanda area, industrial usage of gas as a fuel and expansion of the domestic market for LPG.

Namibia.

Shell said July 2nd 2002 it was evaluating options for its Kudu gas field offshore Namibia and would make a decision by August after shelving a plan to install a floating LNG barge there. Shell's plan to build the world's biggest floating LNG barge at Kudu was contingent on finding gas reserves in excess of 5 Tcf. But two appraisal wells drilled in the last three months failed to meet the required reserves for the $2-bil scheme.

Namibia's mines and energy minister, Jesaya Nyamu, says that the Windhoek government was locked in negotiations with Shell on alternative options for Kudu. "I am disappointed that we have not been able to embark on what would really be a major project in southern Africa," he said. "But, given the fact sufficient gas is there, I think there will be a possibility to embark on other projects," he said.

Shell owns 75% of the Kudu field, with ChevronTexaco holding 15% and Energy Africa 10%.

Russia.

Currently Russia has only one export terminal for LNG, on its Pacific coast near Korea. This is Sakahlin, which is far from the UK. Another disadvantage of Russia is that Russia will be the main supplier of piped natural gas. If Russia decides to indulge in "gas tap diplomacy" then she will turn off supplies of both piped gas and LNG.

LNG Storage in the UK.

In the UK there are no existing operational large scale LNG importation facilities. There are commercial plans for the development of such LNG import facilities at the Isle of Grain and Milford Haven.

There are five LNG (liquefied natural gas) storage facilities which are integral to the national transmission system and are owned and operated by Transco (at Avonmouth, Avon; Dynevor Arms, mid-Glamorgan; Glenmavis, Lanarkshire; Isle of Grain, Kent; and Partington, Lancashire).

The oil and gas industry's forecasts, supported by those of the UK Government, show Britain's dependency on imported gas will rise to nearly 50% by 2011/12. In order to access the still plentiful supplies of gas that exist elsewhere in the world a substantial amount of new infrastructure is required.

The industry has recommended that up to 3 more interconnections (fixed pipelines) with the Continent or the equivalent in LNG importation facilities – or, more likely, a combination of the two – will be needed in the next ten years to fill this gap.

There will also need to be considerable investment to extend and upgrade the National Transmission System (NTS).

Given Britain's position on the western edge of an integrated pan-European supply system, and in light of the growing import dependency, it is widely acknowledged that in order to guarantee security of supply there needs to be investment in an energy insurance policy which would be designed to mitigate the risk of supply shocks (such as the sudden loss of a major supply source). This is much easier to achieve for gas than it is for electricity as gas can be temporarily stored given the right conditions.

Many stakeholders in the industry believe that importing gas to the West Coast of the United Kingdom (taking advantage of the stocks of untapped gas in the Atlantic basin) and the associated pipeline extension are a realistic short-term opportunity to further ensure diversity and security of supply.

Proposed LNG terminal at Milford Haven.

Petroplus is planning to develop a terminal for the importation and storage of Liquefied Natural Gas (LNG) at its site at Waterston, Milford Haven. The Waterston site was formerly the Gulf Oil Refinery which operated from the mid 1960's until 1997, when refining operations ceased. Petroplus acquired the site in 1998, when it purchased Gulf Oil Refining Ltd. UK from Chevron. Since that time the site has operated as Petroplus Tankstorage Milford Haven Ltd., providing storage and other services relating to the oil and energy industry.

LNG would be delivered to Milford Haven by marine tankers, which would berth at one of the existing jetties on the Petroplus site and pump the LNG cargo into two storage tanks. From the storage tanks the liquefied gas would be re-gasified and sent out to consumers via a gas pipeline connecting with the National Transmission System (NTS). The development would take place within the existing operational site and adjoining land that Petroplus owns.

The terminal would operate continuously, on a 24 hours per day, 365 days a year basis. Two full containment storage tanks each of 165,000m^3 nominal capacity would be constructed, providing the terminal with a total of 330,000m^3 nominal capacity of LNG storage.

The existing Petroplus site includes marine docking and unloading facilities at 3 berths, constructed in the late 1960s for the import and export of oil industry products. The development proposals include the adaptation of these facilities for use as an LNG tanker berth, with pipelines and other facilities as necessary for unloading LNG and transporting it to storage tanks on shore within the existing refinery area whilst maintaining the capability of unloading oil.

New UK LNG Terminal Planned for River Medway

Mersey Docks & Harbour will submit plans for a major liquid natural gas terminal and production plant on the River Medway. The Port Authority, which is part of the Mersey Docks, has agreed to transfer a 10-hectare stretch of the river bed to Lattice Group PLC, which will develop the site.

Pending approval by the Medwya Borough Council, plans call for the construction of a new jetty, vaporisers and a pipeline running from the Medway to the nearby existing LNG storage and re-gasification plant. The deepwater jetty would be capable of handling the first of the giant specialist carriers by the end of 2004. This would substantially increase shipping and cargo volumes on the river. As Britain's gas market will become increasingly dependent on imports, shipments to this deepwater terminal from sources such as the Middle East and Nigeria will play an increasingly important role.

Qatar Petroleum and ExxonMobil Corporation sign Agreement for the supply of LNG from Qatar to the UK.

Qatar Petroleum and ExxonMobil Corporation have signed a Heads of Agreement for the supply of Liquefied Natural Gas from Qatar to the United Kingdom. The HOA covers the development of two LNG trains that are expected to be the largest ever built by industry. The feed gas for these trains will be sourced from Qatar's giant North Field, which has proven natural gas reserves in excess of 900 trillion cubic feet (tcf). Qatar Petroleum will have a 70% equity interest in the LNG trains, and ExxonMobil 30%.

The LNG trains will be built at the Ras Laffan Industrial City in Qatar.

LNG shipments to the UK are scheduled to begin in the 2006/7 timeframe and extend over 25 years.

ExxonMobil is currently investigating a number of potential sites in the UK for the import facility that will receive the LNG.

Gas Storage, Including LNG, in the UK.

The UK can store gaseous gas as well as LNG.

The major gas storage facility serving the market in Great Britain is the partially depleted Rough field in the Southern North Sea.

The main existing onshore facilities are:

- Hornsea, east Yorkshire;
- five LNG (liquefied natural gas) storage facilities which are integral to the national transmission system and are owned and operated by Transco at
    - Avonmouth, Avon;
    - Dynevor Arms, mid-Glamorgan;
    - Glenmavis, Lanarkshire;
    - Isle of Grain, Kent; and
    - Partington, Lancashire
- and two facilities which recently commissioned, at
- Hatfield Moor in east Yorkshire and
- Hole House Farm in Cheshire.
- A proposed facility at Aldborough, east Yorkshire, has secured planning permission and is under development.
- In addition a project at Byley in Cheshire is currently seeking planning permission, and a project at Fleetwood in Lancashire is understood to be close to applying for planning permission.

Liquefaction.

Figure 11 summarizes liquefaction projects and Figure 12 deals with liquefaction capacity; both Figures are for LNG the world over.

Figure 11 Liquefaction Projects.

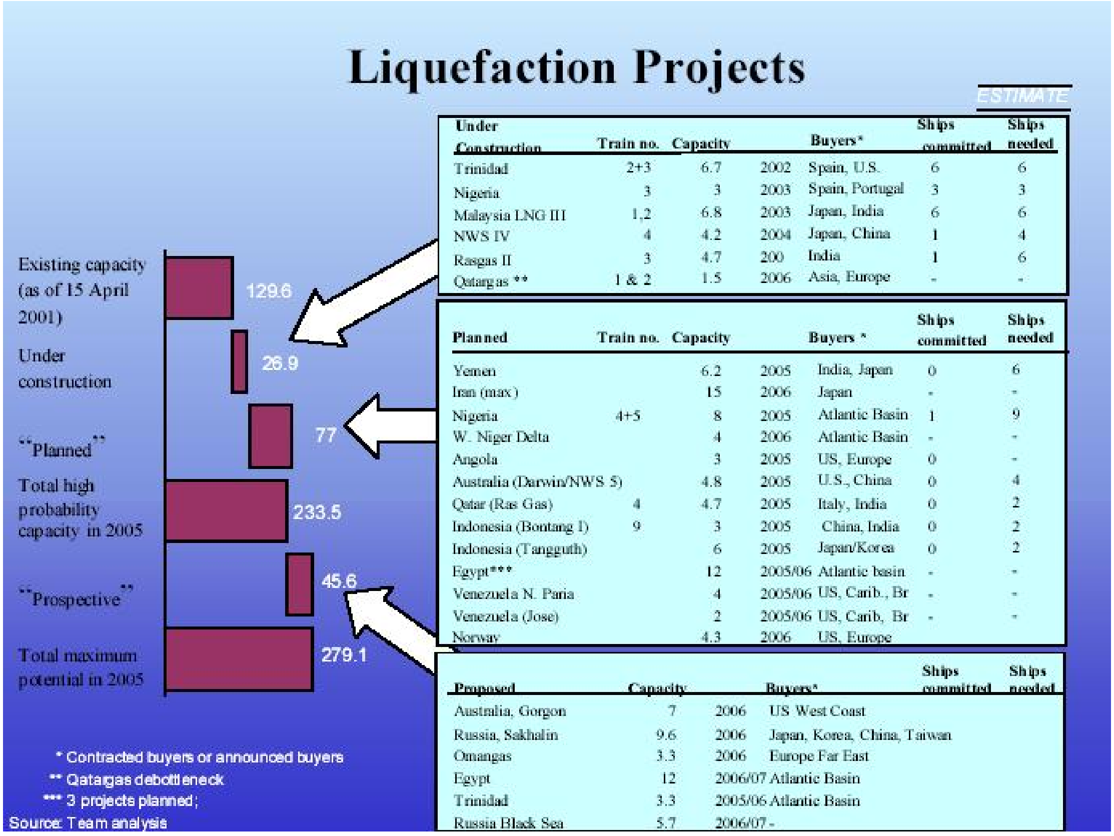


Figure 12. Existing Liquefaction Capacity.

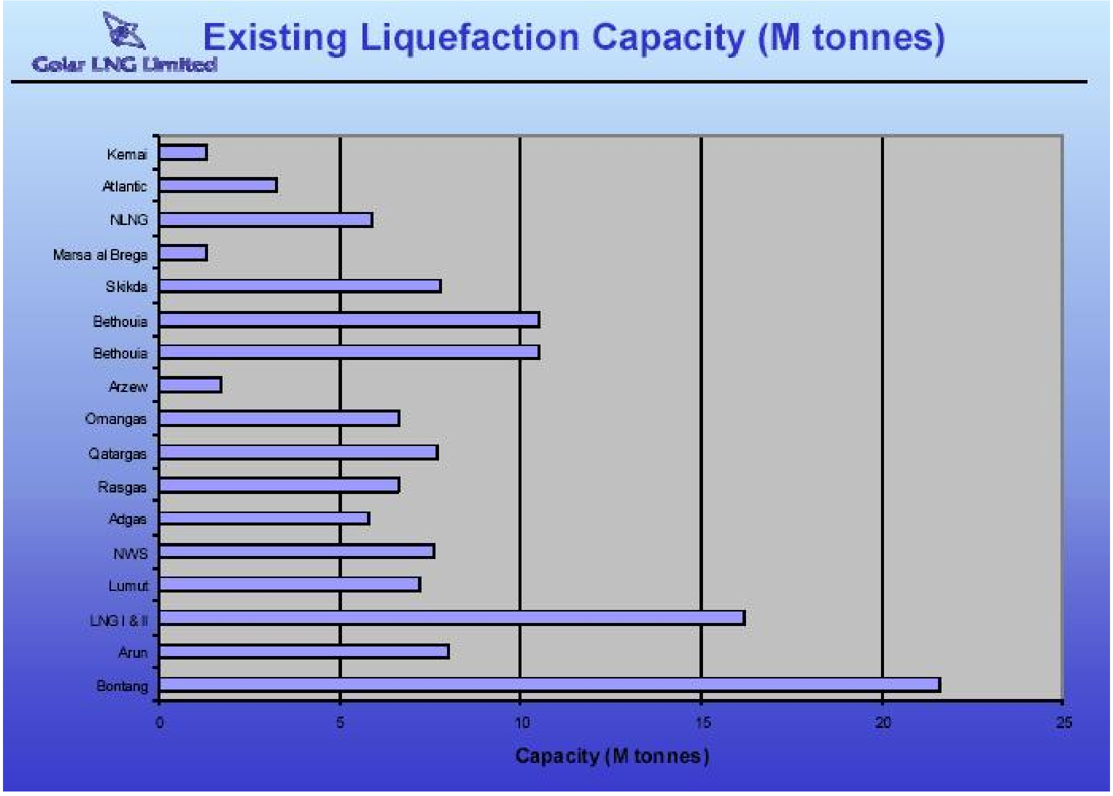


Figure 13: Example of Liquefaction Plant.

Liquefaction Plant: Example in Nigeria, 9.8million m^3 / day Train 1,2,3

Figure 13 shows an example of a liquefaction plant. Located in Nigeria, it comprises LNG Trains 1 & 2 with the capacity of producing 9.8 million m³/day.

BASIC UNITS

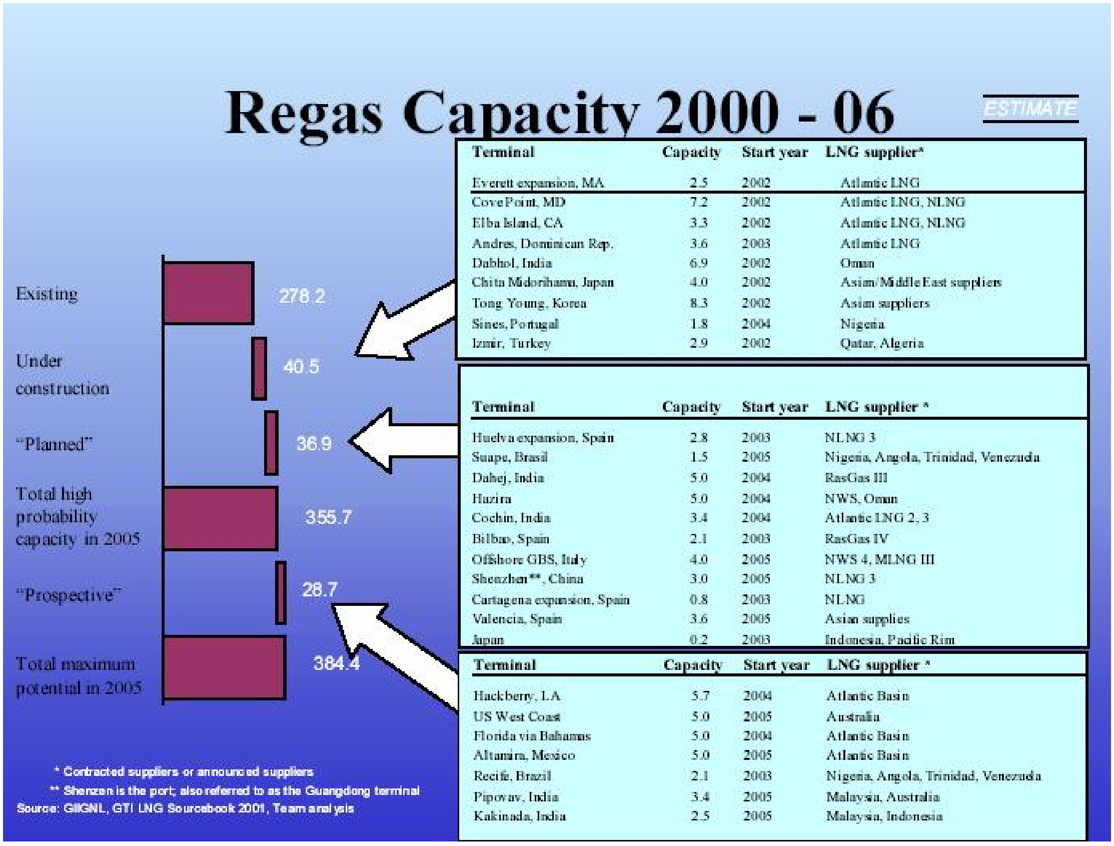
- Fractionation Section
- Mixed Refrigeration Cooling
- Propane Refrigeration Condensers
- Acid Gas Removal & Hot Oil System
- Dehydration & Mercury Removal
- Refrigeration Compressor Section

This plant it very exposed and would not resist the attack of a diving commercial aircraft.

Regas Capacity, 2000 to 2006.

Figure 14 summarises World Regas Capacity for the period 2000 to 2006.

Figure 14. Regas Capacity, 2000 to 2006.



Market and Costs.

Figure 15 summarizes the strength of the current LNG market.

Figure 15: Strength of LNG Market.

Commercial Structure.

Business Risk and therefore Security of Supply depends on the Commercial Structure of the LNG supply process. Similarly, definition of commercial structure is a key part of LNG project development. LNG project structures must meet a range of objectives including,

- ensuring stability of operation,
- sharing risks and rewards equitably,
- satisfying the requirements of the host government, and
- minimising the potential for conflict and delay.

Project structures can be grouped into three generic models:

- integrated projects,
- transfer pricing arrangements, and
- throughput arrangements.

Integrated Project.

In an integrated project there is ***common ownership*** of

- the gas reserves,
- Liquefaction plant, and in most cases
- the LNG ships.

An integrated project has the advantages of aligning the partner interests and avoiding negotiation of transfer prices. There is a case study of the RasGas trains 1 and 2 integrated project.

Transfer Pricing.

An integrated structure may not be possible in many situations because the owners of the gas reserves differ from the liquefaction plant owners. In these cases the most common alternative is a transfer pricing arrangement. The partners in each stage agree a transfer price for sale of the gas or LNG into the next stage of the process.

Transfer pricing arrangements may lead to conflict, particularly when changing market conditions shift the risk/reward balance between different partners. There is a case study of the Malaysia LNG Dua transfer pricing arrangement.

Throughput Arrangements.

The third form of project structure is a throughput arrangement where the upstream partners pay a tolling fee to use the LNG plant and then market the LNG on their own behalf. Although there are no LNG projects currently operating on this basis, there is a case study of Atlantic LNG trains 2 and 3, which will operate with a form of throughput arrangement from 2002.

World LNG Imports[3] and Exports[4].

Figure 16: World Imports and Exports of LNG, 1995 to 2020.

Indigenous Production (MTOE)	1995	2000	2010	2020
OECD North America (including Mexico)	592	674	799	478
OECD Europe	199	222	276	238
OECD Pacific	31	54	87	68
Transition Economies	585	631	882	1316
China	17	30	57	78
Rest of World (excluding Mexico)	396	486	795	1630
World Total	1819	2098	2895	3807
Net Imports (MTOE)				
OECD North America (including Mexico)	-2	-2	61	526
OECD Europe	104	153	232	386
OECD Pacific	42	42	42	74
Transition Economies	-74	-108	-173	-363
China	0	0	0	0
Rest of World (excluding Mexico)	-76	-91	-168	-629
World Total	-6	-6	-6	-6

Tables for the years 1994, 1998, 1999, 2000 and 2001 are given in the accompanying Spreadsheets, “LNG master”.

Clearly France is Europe’s biggest importer of LNG. Most of France’s LNG comes from Algeria.

The UK could take re-gasified by Interconnector from France.

[3] Source: **Imports to the United States and Imports to Japan and Mexico from the United States**: Energy Information Administration, *Natural Gas Monthly* (July 2002). **Imports to France and Turkey from Nigeria, Imports to France and Italy from Qatar, Imports to Spain and Japan from Oman, and Imports to Puerto Rico and Oman from Trinidad and Tobago**: Cedigaz Centre International d'Information sur le Gaz Naturel et tous Hydrocarbures Gazeux, *Natural Gas in the World - 2002 Survey*. **All other countries**: Organization for Economic Cooperation and Development, International Energy Agency, *Natural Gas Information 2002* (With 2001 Data)

[4] WORLD ENERGY PROSPECTS TO 2020, paper prepared by the International Energy Agency for the G8 Energy Ministers' Meeting Moscow 31 March - 1 April 1998

Forecast Price of Gas and LNG.

LNG Pricing Systems.

There are different pricing systems in place in the three major market regions of Asia-Pacific, Europe and the USA. In the Asia-Pacific LNG prices are typically indexed to crude oil prices, either in Japan or Indonesia, in some cases with an ‘S’ curve to limit the impact of extreme oil price movements. In Europe LNG is competing with pipeline gas and adopts similar formulae which are typically indexed to crude oil or oil products (gasoil and fuel oil), although there may also be elements of coal, electricity or inflation indexation. In the USA gas prices are set by gas to gas competition, driven by supply and demand. LNG delivered prices to the US market are typically based on Henry Hub gas prices plus or minus a locational differential reflecting the basis between the LNG delivery point and the Henry Hub.

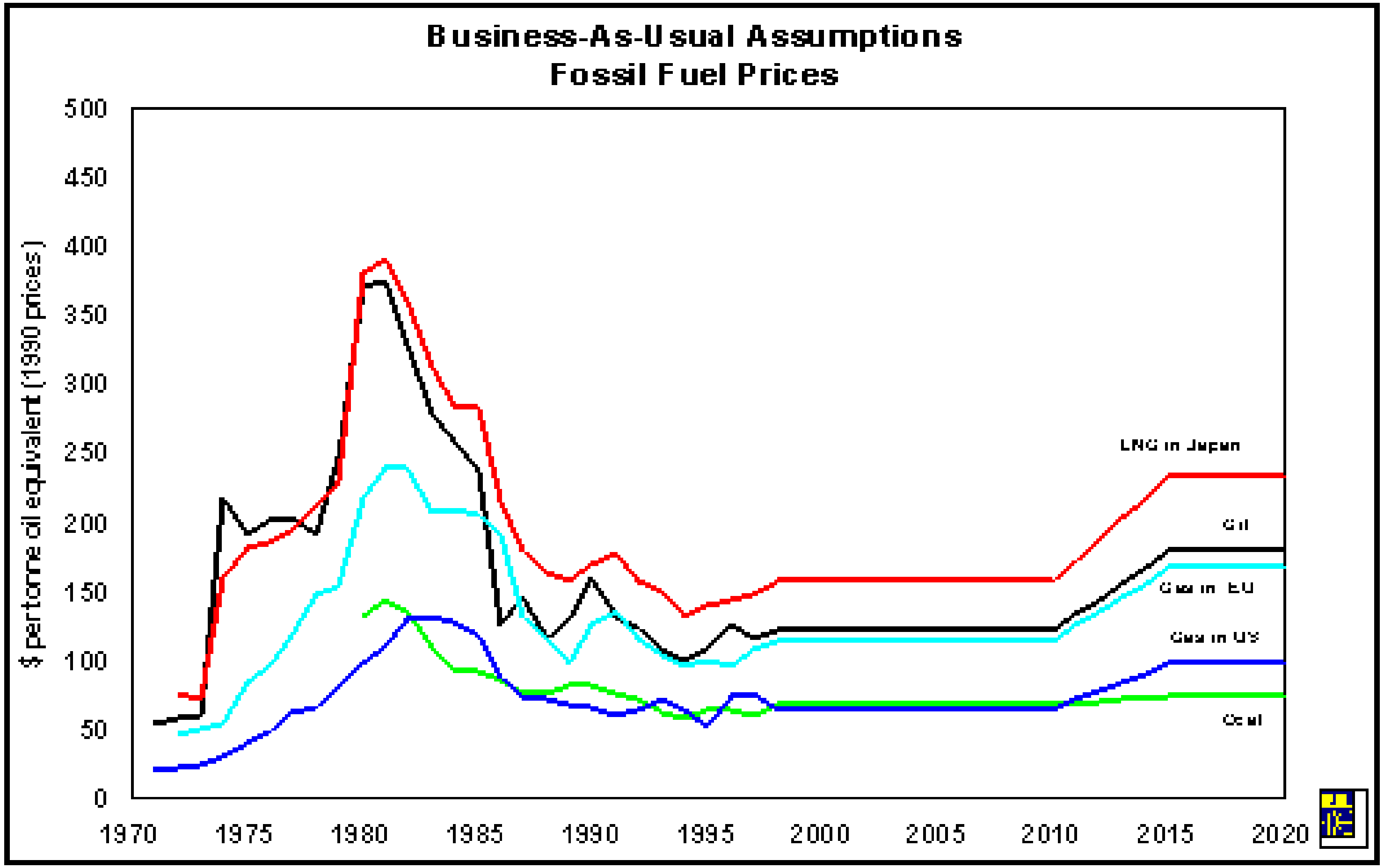

Business-As-Usual Assumptions
Fossil Fuel Prices
$ per tonne oil equivalent (1990 prices)
500
450
400
350
300
250
200
150
100
50
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
LNG in Japan
Oil
Gas in EU
Gas in US
Coal

Figure 17

Volatility of LNG Price.

Two recent examples of the volatility of LNG pricing is given by these News Items dated February 24th 2003:

"Taiwan's state-owned Chinese Petroleum Corp (CPC) said it would raise prices of domestic liquefied petroleum gas (LPG) from Tuesday, the second hike this year as international prices rise. Chinese Petroleum ***would raise LPG prices from 4.76 percent to 8.75 percent*** *as import costs in February have risen 13.39 percent from the previous month, it said in a statement on Monday. The hike came after Chinese Petroleum raised local wholesale gasoline and diesel prices on Saturday in response to rising crude oil prices. After the hike, household LPG prices will rise to T$16.70 per kg from T$15.70, while wholesale LPG prices for cars will grow by T$1.10 to T$16, it said. (US$=T$34.80)"*

"CALGARY, Alberta, Feb 24 (Reuters) - Canadian energy stocks surged to a nine-month high on Monday, fueled by a massive spike in North American natural gas prices and oil markets made increasingly jittery by the prospect of war in Iraq. The big driver was ***natural gas, which soared $2.14 per million British thermal units, or more than 32 percent,*** *to $8.75 on the U.S. futures market, the highest level in more than two years. It all adds up to a gusher of profits for Canadian oil companies in the current quarter, said analyst Martin Molyneaux of FirstEnergy Capital Corp., who projected the sector could rise another 15 percent within 12 months."*

Price of LNG Ships and Transit.

Prices of LNG ships have varied considerably over the last two decades, however in recent years prices have fallen and current price for a standard 135,000 m3 to 140,000 m3 LNG ship is around $170m.

LNG shipping costs are very much a function of the distance between the liquefaction plant and the receiving terminal. Shipping costs include fixed costs (capital charges, crew costs and insurance) and variable voyage costs (fuel, boil-off gas and port charges), with fixed costs generally accounting for two-thirds of total transportation costs.

Spot Market Trading.

Although long-term contracts have traditionally underpinned the LNG market, there has been a low level of short-term or spot LNG trading throughout its history. In recent years the level of short-term trading has increased, reaching nearly 6% of total LNG production in 2000. Short-term trading began as sellers sought to utilise spare liquefaction capacity and some buyers found that gas demand increased more quickly than forecast. In the 1980s almost all short-term trading was between suppliers and buyers that already had a long-term contractual relationship. In the early 1990s this changed somewhat as shut-downs of Algerian production forced European buyers to seek LNG cargoes from the Middle East and Australia. From 1996 the US market also began to buy spot LNG cargoes as Asia-Pacific sellers aimed to offload excess LNG following the downturn in demand in Japan, Korea and Taiwan.

Short-term LNG trades may follow a variety of pricing structures, including

- indexation to crude oil or oil product prices, or
- netback from pipeline gas prices.

In the Atlantic basin the proximity between the US and European markets provides sellers and buyers with an opportunity to arbitrage prices and divert LNG cargoes to attract the
highest price. Analysis of deliveries from the Atlantic LNG plant in Trinidad shows that when prices in the US are above European prices deliveries will be diverted to the US from Spain, whereas the situation reverses when European prices are above US prices.

The main factors needed for the expansion of short-term trading are

- surplus LNG supply,
- market demand and receiving capacity,
- uncommitted ships, and
- flexible contracts.

At the current time the main constraints on the further development of short-term trading are the shortage of uncommitted ships and the lack of flexibility in existing contracts. This seems likely to change in the near future as a number of uncommitted ships come online and buyers push for greater flexibility in supply contracts. Given these factors, the short-term LNG market is expected to expand somewhat in the medium-term, however, the large investments and commitments required for the construction of LNG plants, ships and terminals, is likely to prevent the short-term market replacing the current framework of long-term contracts.

LNG Market to 2020: Forecasts.

LNG trade has grown significantly in recent years and there are now predictions of annual trade doubling by 2010 and tripling by 2015. Although these forecasts may be over-optimistic, further acceleration in the pace of change will be needed. Expected gas supply gaps in the USA and Europe, and reducing LNG costs, make LNG an increasingly attractive prospect for these growing markets. The opportunities for sellers to arbitrage prices between the US and European markets also increases the attractiveness of trading in the Atlantic basin. During 1996 to 2001 Atlantic basin LNG demand grew by an average of 12%/year. Growth in the Asia-Pacific region has been slower, at 5%/year over the same period, and prospects for growth in the existing markets are uncertain, however, India and China hold out the possibility of large new markets for LNG. There are currently a very large number of liquefaction capacity expansions or Greenfield projects proposed, both in existing regions and new areas such as Russia, Norway, Iran, Venezuela, and south-west Africa.

This is likely to lead to fierce competition between projects with only those able to secure markets proceeding to completion. The initial effect will be to make it impossible for a few suppliers to corner the market. If one supplier withdraws supplies to the UK (say) on political grounds then there will be no shortage of others to take over in the present market.

However, in the medium term, when competition has driven all save the strongest out of the market, the situation will be reversed. It will then be more possible for one supplier, acting on behalf of a political faction, to withdraw supplies without these supplies being quickly substituted by a competitor.

The key issue for new projects will be cost, with those projects in the Atlantic basin having a significant advantage due to their proximity to growing markets.

Buyers' Market has Emerged.

The emergence of a buyers' market and increased short-term trading is changing the structure of the LNG market, including increased flexibility in contracts, and increasing volumes of uncommitted liquefaction and transportation capacity. Sellers are learning to deal with new types of buyers, as new players such as IPPs and new entrant suppliers seek to secure gas supplies in liberalising gas markets. The development of short-term LNG trading will continue, however, the market is likely to remain largely dependent on long-term contracts in the medium to long-term.

The future is likely to owe much to three emergent trends.

- Changes in downstream markets and the emergence of new markets that are forcing buyers to seek much more flexible supplies than in the past.
- Reductions in the costs of LNG to the point where it is already competitive with pipeline gas in a number of growing markets.
- The development of short-term LNG trading and the flexibility this gives for LNG players to improve returns on investment and exploit and further develop niche market opportunities.

Competition in the Market for LNG Rising.

An example of the manner in which competition for LNG is rising in the market place is given by this recent news report:

"State-run Korea Gas Corp (KOGAS) unveiled on Monday February 24th 2003 ***plans to expand into power generation****. KOGAS planned to build a gas-fired power plant in the country which could have at least 1,000 megawatts (MW) of capacity but it had yet to decide on other details in the long -term plan, a company spokesman said. "We have been planning to enter the electricity generation business as it is important for our overall business," chief company spokesman Kim Cha-joong told Reuters. KOGAS is the sole importer and wholesaler of liquefied natural gas (LNG) in South Korea, the world's second-largest LNG importer behind Japan."*

European Gas Consumption.

Figure 18 shows LNG Imports and total gas consumption for European countries, from 1995 to 2000. LNG Imports are seen to have supplied about

20% of Europe's natural gas in the period.

Figure 19 shows that France imported the most LNG, followed by Italy. The UK does not figure on this plot, as it imported so little LNG.

Figure 18: LNG Imports and Total Gas Consumption for European Countries, 1995 to 2000.

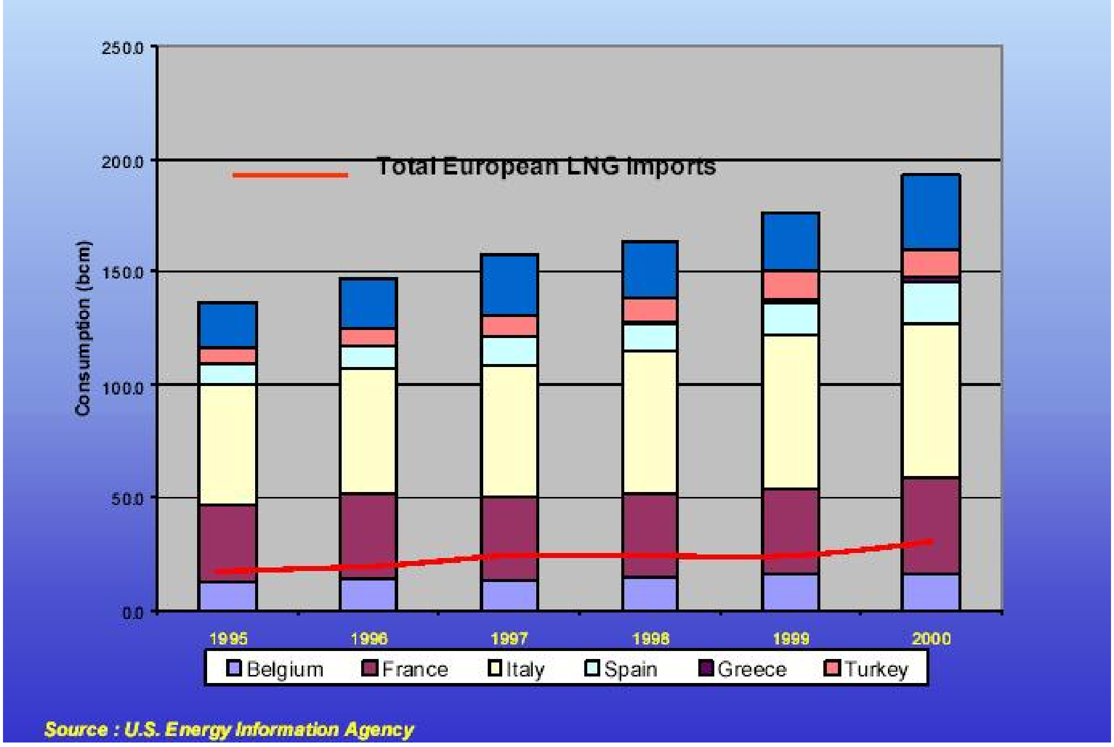
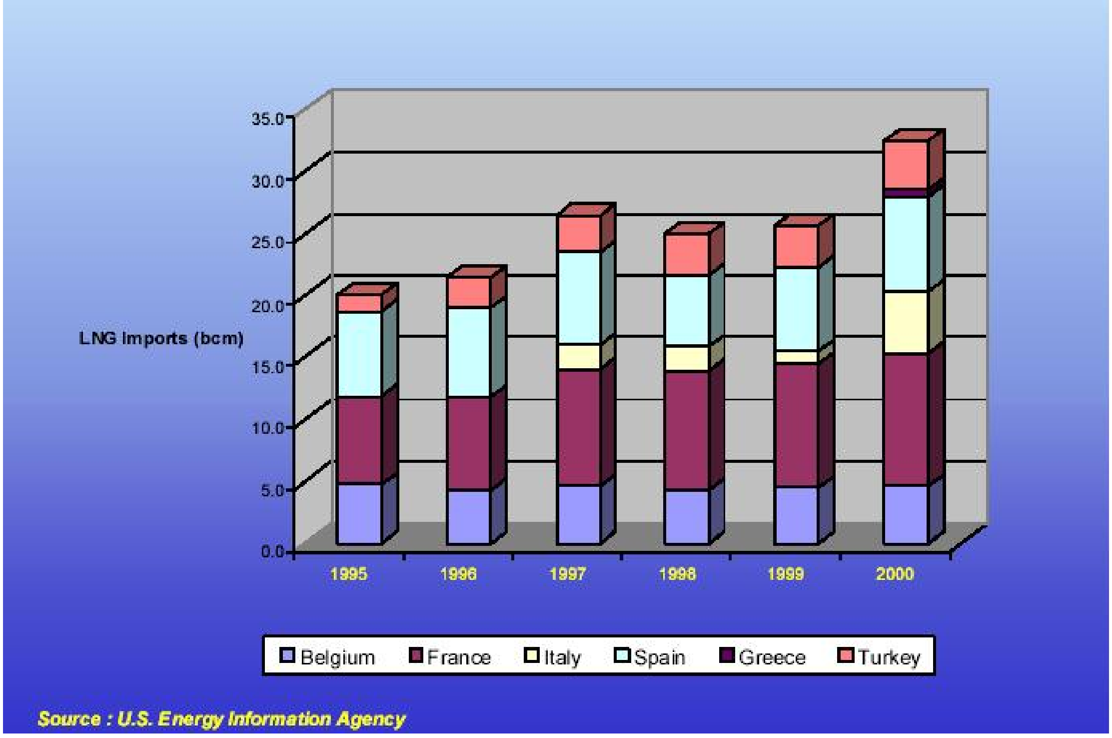


Figure 19. LNG Imported by European Countries, 1995 to 2000.



Natural Gas Will meet 28% of Europe's Primary Energy Needs by 2020.

Natural gas is an important source of energy for the European Union, currently meeting more than 23% of the region's primary energy needs. Eurogas, the European natural gas industry association, forecasts that this figure will rise to more than 28% by 2020.

While Europe has a substantial natural gas supply, it is still a net importer. Production from fields in Europe, situated in the North Sea offshore the UK, the Netherlands and Norway, is slowly decreasing while at the same time consumption is increasing. One way of securing the supply is to import gas from Russia and Algeria. These countries, together with Norway and the Netherlands, are currently supplying continental Europe with natural gas.

Europe Imports LNG by Tanker-Ships, Mostly From Algeria.

Several European countries such as France, Spain, Greece, Portugal, Turkey, Italy and Belgium are importing liquefied natural gas (LNG) shipped on tankers. The main exporter to Europe is Algeria. LNG accounts for about 50% of the country's natural gas exports. France and Spain are the big LNG importers in Europe, with 31% and 29% respectively of the region's total LNG imports of 33.53-bil cubic meters (cu m), according to BP's and Cedigaz 2002 energy review[5]. LNG imports contributed to 7% of the region's total natural gas consumption in 2001, the review shows.

LNG imports to Europe will most likely increase by 2005, but opinions differ on how large this increase will be.

Although the demand for LNG is rising, the increase is slow and will continue to be so for at least the next few years, Michael Mollner, adviser at Eurogas, says. "As long as import needs can be fulfilled using existing pipelines, I don't think we will see a big increase in LNG imports to Europe in the short term." Graham Friedman, manager of European gas services at Dri-Wefa, is more optimistic. "The LNG demand will increase considerably by 2005," he says, estimating a 5% increase in natural gas imports from other markets than Russia and Algeria compared with 2003. Although not all of that will be LNG, a vast majority will be, he says. "We will probably see another 25-bil cu m of LNG coming into the market by 2005, mostly from Nigeria, Egypt, Trinidad and the Middle Eastern countries," Friedman says. Dri-Wefa also estimates that LNG imports will increase in the long-term. In a recently published report[6], Dri-Wefa says about 118-bil cu m, or 15%, of the region's demand will be met by non-traditional sources by 2025. The new supplies will be mainly LNG, the report says. The non-traditional exporters include countries like Iran, Libya, Trinidad &

[5] BP's and Cedigaz 2002 energy review.
[6] European Gas Supply and Demand: The Outlook to 2025, Dri-Wefa, 2002.

Tobago, Nigeria, Egypt and Qatar. It is also likely that a global LNG market will be created, as projects are being developed to supply both the US and Europe, Dri-Wefa says. "This ultimately means that European prices will be driven by the US benchmark price at Henry Hub, which in the past has generally been similar to the oil indexed gas price. We therefore believe that within a short space of time, natural gas will become a globally traded commodity," the report says.

Safety Provisions.

USA LNG Anti Terrorism Provision under 33 CFR Part 165

Liquefied Natural Gas (LNG) Tanker transits and allied operations at Phillips Petroleum LNG Pier, Cook Inlet, Alaska (AK) were the subject of anti-terrorism provisions that may typify the reaction of the LNG industry to the WTC attack of 9/11/2001.

There the Coast Guard has established 1000-yard radius security zones in the navigable waters around liquefied natural gas (LNG) tankers while they are moored and loading at Phillips Petroleum LNG Pier and while they are transiting outbound and inbound through the waters of Cook Inlet, Alaska between Phillips Petroleum LNG Pier and the Homer Pilot Station. These security zones temporarily close all navigable waters within a 1000-yard radius of the tankers. This action has been taken to protect the LNG tankers, the marine terminals, the nearby community of Nikiski and the maritime community against sabotage or subversive acts.

Design of Typical LNG Above-ground Storage Tank.

Figure 20 shows a typical above ground LNG storage tank. It is the Inchon-100,000 cubic meter LNG Storage Tank (TK-204/205/206).

Figure 20 Design of typical Above-ground LNG Storage Tank.

These tanks have a capacity of 100,000m³ with full Containment above ground.

DIMENSIONS

Inner Tank Diameter	:	68.0m
Outer Tank Diameter	:	70.0m

Height : 36.0m

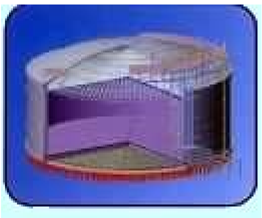
BASIC STRUCTURE

- Type : LNG Storage Tank with 9% Ni Steel
- Roof : Concrete Dome Roof with Steel Plate and Suspended Deck
- Primary Barrier : 9% Ni Steel
- Side Structure : Prestressed Concrete Wall
- Bottom Slab Structure : Elevated Type
- BOG Rate : Less than 0.075%/day[7]
- Max. Liquid Level : 29.94m

[7] The gas is kept liquid by allowing it to boil off. BOG is the percentage that boils off in a day.

Figure 21; TongYoung-140,000cubic meter LNG Aboveground Storage Tanks at the Anjung CCGT Power Station. (TK-201/202/203)

The Anjung power station in South Korea comprises six 450 MWe Combined Cycle Gas Turbine Generators.



DIMENSIONS

LNG (Liquefied Natural Gas) Tanks :

Inner Tank Diameter	:	84.0m
Outer Tank Diameter	:	86.0m
Height	:	34.4m

BASIC STRUCTURE

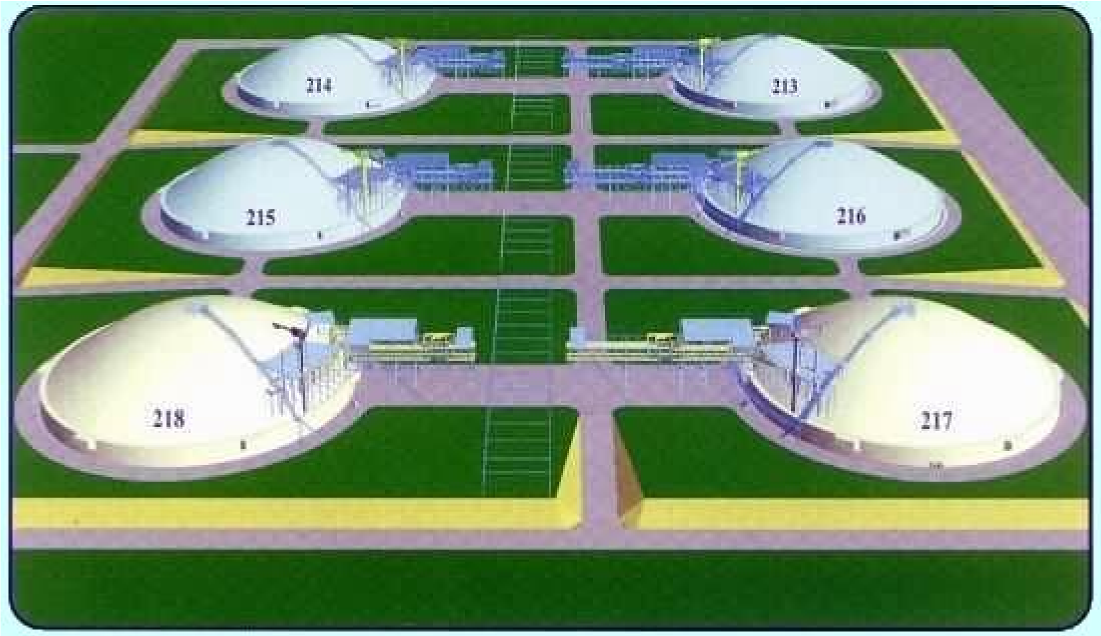
- Type : Aboveground LNG Storage Tank with 9% Ni Steel
- Roof : Concrete Dome Roof with Steel Plate and Suspended Deck
- Primary Barrier : 9% Ni Steel
- Side Structure : Prestressed Concrete Wall
- Bottom Structure : Brine Heating System

- BOG Rate : Less than 0.075%/day
- Max. Liquid Level : 27.68m

Design of Typical LNG In-ground Storage Tank.

Figure 22 shows typical in-ground LNG storage tanks. They clearly present less of a target for a diving jumbo jet than the above ground tanks, but the roof of a tank is not considered to be proof against the impact of the engine-shaft of an aircraft jet engine.

Figure 22; Inchon-200,000 cubic meter LNG Inground Storage Tank (TK-213~218)



DIMENSIONS

Inner Tank Diameter	:	72.0m
Outer Tank Diameter	:	78.6m
Height	:	53.0m

BASIC STRUCTURE

- Type : Inground LNG Storage Tank with membrane
- Roof : Concrete Dome Roof with Steel Plate and Suspended Deck
- Primary Barrier : Membrane (18-8 stainless steel 2.0mm)
- Bottom Slab Structure : Strong Bottom

- BOG Rate : Less than 0.1%/day
- Max. Liquid Level : 49.2m

Automated Systems that Help to Avoid LNG Accidents to Shipping.

LNG tankers currently being delivered have automated systems that are designed to help avoid LNG accidents by making operations less dependent of human beings. There are integrated bridge, radar-based cargo level measurement and custody transfer systems, providing automatic navigation and collision and grounding avoidance

LNG Accidents

The LNG industry has an almost accident-free record for the last 33-years.

Since 1970, there have been only sixteen LNG-related accidents world-wide;

Since 1980, there have been two LNG-related fatalities world-wide.

All prior accident-causes have been incorporated into existing regulatory standards.

Of only 20 LNG-vehicle accidents since 1971, none were fatal, only 6 released LNG, and only 3 resulted LNG-related fires.

LNG's flammability limits, ignition temperatures, vapour densities and explosive potentiality are less hazardous than that of propane and gasoline.

Before the storage of cryogenic liquids was fully understood there was a serious incident involving LNG in Cleveland, Ohio in 1944. This incident virtually stopped all development of the LNG industry for 20 years. The race to the Moon led to a much better understanding of cryogenics and cryogenic storage with the expanded use of liquid hydrogen (-423°F) and liquid oxygen (-296°F). LNG technology grew from NASA's advancement.

In addition to Cleveland, there have two other U.S. incidents sometimes attributed to LNG. Some parties have cited a construction accident on Staten Island in 1973 as an "LNG accident" because the construction crew was working inside an (empty, warm) LNG tank. In another case, the failure of an electrical seal on an LNG pump in 1979 permitted gas (not LNG) to enter an enclosed building. A spark of indeterminate origin caused the building to exploded. As a result of this incident, the electrical code has been revised for the design of electrical seals used with all flammable fluids

No BLEVE Events have been Produced with LNG.

In laboratory and open ocean combustion trials involving LNG there have been no reported cases of BLEVE. That is to say of Boiling Liquid Expanding Vapour Explosions. BLEVE s have occurred in accidents involving liquid petroleum products such a gasoline and Liquid Petroleum Gas, LPG.

No Cargo Explosions have Occurred with LNG.

Liquefied Natural Gas tankers have

- been run aground,
- experienced loss of containment,
- suffered weather damage,
- been subjected to low temperature embrittlement from cargo spillage,
- suffered engine room fires, and
- been involved in serious collisions with other vessels.

No cargo explosions have occurred as a result of these or any other events.
-
LNG history in the US dates back to 1940's; LNG tanker trade was initiated with exports in 1969.

Eight marine incidents have resulted in spillage of LNG - some hull damage due to cold fracture and no cargo fires.

Seven incidents not involving spillage have occurred, two from grounding. There was no significant cargo loss in these incidents.

Lloyds Register Report.

As an independent risk management organisation, Lloyd's Register has had extensive involvement in many post-September 11 LNG studies for ships and terminals. Within this scope of work, Lloyd's Register has examined the possible consequences of a terrorist attack on an LNG facility or ship, on surrounding communities and the general public. Many of the fears and misconceptions have been proven to be false, particularly the notions of huge explosions flattening cities, or freezing gas clouds engulfing whole communities. This solid understanding of the risks and personal exposure can be crucial to allaying the fears of terrorist attacks and in re-establishing confidence in a business venture.

From a review of marine incidents involving LNG carriers, the Lloyd's Register report concludes that there have been no recorded incidents of collision, grounding, fire, explosion or hull failure which have resulted in cargo spillage. Also, no fatalities have occurred, nor has there ever been damage to land-based property or the environment as a result of a LNG release from a vessel. Further, the report indicated that if a ship was attacked, the likely consequence would probably involve a fire, not an explosion.

The Lloyds Register Report draws from many sources, historical, experimental, and modelling. It concludes that, historically for all types of LNG accident, the inherent strength of LNG carrier-ships has prevented loss of containment.

However, a missile hit or explosion will provide a large number of ignition sources and there is then potential for escalating failure due to embrittlement - with subsequent explosion/fire. Ignition and sustained burn of a vaporized LNG cloud is difficult - multiple ignition sources would probably result in a burn back to the source probably result in a burn back to the source. Unconfined LNG vapour cloud detonation has not been demonstrated an is unlikely

External ignition (of vapur cloud) results in a slow moving flame. So-called Rapid Phase Transition will not cause ignition but it would be potentially damaging for ship/equipment. In terms of pool spread, the LFL for methane/air mixtures is ~5% so the LFL boundary is well within the visible cloud.

Modelling of dispersion cloud 3-6 km, it is concluded that dispersion on that scale is unlikely because of local ignition sources.

Exposure at 300 meters (1000ft) from a pool fire would cause pain within 60 seconds. The warming gas cloud will become lighter than air and rise. There will be no direct environmental damage or clean up from the primary spill.

A fire fed by single (25,000 m^3) cargo tank vented through a $1m^2$ hole would last 1hr - burn diameter 25 meters.

It is concluded that Risk scenarios do not produce results outside of those contemplated in previous EIS documentation for siting facilities and transportation of LNG.

Risk Analysis for LNG.

Risk analysis methods have been applied to LNG. In a study presented by Det Norske Veritas, Norway[8], the risk matrix approach combining the likelihood of an event with its consequences (severity) into a risk level for each scenario was adopted. The evaluation was carried out for seven consequence classes; crew, 3rd party personnel, environment, own property, down time, reputation and 3rd party assets. Qualitative likelihood and severity categories were established for each consequence class.

8 **Use Of Risk Analysis For Emergency Planning Of Lng Carriers.** Mr. Erik Skramstad, Det Norske Veritas, Norway; Mrs. Stine U. Musæus, Det Norske Veritas, Norway; Capt. Steingrim Melbø, Osprey Maritime, UK. March 2002.

A standard qualitative risk analysis approach was adopted comprising the following main
steps:

- Propose and agree a set of acceptance criteria forming a basis for the study
- Perform a hazard identification to systematically identify potential risks for different
- operational modes.
- Evaluate the likelihood of the different risks.
- Evaluate the impact of the different risks with respect to the different consequence categories.
- Categorise and rank the different hazards.
- Identify possible risk reducing measures that could be considered.

Hazard Identification.

The hazard identification was carried out as a work group session with DNV and Osprey (the client, a LNG shipping owner) personnel. The group included personnel with experience in risk analysis methodology, and familiarity with LNG ship design and operations. The "Hazid" was carried out as systematic review of all operations in all operational modes reviewing the different sections of the vessel, the operations and also external events.

Example of identified Hazards:

1. Structural failure to hull
2. Structural damage due to incorrect loading
3a Overfilling of tanks
3b Overpressure of tanks
4. Unignited leak in the cargo system
5. Release of Nitrogen
6. Release of bunker oil
7. Fire in engine room
8. Accommodation fire
9. Fire on open deck
10. Fire in cargo handling module
11. Fire in void spaces around LNG tanks
12. Fire in void spaces like ballasting tanks
13. Fire in forward storage area
14a Explosion in engine room due to fuel gas
14b Explosion in engine room due crank house failure
15. Boiler explosion
16. Explosion in accommodation
17. Explosion in open area on deck
18. Explosion in cargo handling module
19. Explosion in void spaces around tanks
20. Explosion in ballasting tanks
21. High wind/ waves
22. Earthquake- tsunami
23. Lightning
24. Sabotage
25. War action
26. Collision
27a Workplace accident
27b Crane operations
27c Working in tanks/ enclosed spaces

28. Operating error
29. Failure of mooring system due to tidal effect
30. Leak from loading arm
31. Loss of instrumentation during loading operation
32. ESD not functioning
33. Loss of power supplies
34. Loss of emergency powers
35. Loss of Nitrogen
36. Loss of hydraulic system-compressed air
37. Stowaway
38. Unignited leak from tank
39. Ignited leak from tank
40. Loss of navigational or manoeuvring capabilities
41. Grounding
42. Hitting the quay
43. Mooring failure/ anchor dragging
44. Man over board
45. Fire on bridge
46. Piracy/hijacking
47. Fire onboard neighbouring vessel
48. Illness or epidemics
49. Loss of stability
50. Gas freeing
51. Upstart after repair

Risk Assessment.

The identified hazards were categorised based on the likelihood and impact by the work group. The different hazards were considered for the following operational modes:

- Loading/ offloading at Terminal T (Terminal)
- Entering/ Leaving Port P (Port)
- Transit close to coast/ shore C (Coast)
- Transit in open sea S (Sea)
- Preparation for inspection/repair /recommissioning R

This review was carried out for all hazards, operational modes and all risk categories.

Examples of Incidents Identified and for which the Risk has been Assessed.

- Leak on the cargo system; unignited release continuous flow. This comprises all leak sizes that cannot easily be stopped by operational routines to a rupture in a pipe. Potential consequence is brittle fracture of hull or secondary structure.
- Release of liquid nitrogen. Can give local effects to steel due to low temperature. The loading operation is carried out simultaneously with the LNG operation. Less attention by the operators to nitrogen than LNG.
- Release of bunker oil during loading operation. Very low risk of fire and personnel injuries. The oil may mess up nearby quays. Environmental effect depends on the amount released and recipient in the terminal area.

- Fire in the engine room. Since always manned during this operational mode, the escalation potential is considered low. The event is considered not to effect 3rd party. All fires will have to be reported to terminal, thus local reputation is affected. The likelihood and corresponding consequences depend on the fire size. The results listed in the columns refer to a large fire. Minor fires are assessed to give one category lower, both for likelihood and consequences.
- Accommodation fires. The crew present in the accommodation most likely quickly extinguishes these fires. It is considered to be less likely to occur than fire in the engine room, but still a remote probability. If developing to a large fire more crewmembers may be affected by the accident, than for an engine room fire.
- Fires on open deck. Ignited cargo release. The consequences depend on the release size and the development of the event, including shut down. Early ignition gives smaller consequences than late ignition. Most likely there is a flash fire which burn back to a smaller fire at the release location (jet or diffusive, depending on pressure in the system and if the release hits obstructions or not). Whether the fire may escalate to the LNG tanks depend on the possibility to shut down fuel to the fire.

Since 4 operational modes and 7 consequence classes were considered for some 30 hazards (average for each operational mode) around 840 entries were considered in the different risk matrices.

The Events Constituting the Majority of the Risk.

Six events stands out in the respect they enter either into ALARP or unacceptable level for nearly all the consequence classes and operational modes. These are

- sabotage,
- war action,
- collision, A fire or explosion in the engine room has been assessed to give collision as a secondary effect when sailing in port or close to shore. This latter situation is considered unlikely.
- ignited release from a cargo tank
- overfilling during loading operation and
- structural damage to hull.

#

Cost of terrorist incidents

Terrorist activity is likely to be concentrated in areas where maximum destruction can be achieved, hence there can be no spread of risk, and the likely damage unquantifiable.

Examples of some of the most expensive terrorist incidents in terms of physical damage include:

Date	Country	Event	Insured Property Loss USD ($m)
11 Sept 01	USA	Attack on WTC and Pentagon	19,000
24 April 93	UK	Bomb attack on NatWest Tower	907
15 June 96	UK	Manchester City Centre	744
26 Feb 93	USA	Bomb in WTC Garage	725
10 April 92	UK	Bomb in St.Mary Axe,London	671

Changes to Insurance Policy cover.

World insurance markets have seen the curtailment of terrorism cover across most classes of risk which has impacted particularly hard on industries such as aviation causing a number of governments to step in to provide some terrorism cover. The US property market is the largest in the world and therefore US events have a disproportionate effect on the global insurance market.

The rules for terrorism insurance are altering for commercial Policies incepting or renewing on or after 1st January 2003. This is in accordance with market agreement and these rules apply - regardless of Insurer - in respect of material damage and business interruption:-

- There is now no ‘free’ cover.
- Policies will either have no cover for terrorism, or will have been extended to provide full cover to match the sums insured provided by the existing material damage and business interruption cover.
- Terrorism cover is not automatically provided. Each individual Policyholder must apply for, and be accepted for, and pay the additional premium due.
- The terrorism cover will be on an ‘All Risks’ basis, regardless of the scope of the main Policy and will include nuclear, chemical and biological radiation.
- Unlike previously, a separate Policy will not be issued. Cover will be added by Endorsement to the main Policy.

Traditionally US property insurance cover did not exclude terrorism cover from the ‘all risks’ wording, but insurers never rated, nor had the expertise to rate, the terrorism risk. This has resulted in the reticence to provide cover now.

In mainland Great Britain, terrorism fire and explosion cover was excluded from property and business interruption insurance contracts in December 1993 following terrorist attacks in the City of London. (Cover was withdrawn for Northern Ireland in 1975).

The UK government became reinsurer of last resort to a market mutual reinsurer called Pool Re, which was set up to guarantee the fire and explosion cover. Its voluntary membership comprises most of the recognised retail insurers and Lloyd's syndicates.

Terrorism exclusions have now been extended and applied to insurances of transportation e.g. transit static marine and motor and to liability insurances.

From the UK perspective the current situation is as follows:

Pool Re offers terrorism cover From 23/07/2002)

Pool Re does not directly govern or control the coverage provided in the primary insurance contracts; however, Pool Re's reinsurance contract provides coverage only against acts of terrorism as defined in the Reinsurance (Acts of Terrorism) Act 1993. The primary insurer is responsible for the first £100,000 (about $150,000) under each section of the policy (building, contents, business interruption, etc.), with Pool Re covering the excess up to the limits of primary coverage. As a consequence, the standard commercial property policy specifically excludes coverage for such defined acts of terrorism above the deductible and then restores coverage for them via a standard endorsement. The insured can purchase coverage under this endorsement for an earmarked additional premium. In effect, Pool Re provides an automatic facultative excess of loss cover with a retention of £100,000 per coverage section. On the excess, Pool Re provides 100% quota share coverage. Any insurer operating in Great Britain and offering commercial property insurance can become a member of Pool Re, whether an insurance company or a Lloyd's syndicate, and regardless of domicile. Insurers are not obliged to become members. However, the protection of government-backed reinsurance is available only to Pool Re and through Pool Re to its members. At the end of 1999, Pool Re had 213 members, including 32 Lloyd's syndicates, 104 insurance companies incorporated in the United Kingdom and 77 insurance companies incorporated in other EU countries, the United States, Australia, the Isle of Man or Guernsey. If an insurer chooses not to become a member of Pool Re, then it has three options if it wishes to write commercial property insurance.

- It may offer cover without protection against terrorism.
- It may try to find terrorism reinsurance cover in the private market.
- It may operate without reinsurance protection.

The definition in the Act is acts of persons acting on behalf of, or in connection with, any organization which carries out activities directed towards the overthrowing or influencing, by force or violence, of Her Majesty's government in the United Kingdom or any other government de jure or de facto. Insurers wishing to purchase reinsurance from Pool Re must enter into a membership agreement that governs their relationship with Pool Re. All terrorism coverage provided by members on eligible commercial property must be reinsured with Pool Re.

The primary policies subject to the reinsurance must have the standard terrorism exclusion, with terrorism coverage restored by the standard endorsement.

The primary insurer must charge a separate premium for the terrorism coverage on the policy based on Pool Re's rate manual, and 100% of the premium charged must be ceded to Pool Re. Pool Re sets its premium rates using normal commercial considerations, and uses risk factors of its own choosing - including the location of the insured property. Discounts are available if the insured engages in prescribed risk management programs. Pool Re reviews its premium rates on a regular basis with the assistance of independent consulting actuaries.

Pool Re's capital is its own, and is built up entirely from its accumulated profits. According to its annual returns to the Financial Services Authority, at the end of December 2000 the accumulated surplus amounted to £665 million. Pool Re may borrow, and the government guarantees any loans or other lines of credit, but it has never made use of this ability. Pool Re pays its claims using a combination of internal and external resources, arranged in layers.

First, accumulated underwriting profits since inception are used (this is the £665 million mentioned above).

If these are exhausted, Pool Re can call for an assessment on its members of up to 10% of their current-year ceded premiums.
I
If this is still insufficient, then Pool Re may draw on any investment income it has accumulated to pay claims.

Pool Re Extended to Cover Nuclear and Biological Warfare.

The UK Government scheme to insure businesses against terror attacks, Pool RE, was on July 23rd 2002 extended to include September 11-type attacks and nuclear and biological warfare. The current scheme was set up in 1993 to insure against the threat of IRA attacks after insurers began to shun the risks of cover. It only covered damage caused by fire and explosion but has now been widened in the wake of the September 11 attacks in America.

The Government said it would now cover destruction caused by biological contamination, the use of aircraft in attacks and damage by floods. From the start of 2003 it also gives insurance cover against nuclear contamination. Ruth Kelly, Financial Secretary to the Treasury, says: "These changes will provide more certainty for the insurance industry and its customers and put Pool Re on a more modern footing."

There is an option to backdate the policies to January 1 2002. From January 2003, premium rates now imposed by Pool Re have been doubled for the period covered to encourage competition in the insurance market.

The maximum amount that individual insurers can be liable for has also been capped to £30m per terrorist event and £60m a year. This will rise each year up to January 1 2006 up to £100m per event and £200m a year.

Pool Re is a mutual reinsurance company owned by most of the UK commercial insurers. The Treasury pays out for claims if the company's funds ever become exhausted. It stands behind Pool Re as the reinsurer of last resort, although the Government has not been called upon to step in during the lifetime of the scheme.

Employer's liability

Policy cover included up to a limit of £5m then total exclusions apply.

Public liability.

Total exclusions apply although some insurers are providing cover up to a limit of £5m for selected risks.

Motor

Total exclusions apply to property damage claims, although some insurers are providing a small limit of up to £250,000. Cover relating to personal injury claims is unaffected.

Marine Cargo

Institute Cargo Clauses already excluded acts of terrorism for which cover was then purchased through the Institute Strikes Clauses usually in conjunction with War risks. The situation on cover for 'property in transit' has not changed but for static risks, i.e. property in store or at exhibitions etc, the £100,000 limit will usually apply with terrorism above £100,000 excluded. Some insurers will give full cover for exhibitions and demonstration sites for an additional premium.

War Risk.

War and similar catastrophic risks have usually been excluded from insurance cover and the risk assumed by Governments. This is because the private insurance industry has a limited capital base and the potential losses will be too large for it to absorb for an economic premium. There have been no changes to this arrangement.

Summary.

The immediate market reaction to the terrorist activity at the World Trade Centre has been for terrorism cover to be curtailed or excluded completely. However, insurer reaction has been inconsistent, fragmented, and driven to a large extent by the attitude of their reinsurers. The market has since had time to evaluate the total cost of the event and make appropriate reserves. In this time the green shoots of new markets for terrorism cover, particularly for US risks, have emerged. The government backed reinsurer Pool Re has recently announced an extension to the one it provides. Whilst the threat of continued terrorist activity still exists, the market will be reluctant to expand its exposure for a risk which is statistically random, and potentially catastrophic.

Scenario: UK Obtains LNG From Algeria, through France.

In this Scenario the UK obtains supplies of LNG as regasified LNG from France. France obtains its LNG from Algeria, regasifies it and supplies gas through an inte-connector to the UK.

We consider the following elements contributing to unreliability of these supplies of regasified LNG to the UK:

Adequacy of Algeria's Reserves and R/P Ratio.

At the end of 2001, Algeria had 2.9% of the world's reserves of natural gas and R/P ratio of 57.8 Years. Its reserves rose from 3.30 trillion cubic meters at the end of 1991 to 4.52 trillion cubic meters at the end of 2001. So it can continue to supply France at or above the present rate until 2020.

Figure 23: Algeria's Gas Reserves and Ratio of Reserves to Production, R/P.

% of World Gas Reserves, 2001	R/P Ratio, Years at the 2001 rate of Production.	Natural Gas Reserves at the end of 1991. Trillion cubic meters.	Natural Gas Reserves at the end of 2001. Trillion cubic meters.
2.9%	57.8 years	3.30 tcm	4.52 tcm

Trade Movements.

In 2001 Algeria exported 35.54 billion cubic meters of LNG of which France took most: 9.80 cubic meters, or about a third. This 9.80 bcm was most of the 10.45 bcm that France imported, so by relying on France for its LNG, the UK would be relying almost entirely on Algeria. As France only takes one third of Algeria's exports of LNG, the UK could take as much as does France, if it displaced other customers for Algeria's LNG or if Algeria expanded its exports by one third, both of which are possible extremes. The UK would then become the joint largest user of LNG in the EU.

Figure 24: Trade Movements of LNG Between Algeria and France.

	France's Imports of LNG in 2001 from:	Rest of World's Imports of LNG in 2001 from:	Total
Algeria's Exports of LNG in 2001, to:	9.80 bcm	15.74 bcm	25.54 bcm
Rest of world's Exports of LNG in 2001, to:	0.65 bcm		
Total	10.45 bcm		

Bcm means Billion Cubic Meters.

Political Risks and Insurance Premiums for Algeria, France and the UK.

From worksheet "POLITICAL RISKS AND PREMIUMS" from the Workbook "LNG MASTER" the following values for Political Risks and Political Risk Insurance Premiums are taken, for Algeria, France and the UK:

Figure 25: Political Risks and Political Risk Insurance Premiums are taken, for Algeria, France and the UK.

	2002 Premium	2002 Political Risk.	2020 Premium	2020 Political Risk
Algeria	2%	53	2%	53
France	0.1%	20	0.1%	20
UK	0.1%	11	0.08%	8

Incidents that Could Interrupt the UK's LNG Supplies for this the "Algerian" Scenario.

In this section we consider, one by one, the incidents that could interrupt the UK supplies of regasified LNG from France, France having obtained the supplies of LNG, together with its own, from Algeria.

Political Interruption of LNG Supplies by Algeria.

Given the state of unrest in Algeria coupled with a history in which a million Algerians lost their lives fighting for independence from France, it is not difficult to imagine a scenario in which a future Algerian Government decides to stop exporting LNG to France to exert political point. This cessation would not be for a day or two in such a case: it could well last for a month or more. Again a heightened level of internal conflict, leading to intervention from France and perhaps other countries of the EU or the USA could interrupt LNG exports for some months.

To obtain an independent view of the likelihood of such interruptions, we turn to the values of Political Risk Index and Political Risk Insurance Premium shown in Figure 25. If we take the reasonable view that such politically-inspired interruptions of LNG exports will last for a significant part of a year, then the Political Risk Insurance Premium of 2% for Algeria implies a frequency of the order of 0.02 per year for such interruptions. If insurance was to be sought against such interruptions then the maximum insurable amount would be of the order of $\$10^5$. The loss of LNG to France would be total during a period of the order of 3 months, drawing the parallel with the periods during which analogous political problems have, historically disrupted supplies of oil from the Middle East. Supposing the UK's share to be the same as the amount of LNG imported by France for France's own consumption, from Algeria, the loss to the UK would be 0.027 billion cubic meters per day.

Figure 26: Risk Parameters for LNG Supplies for UK from Algeria to France.

Source of Interruption.	Days: Duration	Per Year: Likelihood	$ Maximum Insurable Amount	Loss, bcm/day
Political Risk in Algeria	90	0.02	100,000,000	0.026849

Political Interruption of UK's LNG Supplies, from Algeria, en Route through France.

Superficially it seems that there would be little political risk to the transit of UK LNG supplies through France, on their way to the UK from Algeria. Figure 25 shows that the political risk indices and premiums for France are low and likely to remain so until and beyond 2020.

However LNG is stored at the two terminals in France, described above, and should Algeria interrupt supplies for some months for political or other reasons then France will run-down these supplies so as to keep its power stations and factories operational. Indeed the stocks of LNG cannot be stored indefinitely since as we have shown in this Report, it is necessary to allow about 0.1% to evaporate every day in order to maintain the remainder of the LNG in the liquid state.

There is therefore a finite risk that when Algeria recommences supplying France with LNG, France will restock its LNG tanks whilst simultaneously supplying the requirements of her industry and domestic consumers, before she resumes the supply of regasified LNG to the UK.

It is sensible to assume that, if ***we*** can perform an analysis of the kind here presented, then France can too. The implication is that, if France does not already have storage for 90 days' supply of LNG then she will build additional storage tanks in the next few years. It follows that the UK can anticipate that there is a definite likelihood that, if Algeria on political or technical grounds halts its exports of LNG to France for 90 days, which we have argued has a frequency of 0.02/year, then France will not resume supplies of regasified LNG to the UK until it has restocked its own storage tanks, which will take as long again: another 90 days. Thus normally the amount in store does not change. If it takes 90 days to exhaust stocks then it will take 90 days to replenish them, therefore.

We guess that France would not always behave in this way, but that she would do so more frequently than once in one hundred times: in this way we arrive at a ***prior*** of 0.1 for the conditional frequency with which, if Algeria interrupted its LNG supplies to France for 90 days, France would not resume its supplies to the UK until another 90 days had elapsed: a total period of 180 days stoppage for UK LNG supplies, with a frequency of 0.1 x 0.02/year = 0.002/year.

Political Interruption in the UK of UK's LNG Supplies, from Algeria.

The UK, like France, has a low Political Risk Index. It costs little to insure Political Risks in the UK (Figure 25). Nevertheless, there have been protracted Miners' strikes in the UK. So supplies of coal from our own coalmines have been interrupted on what may loosely be termed political grounds on a number of occasions in the last fifty years. There was a one-year miners' strike in 1982, for example. There have also been attempts to blockade depots that store petrol, to prevent it from being delivered to filling stations. What action could disgruntled workers take to disrupt LNG supplies and why might this occur?

The design of the LNG system is such that, once the LNG has been regasified there is little that can be done to prevent its distribution through the national gas grid or other pipelines to specific power stations. It is only in France, therefore that industrial action could halt the unloading of LNG at the two terminals. This possibility exists, but it is a slender one and it is suggested that it does not add significantly to the component of risk due to re-stocking that we calculated above.

It is concluded that the political risk to LNG supplies within the UK is very low and is reflected in the Risk Indices and Insurance Premiums cited for the UK in Figure 25.

Interruption of LNG Tankers in Transit from Algeria to France.

Two tankers are needed to supply France with LNG from Algeria. Two would be needed to supply an equal amount of LNG to France for regasification and export to the UK. The calculations leading to this conclusion are on worksheet RESULTS in Workbook LNG MASTER. Two sources of interruption are considered: Political or Strike Action and Accidents.

Political or Strike Action by Ship Owners or Crew.

The Data Base summarized in the Annex to this Report: "LNG Incidents and Accidents that have occurred in the Period up to December 2002[9]" does not contain details of any such incidents. The overall safety record compiled by LNG ships during the thirty-nine year period 1964 - 2002 has been remarkably good. During this period, the LNG tank ship fleet has delivered more than 30,000 shiploads of LNG, and traveled more than 100 million kilometers while loaded (and a similar distance on ballast voyages). In all of these voyages and associated cargo transfer operations (loading/unloading), no fatality has ever been recorded for a member of any LNG ship's crew or member of the general public as a result of hazardous incidents in which the LNG was involved. In fact, there is no record of any fire occurring on the deck or in the cargo hold or cargo tanks of any operating LNG ship.

Accordingly we shall assign them a ***prior*** likelihood based on the assumption that "one will occur tomorrow". To arrive at a frequency we argue as follows: there are approximately 200 LNG tankers today and each could make the round trip from Algeria to France at least 20 times per year, making a total of 4,000 such trips per year. Of course they are engaged on other trips, for the most part, but those trips are equivalent to 4,000 round trips between Algeria and France. Fifty years ago the number of such equivalent round trips was virtually zero and so, on the assumption that the number of equivalent round trips per year has risen monotonically between 0 and 4000 in 50 years, the total number of round trips is of order 100,000. The same result is obtained when it is considered that the LNG tank ship fleet has traveled more than 100 million kilometers while loaded (and a similar distance on ballast voyages). The distance between Algeria and France being of order 1,000 km, it follows that the equivalent of 100,000 round trips has been covered.

The frequency with which Political or Strike Action by Ship Owners or Crew can be expected to cause interruption of supplies of LNG destined (after regasification in France) for the UK is then 1/100,000 trips and as 163 trips per year will be required to supply the UK's LNG this frequency is 0.00163/year. This would deprive the UK of gas for 3.125 days per round trip interrupted or 6.250 days if both ships participated in the incident. (worksheet RESULTS).

Tanker Accident.

The Data Base summarized in the Annex to this Report: "LNG Incidents and Accidents that have occurred in the Period up to December 2002[10]" contains 30 incidents and accidents to LNG tankers, at sea or in dock. These accidents resulted in the interruption of a trip and we shall assume that this interruption was the equivalent

[9] Material in this Annex has been obtained from Insurance Industry sources and from Lloyd's Register.

[10] Material in this Annex has been obtained from Insurance Industry sources and from Lloyd's Register.

to the cancellation of that trip. As each trip is part of a contract, save for those undertaken for the spot market, supplies will have been made up by additional trips and on-land storage will have usually served to even out the amounts of regasified LNG pumped into the customer-country's gas pipelines. However, this effect of storage is a separate issue, to be included separately as a distinct factor in the estimation of the UK's future of electricity supplies.

The frequency with which Tanker Accidents can be expected to cause interruption of supplies of LNG destined (after regasification in France) for the UK is then 30/100,000 trips and as 163 trips per year will be required to supply the UK's LNG this frequency is 0.049/year or once in twenty years. This would deprive the UK of gas for 3.125 days per round trip interrupted. (worksheet RESULTS).

Accidental Interruption of LNG Supplies from Algeria.

Algeria was the world's first LNG producer in 1964. As summarized in this Report, it now has four LNG plants owned by Sonatrach, the Algerian oil and gas company. Algeria was the second-largest exporter, behind Indonesia, in 2000 with 19% exported to Europe and the US. In 2001, Algeria was again the second-largest exporter, behind Indonesia, with 25.54 Bcm. Most of its exports were to Europe and the US. Algeria's liquefaction plants, two in Bethioua, one in Arzew and one in Skikda, produce 30.5 Bcm per year of LNG.

Increasing competition from Asia and competitive alternative energy prices have slowed Algeria's run as a leading LNG exporter. To reduce operating costs Sonatrach has completed refurbishments of its LNG facilities. The improvements will also keep its oldest facility in Arzew – now at 260 Mmcf/d – operating until 2003. It also has signed a memorandum of understanding with an Australian firm on a feasibility study for another LNG plant and terminal in the Arzew region.

The Annex to this Report entitled: LNG Incidents and Accidents that have occurred in the Period up to December 2002[11] lists shows that there have been four incidents in operating LNG facilities directly attributable to LNG that resulted in one or more fatalities –

- P. T. Badak (Bontang, Indonesia), 1983;
- Cove Point Maryland, 1979;
- Arzew, Algeria, 1977; and
- Cleveland, Ohio, 1944.

There were two other "LNG" incidents involving death:

- Portland 1968 and
- Staten Island 1973,

[11] Material in this Annex has been obtained from Insurance Industry sources and from Lloyd's Register.

but these last two correctly should be classified as construction accidents since no LNG was present. Appendix A gives a complete listing of the 15 significant land-based LNG facility incidents and accidents, which include the above six accidents. Examination of the information collected in this Report for these 15 accidents leads to the conclusion that fewer than 10 of them could have their counterparts at Algeria's liquefaction plants, two in Bethioua, one in Arzew and one in Skikda. Of these, the four incidents in operating LNG facilities directly attributable to LNG that resulted in one or more fatalities are identified as most likely to cause an interruption in the flow of LNG from a shore-base facility to a docked LNG tanker.

These interruptions will be longer than one day and shorter than 100 days: we shall assume that each interruption lasts an average of 10 days. This will interrupt the flow of LNG to all customers that are being supplied from that liquefaction plant for 10 days. It will not generally be possible to use the other three liquefaction plants to supply the tankers affected by this brief interruption to supplies from one of the liquefaction plants, although supplies will be made up during the course of the contracts. Effectively then the interruption is the equivalent of the loss of three tanker-trips.

The frequency with which Accidental Interruption of LNG Supplies from Algeria can be expected to cause interruption of supplies of LNG destined (after regasification in France) for the UK is then 4/100,000 trips and as 163 trips per year will be required to supply the UK's LNG this frequency is 0.00652/year or once in 150 years. This would deprive the UK of gas for 9.375 days per round trip interrupted. (worksheet RESULTS).

Accidental Interruption of LNG Supplies from Algeria in France.

As shown in this Report, further to the dismantling of the Le Havre terminal which, from 1965 to 1989, sent out half a billion cu.m of gas each year, Gaz de France now has two LNG terminals, one at Fos-sur-Mer and the other at Montoir-de-Bretagne:

Figure 27: The Two Gaz de France LNG Terminals

	Fos-sur-Mer	Montoir-de-Bretagne
Entry into service	1972	1982
LNG storage capacity	150,000 cu.m	360,000 cu.m
Annual gas send out capacity	above 4.5 billion cu.m	10 billion cu.m

Following a line of analysis similar to that for Algerian liquefaction plants, we deduce that The frequency with which Accidental Interruption at a French Terminal, of LNG Supplies from Algeria, can be expected to cause interruption of supplies of LNG destined (after regasification in France) for the UK is then 4/100,000 trips and as 163 trips per year will be required to supply the UK's LNG this frequency is 0.00652/year or once in 150 years. This would deprive the UK of gas for 9.375 days per round trip interrupted. (worksheet RESULTS).

Terrorist Interruption of LNG Supplies by Algeria.

Given the state of unrest in Algeria coupled with a history in which a million Algerians lost their lives fighting for independence from France, it is not difficult to imagine a scenario in which terrorists interrupt LNG exports.

In my work on terrorist attacks on nuclear plant I have successfully used two approaches. One of these involves an analysis based on the design basis of the plant and the other involves the use of scenarios. The two methods, although different in most respects from one another, gave similar results.

In the present case the most likely place for a terrorist attack on LNG supplies from Algeria through France to the UK is at one of the liquefaction plants in Algeria, since

- There are active terrorists in Algeria itself.
- It is at such a plant that the maximum damage will be produced, to
  - supplies;
  - supply-capacity,
  - property and
  - people
- A tank farm is a much bigger target than a tanker at sea, accessible to attack from
  - the land,
  - the sea or
  - from the air.

The contemporary design philosophy for installations of this type is the same, whether they are nuclear or LNG or some other hazardous plant. It embodies two main requirements:

1. The risk of death posed to the individual most-at-risk should be of the order of one in a million per year.
2. No single factor should contribute more than one tenth of this risk.

Such installations are designed against terrorism. The details of the provisions that are made are not accessible to the public, but in the case of the nuclear power station at Sizewell B in the UK I included such information in the Probabilistic Safety Analysis that I produced for the Public Inquiry that led to permission being given for the station to be built.

I made use of this knowledge, without divulging classified details, when I performed the analysis of terrorist risks for the UK's nuclear installations for the DTI in August 2002.

This same knowledge has informed my present analysis of the terrorist risk to LNG installations.

The designs of Modern LNG Terminals are international. They were designed so that terrorist attacks constituted no more than one tenth of the total risk presented by the installation. This met requirement 2, above. Since the terrorist attack on the WTC on September 11th 2001 the likelihood of terrorist attacks on what the Insurance industry sees as the prime targets for such attack is assessed to have increased by an order of magnitude. That is to say, terrorist attacks that had a design-frequency of n/10, where n is the frequency of all accidents, now have a frequency of n. The non-terrorist element has a frequency of 0.9n and so the total frequency rises from n to 1.9n.

The frequency with which Terrorist Interruption of LNG Supplies from Algeria can be expected to cause interruption of supplies of LNG destined (after regasification in France) for the UK is then 0.9 x 4/100,000 trips and as 163 trips per year will be required to supply the UK's LNG this frequency is 0.0059/year or once in 150 years. This would deprive the UK of gas for 180 days per event. The Terminal would probably be out of commission for more than 180 days, but the other three Algerian liquefaction plants would take over the work and would later be expanded. (worksheet RESULTS).

These conclusions receive support from the information on terrorism and its analysis presented in the body of the present Report.

Scenario: UK Obtains LNG From Qatar.

In this second scenario the case is considered where the UK receives imports of LNG from Qatar. From the information given in the body of this Report, this is judged equally likely with the case where the UK receives LNG from Algeria through France.

LNG from Qatar would dock at a modern Terminal, such as that planned for Milford Haven and described above.

Information in the Workbook shows that Qatar has adequate reserves to supply the UK with as much LNG as France imports: in that case the UK would, with France, be the biggest importer of LNG in the EU.

Political Risks.

From worksheet “POLITICAL RISKS AND PREMIUMS” from the Workbook “LNG MASTER” the following values for Political Risks and Political Risk Insurance Premiums are taken, for Qatar. For comparison, values for Algeria and the UK are given:

Figure 28: Political Risk Indices and Insurance Premiums for Qatar, with comparative values for UK and Algeria.

	2002 Premium	2002 Political Risk.	2020 Premium	2020 Political Risk
Qatar	0.60%	24	0.72%	37
Algeria	2%	53	2%	53
UK	0.10%	11	0.08%	8

Then following the methods used above for Algeria we have:

Figure 29: Political Risk Parameters for LNG Supplies for UK from Qatar to UK.

Source of Interruption.	Days: Duration	Per Year: Likelihood	$ Maximum Insurable Amount	Loss, bcm/day
Political Risk in Qatar	90	0.072	100,000,000	0.026849
Political Risk in UK: Qatar supplies.	90	0.0008	100,000,000	0.026849

Political or Strike Action by Ship Owners or Crew.

The journey from Qatar to the UK is approximately 2000 km each way. This is twice the distance used for trips from Algeria to the UK and accordingly, using the methods used above for Algeria, the values in worksheet RESULTS are obtained.
Similar, self-evident modifications to the Algeria analysis produce the remaining forecasts in that worksheet.

Summary Table for Results of Present Analysis.

The forecasts arrived at above have been tabulated in worksheet RESULTS and that Table is given below:

Figure 30: Summary Table of Results for LNG.

Source of Interruption.	Days: Duration	Per Year: Likelihood	$ Maximum Insurable Amount	Loss, bcm/day
Political Risk in France and Algeria	90	0.02	100,000,000	0.026849
Political Risk in Algeria	180	0.002	100,000,000	0.026849
Political Risk in UK: Algeria supplies.	90	0.0008	100,000,000	0.026849
Algeria Tanker Strike Action	10	0.002	100,000,000	0.026849
Algeria Tanker Accident	10	0.049	100,000,000	0.026849
Algeria Port Accident	10	0.0065	200,000,000	0.026849
French Port Accident	10	0.0065	200,000,000	0.026849
Algeria Port Terrorist Attack.	180	0.0059	10,000,000	0.026849
Political Risk in Qatar	90	0.072	100,000,000	0.026849
Political Risk in UK: Qatar supplies.	90	0.0008	100,000,000	0.026849
Qatar Tanker Strike Action	10	0.0032	100,000,000	0.026849
Qatar Tanker Accident	10	0.098	100000000	0.026849
Qatar Port Accident	10	0.0130	200,000,000	0.026849
UK Port Accident	10	0.0130	200,000,000	0.026849
UK Port Terrorist Attack.	180	0.0117	10,000,000	0.026849
Qatar Port Terrorist Attack.	180	0.0117	10,000,000	0.026849

Adequacy of the Interconnectors.

The gas industry has recommended that up to 3 more interconnections (fixed pipelines) with the Continent or the equivalent in LNG importation facilities – or, more likely, a combination of the two – will be needed in the next ten years.

There will also need to be considerable investment to extend and upgrade the National Transmission System (NTS).

These provisions will make the risk of interruption to regasified LNG from France a small risk compared with the other elements of that risk analysed in the present Report.

Annex: Catalogue of Disasters by Category

The following is a list of selected accidents involving hazardous substances, arranged by category. The list is not comprehensive, but it does provide compelling evidence for the need for effective disaster prevention and response planning. Please see below for information regarding the sources of data used in the list, and for the criteria of inclusion in the list.

Only one entry in this Table involved LNG: labelled # in the Table it occurred in downtown Seoul, South Korea, in 1994. It killed 7 people, injured 50 and involved the temporary evacuation of more than 10,000.

Origin of accident	Year	Date	Location	Products involved	Number of		
					Deaths	Injured	Evacuated
Accident at a peanut factory	1992	24.03	Senegal, Dakar	Ammonia	>40	>300	
Air release	1976	10.07	Italy, Seveso*	TCCD (Dioxine)	-	>200	730
Armament explosion	1980	16.11	Thailand, Bangkok	Explosives	54	353	-
Bulk cargo handling terminal	1997	00.01	India, Mumbai*	Sulphur			
Collision, explosion	1974	09.11	Japan, Tokyo Bay	Naphta	33	..	-
Construction in the subway	1995	28.04	Korea, Taegu	LPG	101	140	>10 000
Defective valve	1991	05.12	USA, Richmond	Emission of dust, soot		300	
Dense gas cloud	1990	22.03	Taiwan, Kaohsiung	Chlorine			540
Derailment	1992	30.06	USA, Duluth	Benzene		20	80 000
Derailment	1987	11.04	USA, Pittsburgh	Phosphorus oxychlorid.	-	14	16 000
Derailment and fire	1982	28.09	USA, Livingston*	Chemicals	-	-	3 000
Derailment of a cargo train	1994	08.03	Switzerland, Zürich*	Gasoline		7	120
Eruption at platform	1979	03.06	Mexico, Gulf*	Oil	-	-	-
Explosion	1979	05.07	USA, Memphis	Methylparathion	-	150	>2 000
Explosion	1991	31.01	Korea, Pyongyang	Dynamite	>120		

Origin of accident	Year	Date	Location	Products involved	Number of		
Explosion	1979	03.06	Thailand, Phangnaga	Oil	50	15	..
Explosion	1979	12.04	Pakistan, Rawalpindi	Fireworks	>30	100	..
Explosion	1988	11.12	Mexico, Mexico City	Fireworks	62	87	
Explosion	1992	08.08	Turkey, Corlu	Methane	32	64	
Explosion	1994	24.01	France, Noyelles-God.*	Zinc		9	
Explosion	1976	12	Colombia, Carthagene	Ammonia	30	30	..
Explosion	1992	20.06	Lebanon, Assawani	Explosives	30		
Explosion	1993	26.11	China, Shuangpai		61		
Explosion	1993	11.01	China, Baohe	Natural Gas	70		
Explosion	1991	24.09	Thailand, Bangkok	Gas	>63		
Explosion	1993	29.08	China, Nanshankou	Fireworks	27	2	
Explosion	1980	16.08	Japan, Shizuoka	Methane	15	222	-
Explosion	1978	07.07	Tunisia, Manouba	Ammonium nitrate	3	150	..
Explosion	1976	13.04	Finland, Lapua	Gunpowder	43	>70	..
Explosion	1982	11.12	USA, Taft	Acrolein	-	-	20 000
Explosion	1987	21.12	Egypt, Alexandria	Smoke bombs	8	142	>1 000
Explosion	1988	06.05	China, Liu Pan Shui	Coal gas	45	5	..
Explosion	1988	15.06	Italy, Genoa	Hydrogen	3	2	15 000
Explosion	1988	23.06	Mexico, Monterrey	Gasoline	4	15	10 000
Explosion	1988	31.11	Bangladesh, Chittagong	Flammable vapours	33	..	..
Explosion	1988	01.12	China	Gas	45	23	..
Explosion	1983	29.09	India, Dhulwari	Gasoline	41	>100	..
Explosion	1989	19.01	China, Henan	Fireworks	27	22	..
Explosion	1989	21.09	USSR, Yurga	Ammunition	1	3	20 000
Explosion	1991	04.05	Mexico, Cordoba	Parathion		300	1500
Explosion	1989	16.11	Pakistan, Garan Chash.	Ammunition	40	>20	..

Origin of accident	Year	Date	Location	Products involved	Number of		
Explosion	1979	01.11	USA, Gavleston Bay	Crude oil	32	..	..
Explosion	1990	05.07	USA, Channelview*	Chemicals			
Explosion	1990	22.07	Korea, Ulsan	Butane			>10000
Explosion	1980	29.11	Spain, Ortuella	Propane	51	90	-
Explosion	1991	14.02	Korea, Daesan*	Hydrogen gas		2	
Explosion	1991	04.05	Malaysia, Kuala Lumpur	Fireworks	41	61	
Explosion	1994	26.07	Korea, Inchon	1-hydroxy benzo triazol	6	39	>10 000
Explosion	1980	11.03	Africa	Crude oil	36	..	..
Explosion	1991	04.06	Ethiopia, Addis Ababa	Ammunition	100	200	
Explosion	1991	20.06	Bangladesh, Dhaka*	Ammonia gas	8	22	
Explosion	1989	23.01	USA, Pasadena	Ethylene	23	125	1 300
Explosion	1996	14.05	Yemen, Aden	Ammunition	38	>100	
Explosion	1975	14.12	USA, Niagara Falls	Chlorine	4	176	-
Explosion	1974	01.06	UK, Flixborough	Cyclohexane	28	104	3 000
Explosion	1973		Czechoslovakia	Gas	47	-	-
Explosion	1973	10.02	USA, Staten Island	Gas	40	2	..
Explosion	1971	26.06	Poland, Czechowice	Oil	33	..	..
Explosion	1971	03.02	USA, Woodbine	Magnesium	>25	61	..
Explosion	1970	17.12	Iran, Agha Jari	Natural gas	34	>1	..
Explosion (ammunition store)	1996	15.02	Afghanistan, Kabuhl	Ammunition	60	>125	
Explosion (chem. industry)	1992	28.07	USA, Westlake*	Ammonia		63	
Explosion (chemical factory)	1994	07.05	Taiwan, Kaohsiung*	Plastics	1		
Explosion (chemical plant)	1997	19.02	Russia, Khabarovsk	Chlorine	1	208	
Explosion (chemical plant)	1991	12.03	USA, Seadrift*	Ethylene oxide	1	20	
Explosion (chemical plant)	1996	20.02	Mexico, Mexico City	Mercaptan		>125	>100

Origin of accident	Year	Date	Location	Products involved	Number of		
Explosion (firework factory)	1991	12.07	India, Meenampalti	Fireworks	38		
Explosion (marine transport)	1979	15.11	Turkey, Istanbul	Crude oil	52	>2	-
Explosion (marine transport)	1979	08.01	Ireland Bantry Bay	Oil, gas	50	..	..
Explosion (petrochemicals)	1991	11.03	Mexico, Coatzacoaloas*	Chlorine	2	122	
Explosion (plant)	1976	10.12	USA, Baton Rouge	Chlorine	-	-	10 000
Explosion (rail transport)	1977	12.11	South Korea, Iri	Dynamite	57	1 300	-
Explosion (rail transport)	1974	21.09	USA, Houston	Butadiene	1	235	1 700
Explosion (rail transport)	1979	11.11	Canada, Mississauga	Chlorine, LPG	-	-	226 000
Explosion (rail transport)	1972	01.07	Mexico, Chihuahua	Butane	>8	800	..
Explosion (rail transport)	1972	22.01	USA, St. Louis	Propylene	-	230	>100
Explosion (rail transport)	1974	31.01	India, Allahabad	Fireworks	42	..	-
Explosion (rail transport)	1988	04.06	USSR, Arzamas	Explosives	73	230	90 000
Explosion (rail transport)	1988	04.01	USSR, Sverdlovsk	Explosives	5	1 020	-
Explosion (road transport)	1978	15.07	Mexico, Xilatopec	Gas	100	200	-
Explosion (storage tank)	1984	19.11	Mexico,St. J. Ixhuatepec	Gas (LPG)	>500	2 500	>200 000
Explosion (storage)	1994	04.01	India, Madhya-Pradesh	Fire crackers	30	100	
Explosion (storage)	1994	02.08	China, Guangix	Dynamite, explosives	73	99	
Explosion (storage)	1988	25.05	Mexico, Chihuahua	Oil	-	7	15 000
Explosion (storage)	1977	23.12	USA, Westwego	Corn dust	35	9	..
Explosion (storage)	1988	10.04	Pakistan, Islamabad	Explosives	>100	3 000	..

Origin of accident	Year	Date	Location	Products involved	Number of		
Explosion (transhipment)	1979	01.01	Greece, Suda Bay	Propane	7	140	-
Explosion (transport)	1983	05	Egypt, Nile River	LPG	317	44	-
Explosion (transport)	1988	22.04	Canada, at sea	Gasoline	29	-	-
Explosion (use/application)	1983	07.05	Turkey, Istanbul	-	42	50	..
Explosion (use/application)	1982	25.04	Italy, Todi	Gas	34	140	..
Explosion (warehouse)	1992	29.04	India, New Delhi	Chemicals	43	20	
Explosion after gas leakage	1991	10.12	Germany, Gelsenkirch.*	Refined products		8	
Explosion Ammunition	1997	03.07	Turkey, Kirikkale	Ammunitions, fireworks	1	1	<200000
Explosion and fire	1995	15.07	France, Annecy*	Chemicals		4	
Explosion and fire	1995	08.11	Jamaica, Kingston*	Chemicals			
Explosion and fire	1991	03.03	USA, Lake Charles*	Petroleum	3	12	
Explosion and fire	1990	09.04	USA, Warren*	Butane			
Explosion and fire	1993	06.04	Belgien, Machelen*	Solvents			>1000
Explosion at a chemical plant	1996	11.01	Russia, Toyatti*	Chemicals			
Explosion at a factory	1992	20.06	Libya, Al-Sanouani	Fireworks	17	143	
Explosion at a factory	1991	0.05	USA, Sterlington*	Nitromethane	>8	>123	500
Explosion at a factory	1996	29.06	China, Piya		36	52	
Explosion at a gas store	1992	23.02	Korea, Kwangju	LPG		16	20 000
Explosion at a plant	1995	03.11	Argentina, Rio Tercero	Munitions	13		>10 000
Explosion at a refinery	1991	13.04	USA, Sweeny*	Petroleum		2	
Explosion at a refinery	1994	24.07	UK, Pembroke*			26	

Origin of accident	Year	Date	Location	Products involved	Number of		
Explosion at a refinery	1990	03.11	USA, Chalmette*	Cloud of flammable gas			
Explosion at a storage	1996	31.01	China, Shaoyang	Explosives	125	400	
Explosion at a store	1997	04.07	Equador, Quito	Ammunitions	3	187	
Explosion at a store	1991	03.09	USA, Hamlet	Chemicals	25	41	
Explosion at a store	1995	16.07	Brazil, Boqueiro	Ammunition	100		
Explosion at a warehouse	1993	06.08	China, Shenzhen	Chemicals, gas	>12	168	
Explosion fire	1989	20.03	USSR, Ionava	Ammonia, NPK fertilizer	6	53	30 000
Explosion in a pipeline	1994	28.12	Venezuela		50	10	
Explosion in a silo	1976	23.02	USA, Houston	Grain dust	7	..	10 000
Explosion in a subway	1970	08.04	Japan, Osaka	Gas	79	425	
#Explosion in downtown	1994	07.12	Korea, Seoul	LNG, gas	7	50	>10 000
Explosion in refinery	1988	22.01	China, Shanghai	Petrochemicals	25	17	..
Explosion in the city sewers	1992	22.04	Mexico, Guadalajara*	Hydrocarbon oil, gas	>206	>1500	500
Explosion of the sewers	1993	28.09	Venezuela, Tejerias	Gas	53	35	
Explosion pipe	1984	12	Pakistan, Gahri Dhoda	Gas	60	..	-
Explosion pipeline	1989	04.06	USSR, Acha Ufa	Gas	575	623	..
Explosion, Fire	1993	26.06	China, Zhengzhou	Chemicals	27	32	
Explosion, fire	1988	05.05	USA, Henderson	Perchlorinat. ammonia	2	350	17 000
Explosion, Fire	1992	25.01	India, Tharia	Fireworks	>25	100	
Explosion, fire (platform)	1988	06.07	UK, North Sea	Oil, gas	167	-	-
Explosion, fire ball	1993	25.11	China, Dulin	Fireworks, Gun powder	26		
Factory	1984		Romania	Chemicals	100	100	..

Origin of accident	Year	Date	Location	Products involved	Number of		
Fire	1988	23.05	USA, Los Angeles	Chemicals	-	-	11 000
Fire	1993	07.01	South Korea, Chongju	LPG	27	50	
Fire	1972	06.04	USA, Doraville	Gasoline	2	161	..
Fire	1997	08.03	France, Annezin*	Plastics			
Fire	1984	30.01	Indonesia, Djakarta	Ammunition	>14	>200	10
Fire	1980	05.06	Malaysia, Port Kelang	Chemical products	3	200	>3 000
Fire	1988	23.08	Canada, St. B.-le-Grand*	PCB	-	-	3 800
Fire	1994	17.02	France, Ducey*	Polyurethane		7	
Fire	1990	09.01	UK, Gateshead	Molten Metal			10100
Fire	1990	26.07	Lebanon, Chtaura	Fuel Oil		45	
Fire	1983	03.11	India, Dhurabari	Oil	76	>60	-
Fire	1987	29.01	France, Nantes	Fertilizers	-	24	25 000
Fire	1985	26.02	USA, Coachella	Pesticides	-	236	2 000
Fire	1985	01.11	India, Padaval	Gasoline	>43	82	..
Fire	1979	20.07	Tobago, Caribbean Sea	Crude oil	26	..	..
Fire	1987	04.04	USA, Minot	Parathion	-	20	10 000
Fire	1987	24.03	USA, Nantichoke	Sulphuric acid	-	-	18 000
Fire	1995	24.07	France, Blotzheim*	Plastics		1	
Fire	1988	08.06	France, Tours	Chemicals	-	3	200 000
Fire (airport fuel storage)	1990	25.11	USA, Denver*	Kerosene			
Fire (car equipment factory)	1995	24.12	France, Dreux*	Trichloroethylene		3	
Fire (chemical factory)	1994	27.05	USA, Belpre*	Styrene	3		1000
Fire (meat industry)	1994	23.08	France, Balanod*	Chemicals (plastic foam)			
Fire (meat industry)	1997	02.11	France, St. Nicolas d.P.*	Plastics			
Fire (office technologies)	1991	15.06	France, Seclin*	Plastics			

Origin of accident	Year	Date	Location	Products involved	Number of		
Fire (rail transport)	1986	08.07	USA, Miamisburg	Phosphorus acid	-	400	40 000
Fire (road transport)	1994	04.11	Nigeria, Onitsha	Fuel oil	60		
Fire (storage)	1985	22.06	USA, Anaheim	Pesticides	-	12	10 000
Fire (textile industry)	1991	30.05	China, Dongguang*		71		
Fire (watch industry)	1995	10.09	Switzerland*	Lubricant			
Fire and Explosion	1993	24.08	France, Mirande*	Plastics			
Fire and explosion	1997	26.01	USA, Martinez*	Hydrocarbons	1	60	
Fire at a chemical store	1991	21.08	Australia, Melbourne*	Phenol, Acrylonitrile			>1 000
Fire at a chemical store	1994	13.11	India, New Delhi	Toxic cloud (chemicals)		500	
Fire at a dairy	1993	09.02	France,Cornille-L-Cav.*	Plastics			
Fire at a refinery	1991	03.11	USA, Beaumont*	Hydrocarbons			
Fire at a refinery	1991	12.01	USA, Port Arthur*	Petroleum			
Fire at a refinery	1990	30.11	Saudi Arabia, Ras Tan.*	Kerosene and benzene	1	2	
Fire at a store	1993	20.08	France, Limoges*	Plastics		2	
Fire at a textile factory	1995	14.05	France, Gerardmer*	Dyes		7	
Fire at sea	1987	05.12	Spain, La Corogne	Sodium	23	..	20 000
Fire in a doll factory	1993	19.11	China, Kuiyong		81	19	
Fire in a shoe factory	1997	20.09	China, Jin Jiang		32	4	
Fire in a textile factory	1994	17.06	China, Zhuhai		76	150	20 miss.
Fire in a toy factory	1993	10.05	Thailand, Bangkok	Plastics	240	547	
Fire in agrochemicals store	1996	06.08	France, Heilliecourt*	Sodium chlorate			

Origin of accident	Year	Date	Location	Products involved	Number of		
Fire in leather tannery	1984	10.05	USA, Peabody	Benzene	1	125	>100
Fire in office building	1981		USA, Binghampton*	PCB	-	-	-
Fire in refinery	1988	09.11	India, Bombay	Oil	35	16	..
Fire, explosion	1980	19.08	Iran, Deh-Bros Org	Dynamite	80	45	..
Fire, explosion	1973	29.08	Indonesia, Djakarta	Fireworks	52	24	>10
Fire, explosion	1983	31.08	Brazil, Pojuca	Gasoline	42	>100	>1 000
Fire, Explosion (printers)	1993	27.07	France, Evry*	Chemicals, paper			
Fire, explosion at refinery	1995	24.01	Indonesia, Cilapcap*	Gas			
Fire, explosion in a storage	1990	01.04	Australia, Sydney	BLEVE			10 000
Fire, gas cloud	1991	00.09	China, Shaxi	Pesticide	30	650	
Fire, gas cloud	1990	25.07	UK, Birmingham	Phosphene, hydrogen, chloride, methanol		>60	70050
Flash flood	1994	00.11	Egypt, Drowka,Durunka	Burning oil	>200		
Food poisoning	1990	15.04	India, Basti	Sulplios	150	>150	
Gas cloud	1995	24.01	USA, Bogalusa	Nitrogen Tetroxide		>400	<3000
Industry	1984	22.01	USA, Sauget	Phosph. trichloride	-	125	-
Industry	1975		India, Chasnala	-	431	..	..
Industry	1985	21.01	USA, Linden	Dimethoate	-	200	-
Leak in oil terminal	1986		USA, Northville*	Gasoline	-	-	-
Leakage	1985	15.08	USA, Institute	Aldicarboxime	-	430	3 100
Leakage	1977	070.1	USA, Michigan	Chlorine	-	>50	>13000
Leakage	1984	03.12	India, Bhopal*	Methyl isocyanate	2800	50 000	200 000
Leakage	1981	19.05	USA, Puerto Rico	Chlorine	-	200	1 500
Leakage	1974	27.12	Spain, Malaga	Chlorine	4	129	..
Leakage	1976	07.03	Mexico, Cuernavaca	Ammonia	2	500	2 000
Leakage	1982	22.12	USA, Vernon	Methylacrylate	-	355	-

Origin of accident	Year	Date	Location	Products involved	Number of		
Leakage	1977	19.06	Mexico, Pueble	Vinyl chloride	1	5	>10000
Leakage	1985	19.05	Italy, Priolo	Propylene	-	-	>20 000
Leakage	1989	05.05	India, Britannia Chowk	Chlorine	-	200	..
Leakage	1990	05.11	India, Nagothane*	Ethane and propane	32	22	
Leakage	1988	15.11	UK, West Bromwich	Nitric acid	-	22	50 000
Leakage	1988	22.12	India, Jhurkully	Sulphur dioxide	-	500	..
Leakage	1989	17.01	India, Bhatinda	Ammonia	-	500	..
Leakage	1995	15.07	Iran, Astara	Chlorine	3	200	
Leakage	1992	22.08	USA, Richmond	Nitric acid		130	
Leakage	1987	24.06	India, Bhopal	Ammonia			200 000
Leakage	1990	22.06	Korea, Ulsan	Acetic acid		36	>10000
Leakage	1987	14.04	USA, Salt Lake City	Trichlorethylene	1	6	30 000
Leakage	1994	30.03	France, Courbevoie*	Gas	1	59	
Leakage (chemical factory)	1991	30.05	France, Berre-L`Etang*	Ethylene		4	
Leakage (factory)	1985	03	Indonesia, Djakarta	Ammonia	-	130	-
Leakage (pipe)	1981	25.08	USA, San Francisco	Lubrif. Oil, PCB	-	-	30 000
Leakage (pipeline)	1986	25.12	Mexico, Cardenas	Gas	-	2	>20000
Leakage (rail transport)	1978	02	USA, Youngstown	Chlorine	8	138	..
Leakage (refinery)	1992	08.01	USA, Wilmington*	Hydrocarbon / hydrogen		16	
Leakage (refinery)	1992	09.11	France, Chateauneuf.L.*	Propane, butane, naphtha	6	1	
Leakage (road transport)	1981	23.07	USA, Blythe	Nitric acid	-	-	15 000
Leakage (storage)	1978	06	USA, Covington	Chlorine	-	240	-
Leakage (storage)	1984	03.09	USA, Omaha	Nitric acid	-	-	10 000
Leakage (storage)	1984		USA, Denver*	Gasoline	-	-	-
Leakage	1974	26.04	USA, Chicago	Silicium	1	300	2 000

Origin of accident	Year	Date	Location	Products involved	Number of		
(storage)				tetrachloride			
leakage (transport accident)	1997	21.01	India, Bhopal	Ammonia		400	
Leakage (transport)	1988	04.07	USSR, Chakhnounia	Pesticides	-	-	20 000
Leakage and explosion	1992	16.01	Japan, Sodegaura*	Hydrogen	10	7	
Leakage and fire	1993	02.08	USA, Baton Rouge*	Hydrocarbons			
Leakage from a pipeline	1991	00.12	India, Calcutta	Chlorine		200	
Leakage in a factory	1991	06.05	USA, Henderson*	Chlorine		55	15 000
Leakage in an Ice Factory	1990	00.07	India, Lucknow	Ammonia gas		200	
Leakage, explosion	1979	02	Poland, Warsaw	Gas	49	77	..
Leakage, explosion	1981	13.02	USA, Louisville*	Hexane	-	4	>100
Leakage, Explosion (pipeline)	1993	04.11	Vietnam, Nam Khe		39	62	
Leakage, fire	1988	17.06	USA, Springfield	Sodium hypochlorite	-	275	20 000
Leakage, platform fire	1984	16.08	Brazil, Rio de Janeiro	Gas	36	19	-
Leakage, transport accident	1990	16.04	India, near Patna	Gas	100	100	
Market	1991	00.01	India, Lhudiana	Fireworks	>40		
Misuse	1987		China, Shangsi	Fertilizers	-	1 500	30 000
Navigation	1979	25.12	USA, Kendrick Bay	-	30	..	..
Pipe explosion	1978	02.11	Mexico, Sanch. Magal.	Gas	41	32	..
Pipeline	1978	02.03	Canada, Ontario	LPG	-	-	20000
Pipeline explosion	1984	25.02	Brazil, Cubatao	Gasoline	89	..	2 500
Plant	1979		USSR, Novosibirsk	Chemicals	300	..	..
Plant	1978	03.08	Italy,	Ammonia	-	-	10000

Origin of accident	Year	Date	Location	Products involved	Number of		
			Manfredonia				
Plant explosion	1980	03.05	India, Mandir Asod	Explosives	50	..	-
Platform fire	1980		USA, Alaska	Oil	51	-	-
Poisoned medicine	1996	16.07	Haiti	Diethylene glycol	>60		
Polluted drinking water	1996	01.01	China, Guizhou	Chemicals		407	
Process failure	1972	30.03	Brazil, Duque de Caxias	LPG	39	51	..
Process failure	1987	30.01	USA, Texas City	Hydrofluoric acid	-	255	4 000
Process failure	1987	15.12	Mexico, Minatitlan	Acrylonitrile	-	>200	1 000`s
Process failure (Fertiliser)	1991	03.09	UK, Immingham	Toxic cloud of chemicals		127	
Process failure, fire	1988	23.09	Yugoslavia, Sibanik	Fertilisers	-	-	>60
Process failure, leakage	1988	03.09	USA, Los Angeles	Sodium hypochlorite	-	37	27 000
Rail transport	1980	03.04	USA, Sommerville	Trichloro phosphate	-	418	23 000
Rail transport	1974	19.07	USA, Decatur	Isobutane	7	349	-
Rail transport	1987	07.07	USSR, Annau	Chlorine	-	200	..
Rail transport	1981	04.08	Mexico, Montanas	Chlorine	28	1 000	5 000
Reactor explosion	1986	26.04	USSR, Chernobyl*	Nuclear	31	299	135 000
Reactor failure	1979	28.03	USA, Three Mile Island*	Nuclear	-	-	200000
Refinery fire	1997	14.09	India, Wishakhaptnam		34	31	150000
Release	1985	26.08	USA, South Charleston	Hydrogen chloride	-	135	-
Release	1993	22.02	Germany, Frankfurt*	o-Nitroanisol		1	
Release	1985	14.05	India, Cochin	Hexacyclo-pentadiene	-	200	..
Release	1993	04.08	Columbia, Remeios	Crude oil	430		
Release	1994	20.01	USA, Houston	Crude oil, fuel oil, gasoline		<70	12000
Release	1990	18.03	Korea, Daesan	Hydrogen sulfide		>100	>10 000

Origin of accident	Year	Date	Location	Products involved	Number of		
Release	1991	29.12	Mexico, San Luis Potosi	Butane		40	
Release	1993	26.07	USA, Richmond	Sulphuric acid		>6250	
Release	1981	01.06	USA, Geismar	Chlorine	-	125	..
Release	1990	29.05	USSR, Ufa	Phenol			400
Release	1991	10.08	Taiwan, Kaohsiung	Sulphur Dioxide		600	
Release	1985	04.12	India, New Delhi	Sulphuric acid	1	340	>10
Release	1989	05.01	USA, Los Angeles	Chlorine	-	-	11 000
Release (rail transport)	1996	11.04	USA, Alberton	Sodium, chlorine		140	<1000
Release (storage)	1988	02.01	USA, Floreffe*	Diesel oil	-	-	-
Release at a store	1992	23.01	Germany, Schkopau	Chlorine		186	
Release at factory forPVCs	1991	0501	Switzerland, Nyon	Chlorine			12 000
Release from a truck	1990	17.01	Germany, Ahlsfeld	Chlorine		>182	
Release near the sea	1974		Japan, Mitzushima*	Heavy oil	-	-	-
Release, Explosion	1993	01.11	Vietnam, Nam Khe	Petrol	47	48	
Release, gas cloud	1990	04.05	Cuba, Matanzas	Ammonia	3	374	> 1000
Road accident	1997	25.01	South Africa, Stanger	Petroleum	34	2	
Road accident, explosion	1998	24.01	China, Peking	Fireworks	40	100	
Road tanker accident	1996	19.07	Togo		40		
Road transport	1974	29.04	USA, Eagle Pass	LPG	17	34	-
Road transport	1976	11.05	USA, Houston	Ammonia	6	178	..
Road transport	1987	17.07	Germany, Herborn*	Gasoline	6	24	-
Road transport	1977	13.07	USA, Rockwood	Hydrogen bromide	1	30	>10000
Road transport	1986	19.09	UK, Hemel Hempstead	Lead oxide	-	150	-
Road transport	1976	03	USA, Deer Park	Ammonia	5	200	-
Road transport	1978	11.07	Spain, San	Propylene	216	200	-

Origin of accident	Year	Date	Location	Products involved	Number of		
			Carlos*				
Road transport	1981	21.08	USA, San Francisco	Silicon tetrachloride	-	28	7 000
Road transport	1985	13.04	Canada, Kenora*	PCB	-	-	-
Second release	1988	04.09	USA, Los Angeles	Sodium hypochlorite	-	7	20 000
Sewage plants	1985	16.07	USA, Cedar Rapids	Polyvenyl chloride	-	56	10 000
Ship collision	1980		Italy, Rome	Oil	25	26	-
Ship collision	1971	11.01	English Channel	Petrochemicals	29	..	..
Storage	1978	12.06	Japan, Sendai	Crude oil	21	350	..
Tank explosion	1982	19.12	Venezuela, Tacoa	Fuel oil	>153	500	40 000
Tank explosion	1983	10.01	Nicaragua, Corinto	Fuel oil	-	17	25 000
Tank overheat	1984	06.01	USA, Linden	Malathion	-	161	-
Tankfire	1970	24.01	Indonesia, Java	Kerosene	50	..	..
Transhipment	1974	30.04	Japan, Yokkaichi	Chlorine	-	521	-
Transhipment	1975	31.01	USA, Markus Hook	Crude oil, phenol	26	35	..
Transhipment	1985	26.05	Spain, Algeciras	Oil	33	37	..
Transport	1985	09	India, Tamil Nadu	Gasoline	60	..	..
Transport	1982	05.03	Australia, Melbourne	Butadiene	-	>1 000	-
Transport	1984	17.12	Mexico, Matamoros	Ammonia		182	3 000
Transport accident	1998	14.02	Cameroon, Yaoundi	Petroleum products	220	130	
Transport accident	1990	25.09	Thailand, Bangkok	LPG	>51	>54	
Transport accident	1991	21.05	Mexico, Mexico City	Hydrochloric		200	
Transport accident	1991	15.02	Thailand, Bangkok	Dynamite, detonators	171	100	
Transport accident	1991	10.04	Italy, Livorno	Naphtha	141		
Transport accident	1997	00.01	Pakistan, Lahore	Chlorine	32	900	1 000
Transport accident	1986		USA, Lynchburg*	Phosphorous oxychlor.		125	
Transport	1994	00.01	India, Thane	Chlorine gas	4	298	

Origin of accident	Year	Date	Location	Products involved	Number of		
accident			District				
Transport accident	1994	14.12	Mozambique, Palmeira	Gas	36		
Transport accident	1991	00.01	India, New Bombay	Ammonia gas	1	150	
Transport accident	1995	12.03	India, Madras	Fuel	~100	23	
Transport accident	1995	00.12	India, Maharashtra	Ammonia gas		2 000	
Transport accident (leakage)	1991	00.11	India, Medran	Inflammable liquid	93	25	
Use/application	1980	24.11	Turkey, Danaciobasi	Butane	107	..	..
Vapour cloud explosion	1997	22.06	USA, Deer Park*	Hydrocarbons		1	
Warehouse fire	1986	01.11	Switzerland, Basel*	Chemicals	-	-	-
Warehouse fire	1975	16.06	Germany, Heimstetten	Nitrogen oxid	-	-	10 000
Washing powder factory	1997	01.04	Salvador, Acajutla	Chlorine		400	>100
	1986		Italy, Naples	Petrol	5	150	2 000
	1987		China, Guangxi Prov.	Methyl alcohol	55	3 600	
	1985		India	Chlorine	1	150	-
	1977		Colombia, Pasacabalo	Ammonia	30	22	-

*** DISASTERS INVOLVING DAMAGE IN EXCESS OF $10 US TO THIRD PARTIES**

Information Sources

A List for the years 1970-1989 was originally compiled by the OECD and appeared in its 1991 publication "The State of the Environment". This has been extended to cover the years 1990-2002. We thank the OECD and the individuals and organisations which provided the information, particularly the Bureau d'Analyses des Risques et des Pollutions Industrielles (BARPI) of the French Ministry of the Environment.
A number of individuals and organisations reviewed the draft revised "List" and supplied comments and corrections. We are particularly grateful to staff of the

UKAEA's MHIDAS database for their extensive input at this stage. The information for 1990-1998 has been amended accordingly; in particular, some cases for which we have only disputed data have been removed altogether. It should also be noted in general that there are minor discrepancies for the whole 1970- 1998 period between different major accident databases around the world.

Source: OECD, MHIDAS, TNO, SEI, UBA-Handbuch Stoerfaelle, SIGMA, Press Reports, UNEP, BARPI.

Inclusion Criteria

25 deaths or more; or
125 injured or more;
10000 evacuated or more; or
10 thousand people or more deprived of water;
Please note that the following are excluded from the list: oil spills at sea from ships; mining accidents; voluntary destruction of ships or aeroplanes; damage caused by defective products.

Annex: USA.FEDERAL TERRORISM INSURANCE LEGISLATION: QUESTIONS AND ANSWERS

Q. What does the program do?

A. The Terrorism Risk Insurance Act of 2002 would provide a federal government insurance backstop in the event of an act of international terrorism. An act, as determined by the Secretary of Treasury, would have result in $5 million or more in damages.

Q. How does it work?

A. The program would pay 90 percent of an insurer's primary property-casualty losses after an annual deductible is met.

Q. How is the deductible determined?

A. Each insurer's annual deductible is determined by comparing its covered losses in that year to its 'direct earned premium' for covered lines in the prior year. For this year, it would be up to 1 percent of the prior year's premium. In 2003, it will be 7 percent of the prior year's premium. In 2004, it will be 10 percent of the year's premium. In 2005, it will be 15 percent of the year's premium.

Q. What does 'direct earned premium' mean?
A. It is the total premium divided by the length of the policy.

Q. The bill provides for surcharges. What are those?

A. Surcharges are levies on policyholders to recover federal assistance for terrorism losses. They apply if an insurer taps the backstop when industry aggregate losses are below $10 billion in the first year of the program, $12.5 billion in the second year and $15 billion in the third year. Then, the surcharge would be collected.

Q. Why those numbers?

A. Those are the figures selected by Congress. They do not refer to any specific event or data from any event.

Q. How will surcharges be collected?

A. The bill gives the Treasury Department the discretion to determine the method and manner of the surcharges. It is likely that the Department will issue regulations or procedures to deal with this issue.

Q. Will policyholders who reject terrorism insurance be surcharged?
A. Every covered policy will be surcharged if the surcharge applies.

Q. What if an insurer has reinsurance … will they still get money from the backstop in the event of an attack?

A. The bill specifically prohibits the reduction of financial assistance based on an insurer's reinsurance arrangements, provided that the federal assistance plus anything recovered through reinsurance does not exceed the insurer's losses during a year.

Q. How does the bill define an act of terrorism?

A. The bill limits the acts to "international terrorism," defined as an act "committed on behalf of any foreign person or foreign interest where the damage from the event is in excess of $5 million and the event was not committed in the course of a war declared by the United States." The certification of an act of terrorism by the Secretary of the Treasury is <u>*not*</u> *open to judicial review.*

Q: The bill says insurers must make terrorism insurance coverage available. What does that mean?

A. It means insurers must have terrorism coverage available for purchase to the extent than a policy would cover that same type of loss if it came from a non-terrorist event.

Q. What does the law say about nuclear, biological and chemical attacks?

A. The legislation requires that insurers make available terrorism coverage "that does not differ materially from the terms, amounts, and other coverage limitations applicable to losses arising from events other than acts of terrorism." Nuclear events have typically not been covered in standard policies.

Q. How does the bill deal with state regulatory powers on pricing of terrorism insurance?

A. The bill places administrative responsibility with the U.S. Treasury Department. In the first year, the bill says rates and forms are not subject to the prior approval of a state, nor can waiting periods be applied. But after the first year, states that have prior approval authority would be allowed to review forms after they are filed, to make sure the forms appropriately and adequately disclose the terrorism pricing. States retain their ability to invalidate a rate judged "excessive, inadequate or unfairly discriminatory."

Q. What happens to the state-adopted terrorism insurance exclusions on policies since Sept. 11, 2001?

A. The bill nullifies those exclusions for acts of international terrorism. The exclusions can be reinstated if the policyholder declines the coverage or does not pay the premium.

Q. What will be the standard for punitive damages in the event of a lawsuit?

A. The bill does not establish a standard, instead, it refers to state law.

Q. Can the backstop money be used to pay for punitive damages?
A. No

Annex: LNG Incidents and Accidents that have occurred in the Period up to December 2002[12].

Introduction.

LNG has been safely handled for many years. The industry is not without its incidents and accidents, but it maintains an enviable "modern-day" safety record[13]. The process of natural gas liquefaction, storage and vaporization is not a new technology. Earliest patents involving cryogenic liquids date back into the mid-1800s. The first patent directly for LNG was awarded in 1914. In 1939, the first commercial LNG peak-shaving plant was built in West Virginia. There are over 120 peakshaving and LNG storage facilities2 worldwide, some operating since the mid 1960s[14]. In addition, there are over 20 base-load liquefaction (LNG export) facilities in Abu Dhabi, Alaska, Algeria, Australia, Indonesia, Qatar, Libya, Malaysia, Nigeria, Trinidad and Borneo. LNG is transported by a fleet of over 130 LNG tankers of varying sizes from 18,500 M3 (cubic meter) to 140,000 M3. This fleet of LNG ships delivers to receiving terminals in the Belgium, France, Greece, Italy, Japan, Korea, Puerto Rico, Spain, Taiwan, Turkey, and the U.S.

The LNG storage tanks at these facilities are constructed of an interior cryogenic wall, usually made of 9% nickel steel, aluminum or other cryogenic alloy. The outside wall is usually made of carbon steel. A thick layer of an insulating material such as Perlite separates the two walls. For land-based facilities, an earthen or concrete spill containment having a minimum capacity exceeding the capacity of the LNG tank(s) surrounds the LNG tank(s). In some applications a tall concrete wall having an internal diameter slightly greater than the outside wall of the LNG tank, is used to double the integrity of the LNG tank. In others, the tanks are buried below ground level. In both cases, the objective is to minimize the area of contact between the LNG and the dike based on a *catastrophic tank failure* scenario. Many tanks are equipped with top tank penetrations only, i.e., no bottom penetrations; thus, even in the event of an unlikely piping failure tank contents remain in place[15].

With a few exceptions, LNG handling facilities have revealed an exceptionally superior safety record when compared to refineries and other petrochemical plants. With the exception of the 1944 "Cleveland Disaster", all LNG-related injuries and/or

[12] Material in this Annex has been obtained from Insurance Industry sources and from Lloyd's Register.

[13] *Modern Day* – Post mid-1950s - Cryogenic technologies came of age during the late 1950s and early 1960s with the development of the U.S. space program where cryogenic fuels such as liquid hydrogen and liquid oxygen had to be routinely and safely handled.

[14] This does not include dozens of small LNG vehicle fueling stations and industrial LNG fuel facilities.

[15] There has never been a *catastrophic tank failure* with any LNG, or similarly designed, storage tank

fatalities, however devastating, have been limited to plant or contractor personnel. There have been no LNG shipboard deaths. Small LNG vapor releases and minor fires have also been reported, but impact was limited to the plant and plant personnel promptly handled the hazard. Other accidents have occurred during the construction and repair of LNG facilities. Some of these accidents have been used to tarnish the exceptional safety record of LNG, but as no LNG was directly involved in the incident these accidents can only truly be called “construction” accidents. Damage has always been limited to the plant proper. The following three sections discuss land-based and LNG ship transport incidents respectively. Each section references an appendix listing the various incidents.

Land-Based LNG Facilities.

The first commercial facility for producing or utilizing LNG was a peakshaving plant that began operations in 1941 in Cleveland, Ohio. (A peakshaving plant liquefies natural gas when customer demand for gas is low and then vaporizes the LNG when demand is high, thus handling periods of peak demand that cannot be met by existing gas pipelines.) Since then, more than 150 other peakshaving plants have been constructed worldwide (approximately one-half of these are satellite facilities that have no liquefaction capability). In addition, 11 large natural gas liquefaction facilities (export terminals) and about 30 large LNG import terminals have been constructed.

There have been four incidents in operating LNG facilities directly attributable to LNG that resulted in one or more fatalities - P. T. Badak (Bontang, Indonesia), 1983; Cove Point Maryland, 1979; Arzew, Algeria, 1977; and Cleveland, Ohio, 1944. There were two other “LNG” incidents (Portland 1968 and Staten Island 1973) involving death, but these correctly should be classified as construction accidents since no LNG was present. See Appendix A for complete listing of land-based LNG facility incidents.

The accident at East Ohio Gas Company’s peakshaving plant in Cleveland, Ohio, is the only incident that involved injuries or fatalities to persons not employed by the LNG facility or by one of its contractors. This accident is often used as an example of the danger or risk involved in the LNG industry. However, the industry has changed dramatically since 1944. Modern LNG plants are designed and constructed in accordance with strict codes and standards that would not have been met by the Cleveland plant. For example, the use of 3.5% nickel steel for the inner vessel of an LNG storage tank is now forbidden, and each LNG tank must now be located within a dike capable of containing at least 100% of the tank’s capacity.

It should be noted that Appendix A is not intended to be a comprehensive listing of potentially hazardous incidents that have occurred in land-based LNG facilities; it is limited to accidents in which one or more persons were killed or seriously injured. Several other potentially hazardous incidents have occurred in LNG facilities without causing any injuries or fatalities. For example, the outer roofs or domes of a few conventional double-wall LNG tanks have suffered small cracks as a result of low temperature embrittlement initiated by leaks of LNG from over-the-top piping. These cracks allowed LNG vapor (i.e., natural gas) to escape from the tanks. In each case, the tanks were safely repaired without being taken out of service. Similarly, the inner tanks of several conventional LNG storage tanks (i.e., cryogenic metal inner tank and carbon steel outer tank) have been cracked as a result of frost heave brought on by inadequate or inoperative below-tank heaters. These tanks have been safely entered, repaired, and put back into service.

LNG Ships.

The first transportation of LNG by ship took place early in 1959 when the *Methane Pioneer* (an ex-Liberty ship that had been extensively modified) carried 5,000 cubic meters of LNG from Lake Charles, Louisiana, to Canvey Island, near London, England. Commercial transportation of LNG by ship began in 1964 when LNG was transported from Arzew, Algeria to Canvey Island in two purpose-built ships—the *Methane Princess* and the *Methane Progress*.

The overall safety record compiled by LNG ships during the thirty-nine year period 1964 - 2002 has been remarkably good. During this period, the LNG tank ship fleet has delivered more than 30,000 shiploads of LNG, and traveled more than 100 million kilometers while loaded (and a similar distance on ballast voyages). In all of these voyages and associated cargo transfer operations (loading/unloading), no fatality has ever been recorded for a member of any LNG ship's crew or member of the general public as a result of hazardous incidents in which the LNG was involved. In fact, there is no record of any fire occurring on the deck or in the cargo hold or cargo tanks of any operating LNG ship.

Among LNG import and export terminal personnel, only one death can be even remotely linked to the loading or unloading of LNG ships. (In 1977, a worker in the LNG export terminal at Arzew was killed during a ship-loading operation when a large-diameter valve ruptured and the worker was sprayed with LNG. His death was the result of contact with the very cold LNG liquid; the spilled LNG did not ignite. See Item 6 in Appendix A.) Appendix B summarizes the historical record of LNG ship incidents. Although a major effort was made to ensure the record presented is complete, it is possible that some incidents have been missed. However, it is very unlikely that a major incident has been omitted.

Lloyd's List.

Firstly, nearly every shipping incident that results in an insurance claim will be published in ***"Lloyd's List."*** Secondly, even if the ship owners are self-insured, news of major incidents travels quickly through the LNG industry because it is composed of a relatively small number of ship and terminal operators that often share experiences through industry associations such as SIGTTO (the Society of International Gas Tanker and Terminal Operators).

Also included at the end of Appendix B is a description of a marine incident involving a liquid petroleum gas (LPG) tanker which is of similar design to many LNG ships.

The incident provides some insight into the integrity of the product storage systems on these ships

APPENDIX A ***Chronological Summary of Incidents Involving Land-Based LNG Facilities***

1. **October, 1944 Cleveland, Ohio, USA ~ "*The Cleveland Disaster*"**

LNG Peakshaving Facility

The East Ohio Gas Company built the first "commercial" LNG peakshaving facility in Cleveland in 1941. The facility was run without incident until 1944, when a larger new tank was added. As stainless steel alloys were scarce because of World War II, the new tank was built with a low-nickel content (3.5%). Shortly after going into service, the tank failed. LNG spilled into the street and storm sewer system.

The resultant fire killed 128 people, setting back the embryonic LNG industry substantially. The following information is extracted from the U.S. Bureau of Mines repor[16] on the incident:

On October 20, 1944, the tanks had been filled to capacity in readiness for the coming winter months. About 2:15 PM, the cylindrical tank suddenly failed releasing all of its contents into the nearby streets and sewers of Cleveland. The cloud promptly ignited and a fire ensued which engulfed the nearby tanks, residences and commercial establishments. After about 20 minutes, when the initial fire had nearly died down, the sphere nearest to the cylindrical tank toppled over and released its contents. 9,400 gallons of LNG immediately evaporated and ignited. In all, 128 people were killed and 225 injured. The area directly involved was about three-quarters of a square mile (475 acres) of which an area of about 30 acres was completely devastated. The Bureau of Mines investigation showed that the accident was due to the low temperature embrittlement of the inner shell of the cylindrical tank. The inner tank was made of 3.5% nickel steel, a material now known to be susceptible to brittle fracture at LNG storage temperature (minus 260°F). In addition, the tanks were located close to a heavily traveled railroad station and a bombshell stamping plant. Excessive vibration from the railroad engines and stamping presses probably accelerated crack propagation in the inner shell. Once the inner shell ruptured, the outer carbon steel wall would have easily fractured upon contact with LNG. The accident was aggravated by the absence of adequate diking around the tanks, and the proximity of the facility to the residential area. The cause of the second release from the spherical tank was the fact that the legs of the sphere were not insulated against fire so that they eventually buckled after being exposed to direct flame contact. Further, it should be noted that the ignition of the two unconfined vapor clouds of LNG in Cleveland did not result in explosions. There was no evidence of any explosion overpressures after the ignition of the spill from either the cylindrical tank or the sphere. The only explosions that took place in Cleveland were limited to the sewers where LNG ran and vaporized before the vapor-air mixture ignited in a relatively confined volume. The U.S. Bureau of Mines, concludes that the concept of liquefying and storing LNG was valid if "proper precautions are observed."

The Cleveland Disaster put an end to any further LNG development in the United States for many years. It was not until the early sixties that LNG began to

[16] *"Report on the Investigation of the Fire at the Liquefaction, Storage, and Regasification Plant of the East Ohio Gas Co., Cleveland, Ohio, October 20, 1944,"* U.S. Bureau of Mines, February, 1946.

be taken seriously through construction of LNG peakshaving facilities. A number of elements came together to bring LNG back; these included:

- The advent of the space program and its associated cryogenic technologies
- Successful large-scale fire and vapor cloud dispersion demonstrations
- Extensive cryogenic material compatibility studies
- Construction and operation of liquefaction plants in Algeria and receiving terminals in France and England.

2. May, 1965 Canvey Island, Essex, United Kingdom

LNG Import Terminal

A small amount of LNG spilled from a tank during maintenance. The spill ignited and one worker was seriously burned. No other details have been made available.

3. March, 1968 Portland, Oregon, USA

LNG Peakshaving Facility –

Construction Accident, no LNG present Four workers inside an unfinished LNG storage tank were killed when natural gas from a pipeline being pressure tested inadvertently entered the tank as a result of improper isolation, and then ignited causing an explosion. The LNG tank was 120 feet in diameter with a 100-foot shell height and a capacity of 176,000 barrels and damaged beyond repair. Neither the tank nor the process facility had been commissioned at the time the accident occurred. The LNG tank involved in this accident had never been commissioned; thus, it had never contained any LNG.

4. 1971 La Spezia, Italy

LNG Import Terminal **–** *First documented LNG Rollover incident:*

The LNG carrier *Esso Brega* had been in the harbor for about a month before unloading its load of "heavy" LNG into the storage tank. Eighteen hours after the tank was filled, the tank developed a sudden increase in pressure causing LNG vapor to discharge from the tank safety valves and vents over a period of a few hours. The roof of the tank was also slightly damaged. It is estimated that about 100 mmscf of LNG vapor flowed out of the tank. No ignition took place. This accident was caused by a phenomenon called "rollover," where two layers of LNG having different densities and heat content are allowed to form. The sudden mixing of these two layers results in the release of large volumes of vapor.

5. January, 1972 Montreal, Canada

LNG Peakshaving Facility - *Although an LNG facility, LNG was not involved*

On January 27, 1972 an explosion occurred in the LNG liquefaction and peak shaving plant of Gaz Métropolitain in Montreal East, Quebec. The accident occurred in the control room due to a back flow of natural gas from the compressor to the nitrogen line. Nitrogen was supplied to the recycle compressor as a seal gas during defrosting operations. The valves on the nitrogen line that were kept open during defrosting operation were not closed after completing the operation. This resulted in the over-pressurization of the compressor with up to 250 - 350 psig of natural gas. Natural gas entered the nitrogen header, which was at 75 psig. The pneumatically controlled instruments were being operated with nitrogen due to the failure of the instrument-air compressor. The instruments vented their contents into the atmosphere at the control panel. Natural gas entered the control room through the nitrogen header and accumulated in the control room, where operators were allowed to smoke. The explosion occurred while an operator was trying to light a cigarette.

6. **February, 1973 Staten Island, New York, USA** LNG Peakshaving Facility - *Construction Accident, no LNG present*

One of Texas Eastern Transmission Corporation's (TETCO) LNG storage tanks on Staten Island had been in service for over three years when it was taken out of service for internal repairs. The tank was warmed, purged of the remaining combustible gases with inert nitrogen, and then filled with fresh recirculating air. A construction crew entered the tank to begin repair work in April of 1972. Ten months later, in February of 1973, an unknown cause ignited the Mylar liner and polyurethane foam insulation inside the tank. Initial standard operating procedures called for the use of explosion-proof equipment within the tank, however nonexplosion proof irons and vacuum cleaners were being used for sealing the liner and cleaning insulation debris. It is assumed that an electrical spark in one of the irons or vacuum cleaners ignited the Mylar liner. The rapid rise in temperature caused a corresponding raise in pressure. The pressure increase lifted the tank's concrete dome. The dome then collapsed killing the 37 construction workers inside.

7. **March, 1977 Arzew, Algeria** LNG Export Terminal

A worker at the CAMEL plant was frozen to death when he was sprayed with LNG, which was escaping from a ruptured valve body on top of an in-ground storage tank. Approximately 1,500 to 2,000 m^3 of LNG were released, but the resulting vapor cloud did not ignite. The valve body that ruptured was constructed of cast aluminum. The current practice is to fabricate large valves in LNG service with stainless steel.

8. **March, 1978 Das Island, United Arab Emirates** LNG Export Terminal

A bottom pipe connection of an LNG tank failed resulting in an LNG spill inside the LNG tank containment. The liquid flow was stopped by closing the internal valve designed for just such service. A large vapor cloud resulted and dissipated without ignition. No injuries or fatalities were reported.

9. **October, 1979 Cove Point, Maryland, USA** LNG Import Terminal

The Cove Point LNG Receiving Terminal in Maryland began operations in the spring of 1978. By the fall of 1979, Cove Point had unloaded over 80 LNG ships. In 1979, a tragic accident occurred at Cove Point that took the life of one operator and seriously burned another. Around 3:00 AM on October 6, 1979, an explosion occurred within an electrical substation at Cove Point. LNG had leaked through an inadequately tightened LNG pump electrical penetration seal, vaporized, passed through 200 feet of underground electrical conduit, and entered the substation. Since natural gas was never expected in this substation, no gas detectors had been installed in the building. The natural gas-air mixture was ignited by the normal arcing contacts of a circuit breaker, resulting in an explosion. The explosion killed one operator in the building, seriously injured a second and caused about $3 million in damages. The National Transportation Safety Board (NTSB) found[7] that the Cove Point Terminal was designed and constructed in conformance with all appropriate regulations and codes. It further concluded that this was an isolated incident, not likely to recur elsewhere. The NTSB concluded that it is unlikely that any pump seal, regardless of the liquid being pumped, could be designed, fabricated, or installed to completely preclude the possibility of leakage. With that conclusion in mind, building codes pertaining to the equipment and systems downstream of the pump seal were changed.

Before the Cove Point Terminal was restarted, all pump seal systems were modified to meet the new codes and gas detection systems were added to all buildings.

10. **April, 1983 Bontang, Indonesia** LNG Export Terminal - *Maintenance Accident, no LNG present*

A major incident occurred on April 14, 1983 in Bontang, Indonesia. The main liquefaction column (large vertical shell-and-tube heat exchanger) in Train B ruptured due to overpressurization of the heat exchanger caused by a blind left in a flare line during start-up. All the pressure relief systems were connected to this line. The exchanger was designed to operate at 60 psig on the shell side. The gas pressure reached 180 psig causing the failure of the exchanger. Debris and coil sections were projected some 50 meters away. Shrapnel from the column killed three workers. The ensuing fire was extinguished in about 30 minutes.

11. **1987 Mercury, Nevada, USA** Department of Energy Test Facility

An accidental ignition of an LNG vapor cloud occurred at the DOE, Nevada Test Site on August 29, 1987. The large-scale tests involving spills of LNG on water were sponsored by the Department of Energy and Gas Research Institute to study the effectiveness of vapor fences in reducing the extent of downwind dispersion of LNG vapor clouds. The cloud accidentally ignited during Test #5 just after a sequence of relatively strong rapid phase transitions (RPTs) which damaged and propelled polyurethane pipe insulation outside the fence. The official explanation was that a spark generated by static electricity approximately 76 seconds after the spill was the most likely source of ignition. An independent investigation on behalf of Gas Research Institute showed that a more likely source of ignition was oxygen enrichment between the surface of the LNG pipe and the combustible polyurethane foam insulation. Oxygen enrichment occurred during the long cool-down period with liquid nitrogen that preceded the LNG test. Such enrichment had been previously observed during tests carried out by an LNG tank design and manufacturing company. Impacts during the RPTs may have ignited the insulation but not the nearby fuel-rich vapor cloud. However, when a smoldering insulation fragment was propelled outside the fence by an RPT, it ignited the portion of the cloud that was within the flammable limits. The duration of the fire was 30 seconds. The flame length was about 20 feet above the ground. There have been other accidental ignitions involving LNG during large-scale tests.

- One occurred in England during large-scale fire tests being carried out by British Gas Corporation. Stray currents from a nearby radar station were blamed for prematurely igniting the primer that was eventually to be used to ignite the LNG cloud.
- Another occurred in Japan during similar large-scale tests carried out by Japan Gas Association. The ignition mechanism was not explained.
- During a test at a research facility near San Clemente, California, a sudden change in wind direction caused the vapor cloud to encounter a tractor that was moving some of the test equipment. The tractor ignited the vapor cloud, badly burning the driver. A researcher was also in the vapor cloud at the time of ignition. He was able to get out of the vapor cloud before the flame front reached him by running crosswind and was not injured.

12. **August, 1985 Pinson, Alabama, USA** LNG Peakshaving Facility

The welds on an 8 1/ 4-inch by 12-inch “patch plate” on a small aluminum vessel (3 ft in diameter by 7 ft tall) failed as the vessel was receiving LNG which was being drained from the liquefaction cold box. The plate was propelled into a building that contained the control room, boiler room, and offices. Some of the windows in the control room were blown inward and natural gas escaping from the failed vessel entered the building and ignited. Six employees were injured.

13. **1988 Everett, Massachusetts, USA** LNG Import Terminal
Approximately 30,000 gallons of LNG were spilled through "blown" flange gaskets during an interruption in LNG transfer at Distrigas. The cause was later determined to be "condensation induced water hammer." The spill was contained in a small area, as designed. The still night prevented the movement of the vapor cloud from the immediate area. No one was injured and no damage occurred beyond the blown gasket. Operating procedures, both manual and automatic, were modified as a result.

14. **1989 Thurley, United Kingdom** LNG Peakshaving Facility
While cooling down the vaporizers in preparation for sending out natural gas, lowpoint drain valves were opened on each vaporizer. One of these drain valves had not been closed when the pumps were started and LNG entered the vaporizers. As a result, LNG was released into the atmosphere as a high-pressure jet. The resulting vapor cloud ignited about thirty seconds after the release began. The flash fire covered an area approximately 40 by 25 m. Two operators received burns to their hands and faces. The source of ignition was believed to be the pilot light on one of the other submerged combustion vaporizers.

15. **September, 2000 Savannah, Georgia, USA** LNG Import Terminal
In September 2000, a 580-foot ship, the Sun Sapphire, lost control in the Savannah River and crashed into the LNG unloading pier at Elba Island. The Elba Island facility was undergoing reactivation but had no LNG in the plant. The Sun Sapphire, carrying almost 20 tons of palm and coconut oil, suffered a 40-foot gash in her hull. The point of impact at the terminal was the LNG unloading platform. Although the LNG facility experienced significant damage, including the need to replace five 16" unloading arms, there was no indication that had LNG been present in the piping that there would have been a release. Given the geometry of the Savannah River at Elba Island, it is doubtful that had an LNG ship been present that a similar ramming could have penetrated the double hull and released any LNG.

APPENDIX B ***Chronological Summary of Incidents Involving LNG Ships***

1. 1964/1965 25,500 M^3 *Jules Verne*
While loading LNG in Arzew, Algeria, lightning struck the forward vent riser of the ship and ignited vapor, which was being routinely vented through the ship venting system. Loading had been stopped when a thunderstorm broke out near the terminal but the vapor generated by the loading process was being released to the atmosphere. The shore return piping had not yet been in operation. The flame was quickly extinguished by purging with nitrogen through a connection to the riser. A similar event happened early in 1965 while the vessel was at sea shortly after leaving Arzew. The fire was again extinguished using the nitrogen purge connection. In this case, vapor was being vented into the atmosphere during ship transit, as was the normal practice at that time.

2. May, 1965 27,400 M^3 *Methane Princess*
The LNG loading arms were disconnected before the liquid lines had been completely drained, causing LNG to pass through a leaking closed valve and into a stainless steel drip pan placed underneath the arms. Seawater was applied to the area. Eventually, a star-shaped fracture appeared in the deck plating in spite of the application of the seawater.

3. May, 1965 25,500 M^3 *Jules Verne*
On the fourth loading of Jules Verne at Arzew in May 1965 an LNG spill, caused by overflowing of Cargo Tank No.1, resulted in the fracture of the cover plating of the tank and of the adjacent deck plating. The cause of the overfill has never been adequately explained, but it was associated with the failure of liquid level instrumentation and unfamiliarity with equipment on the part of the cargo handling watch officer.

4. April 11, 1966 27,400 M^3 *Methane Progress*
Cargo leakage reported. No details.

5. September, 1968 5,000 M^3 *Aristotle*
Ran aground off the coast of Mexico. Bottom damaged. Believed to be in LPG service when this occurred. *No LNG released.*

6. November 17, 1969 71,500 M^3 *Polar Alaska*
Sloshing of the LNG heel in No. 1 tank caused part of the supports for the cargo pump electric cable tray to break loose, resulting in several perforations of the primary barrier. LNG leaked into the interbarrier space. *No LNG released.*

7. September 2, 1970 71,500 M^3 *Arctic Tokyo*
Sloshing of the LNG heel in No. 1 tank during bad weather caused local deformation of the primary barrier and supporting insulation boxes. LNG leaked into the interbarrier space at one location. *No LNG released.*

8. Late 1971 50,000 M^3 *Descartes*
A minor fault in the connection between the primary barrier and the tank dome allowed gas into the interbarrier space. *No LNG released.*

9. June, 1974 27,400 M^3 *Methane Princess*
On June 12, 1974 the *Methane Princess* was rammed by the freighter *Tower Princess* while moored at Canvey Island LNG Terminal. Created a 3- foot gash in the outer hull. *No LNG released.*

10. July, 1974 5,000 M^3 *Barge Massachusetts*
LNG was being loaded on the barge on July 16, 1974. After a power failure and the automatic closure of the main liquid line valves, a small amount of LNG leaked from a 1-inch nitrogen-purge globe valve on the vessel's liquid header. The subsequent investigation by the US. Coast Guard found that a pressure surge caused by the valve closure induced the leakage of LNG through the bonnet and gland of the 1-inch valve. The valve had not leaked during the previous seven or more hours of loading. Several fractures occurred in the deck plates. They extended over an area that measured about one by two meters. The amount of LNG involved in the leakage was reported to be about 40 gallons. As a result of this incident, The U.S. Coast Guard banned the Barge

Massachusetts from LNG service within the U.S. It is believed that the Barge Massachusetts is now working in liquid ethylene service.

11. August, 1974 4,000 M^3 *Euclides*
Minor damage due to contact with another vessel. *No LNG released.*

12. November, 1974 4,000 M^3 *Euclides*
Ran aground at La Havre, France. Damaged bottom and propeller. *No LNG released.*

13. 1974 27,400 M^3 *Methane Progress*
Ran aground at Arzew, Algeria. Damaged rudder. *No LNG released.*

14. September, 1977 125,000 M^3 *LNG Aquarius*
During the filling of Cargo Tank No. 1 at Bontang on September 16, 1977, LNG overflowed through the vent mast serving that tank. The incident may have been caused by difficulties in the liquid level gauge system. The high-level alarm had been placed in the override mode to eliminate nuisance alarms. Surprisingly, the mild steel plate of which the cargo tank cover was made did not fracture as a result of this spill.

15. August 14, 1978 124,890 M^3 *Khannur*
Collision with cargo ship *Hong Hwa* in the Strait of Singapore. Minor damage. *No LNG released.*

16. April, 1979 125,000 M^3 *Mostefa Ben Boulaid*
While discharging cargo at Cove Point, Maryland on April 8, 1979, a check valve in the piping system of the vessel failed releasing a small quantity of LNG. This resulted in minor fractures of the deck plating. This spill was caused by the escape of LNG from a swing-check valve in the liquid line. In this valve, the hinge pin is retained by a head bolt, which penetrates the wall of the valve body. In the course of operating the ship and cargo pumping system, it appears that the vibration caused the bolt to back out, releasing a shower of LNG onto the deck. The vessel was taken out of service after the incident and the structural work renewed. All of the check valves in the ship's liquid system were modified to prevent a recurrence of the failure. A light stainless steel keeper was fashioned and installed at each bolt head. Shortly after the ship returned to service, LNG was noticed leaking from around one bolt head, the keeper for which had been stripped, again probably because of vibration. More substantial keepers were installed and the valves have been free from trouble since that time.

17. April, 1979 87,600 M^3 *Pollenger*
While the Pollenger was discharging LNG at the Distrigas terminal at Everett, Massachusetts on April 25, 1979, LNG leaking from a valve gland apparently fractured the tank cover plating at Cargo Tank No. 1. The quantity of LNG that spilled was probably only a few liters, but the fractures in the cover plating covered an area of about two square meters.

18. June 29, 1979 125,000 M^3 *El Paso Paul Kayser*
Ran aground at 14 knots while maneuvering to avoid another vessel in the Strait of Gibraltar. Bottom damaged extensively. Vessel refloated and cargo transferred to sister ship, the *El Paso Sonatrach. No LNG released.*

19. December 12, 1980 125,000 M^3 *LNG Taurus*
Ran aground in heavy weather at Mutsure Anchorage off Tobata, Japan.
Bottom damaged extensively. Vessel refloated, proceeded under its own power to the Kita Kyushu LNG Terminal, and cargo discharged. *No LNG released.*

20. Early 1980s 125,000 M^3 *El Paso Consolidated*
Minor release of LNG from a flange. Deck plating fractured due to low temperature embrittlement.

21. Early 1980s 129,500 M^3 *Larbi Ben M'Hidi*
Vapor released during transfer arm disconnection. *No LNG released.*

22. December, 1983 87,600 M^3 *Norman Lady*
During cooldown of the cargo transfer arms, prior to unloading at Sodegaura, Japan, the ship suddenly moved astern under its own power. All cargo transfer arms sheared and LNG spilled. No ignition.

23. 1985 35,500 M^3 *Isabella*
LNG released as a result of overfilling a tank. Deck fractured due to low temperature embrittlement.

24. 1985 35,500 M^3 *Annabella*
Reported as "pressurized cargo tank." Presumably, some LNG released from the tank or piping. No other details are available.

25. 1985 126,000 M^3 *Ramdane Abane*
Collision while loaded. Port bow affected. *No LNG released.*

26. February, 1989 40,000 M^3 *Tellier*
Wind blew ship from its berth at Skikda, Algeria. Cargo transfer arms sheared. Piping on ship heavily damaged. Cargo transfer had been stopped. According to some verbal accounts of this incident, LNG was released from the cargo transfer arms.

27. Early 1990 125,000 M^3 *Bachir Chihani*
A fracture occurred at a part of the ship structure, which is prone to the high stresses that may accompany the complex deflections that the hull encounters on the high seas. Fracture of the inner hull plating led to the ingress of seawater into the space behind the cargo hold insulation while the vessel was in ballast. *No LNG released.*

28. May 21, 1997 125,000 M^3 *Northwest Swift*
Collided with a fishing vessel about 400 km from Japan. Some damage to hull, but no ingress of water. *No LNG released.*

29. October 31, 1997 126,300 M^3 *LNG Capricorn*
Struck a mooring dolphin at a pier near the Senboku LNG Terminal in Japan.
Some damage to hull, but no ingress of water. *No LNG released.*

30. September 6, 1999 71,500 M^3 *Methane Polar*
Engine failure during approach to Atlantic LNG jetty (Trinidad and Tobago). Struck and damaged Petrotrin pier. No injuries. *No LNG released*