# Reliability of UK Supplies of Electricity Generated from Gas from Russia and Iran.

Prepared By

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

Thursday, August 12, 2004

## 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.

## Figures.

# Summary

**Figure 1: Summary of Results obtained in this Report.**

| | Frequency/year | % Flow | Duration of Interruption, days | fraction of year during which flow is reduced | % of Year's flow lost | % of year's contract uk receives |
|---|---|---|---|---|---|---|
| Political Risk in Russia, Ukraine, Belarus and Iran | 0.001 | 0 | 10 | 0.03 | 2.74% | 97.26% |
| Political Risk in Russia, Ukraine, Belarus and Iran | 0.0065 | 37% | 30 | 0.08 | 5.21% | 94.79% |
| Political Risk in Russia, Ukraine, Belarus and Iran | 0.019 | 27% | 180 | 0.49 | 36.09% | 63.91% |
| Political Risk in Russia, Ukraine, Belarus and Iran | 0.0425 | 73% | 180 | 0.49 | 13.22% | 86.78% |
| Political Risk in Russia, Ukraine, Belarus and Iran | 0.1235 | 63% | 180 | 0.49 | 18.05% | 81.95% |
| Minor Terrorist Risk | 0.009 | 90.00% | 30 | 0.08 | 0.82% | 99.18% |
| Major Terrorist Risk | 0.00009 | 50.00% | 180 | 0.49 | 24.66% | 75.34% |
| Minor Equipment Failure. | 0.01 | 90.00% | 10 | 0.03 | 0.27% | 99.73% |
| Major Equipment Failure. | 0.0001 | 50.00% | 60 | 0.16 | 8.22% | 91.78% |
| Diversion of gas by Ukraine and Belarus. | 0.1 | 98.00% | 10 | 0.03 | 0.05% | 99.95% |
| | 0.68831 | 100% | 0 | 0.00 | 0.00% | 100.00% |

# Introduction.

In this Report I show that the majority of the UK's electricity will in future come from stations that burn gas and I estimate the security of supply for this source of electric power.

There are mounting concerns that natural gas, imported from outside Europe, will prove unreliable. Russian gas will be the main source of UK electricity in 2020 and thereafter. The second largest supplier of natural gas to the UK will be Iran.

The UK has experienced half a dozen politically-motivated interruptions in its imports of ***oil***, leading for example to the "Three Day Week"; Russia and Iran seem no more likely to be reliable as sources of the UK's gas than the Middle East has been a reliable source of oil[1]. But how are these concerns to be ***quantified***?

A means of quantification does exist:

- the business world has developed data-bases on ***political risk*** for most of the countries of the world and
- the insurance companies have extensive data on the losses that have been sustained due to political action in all countries since they insure many of those risks.

In the work described in this Report these two sets of information are used to produce the first numerical estimates of the likely reliability of Russian and Iranian gas supplies in the years to 2020 and beyond.

## *Sources of the UK's Electricity.*

It is forecast that, by 2020, most of the UK's electricity will be generated from gas. [2]

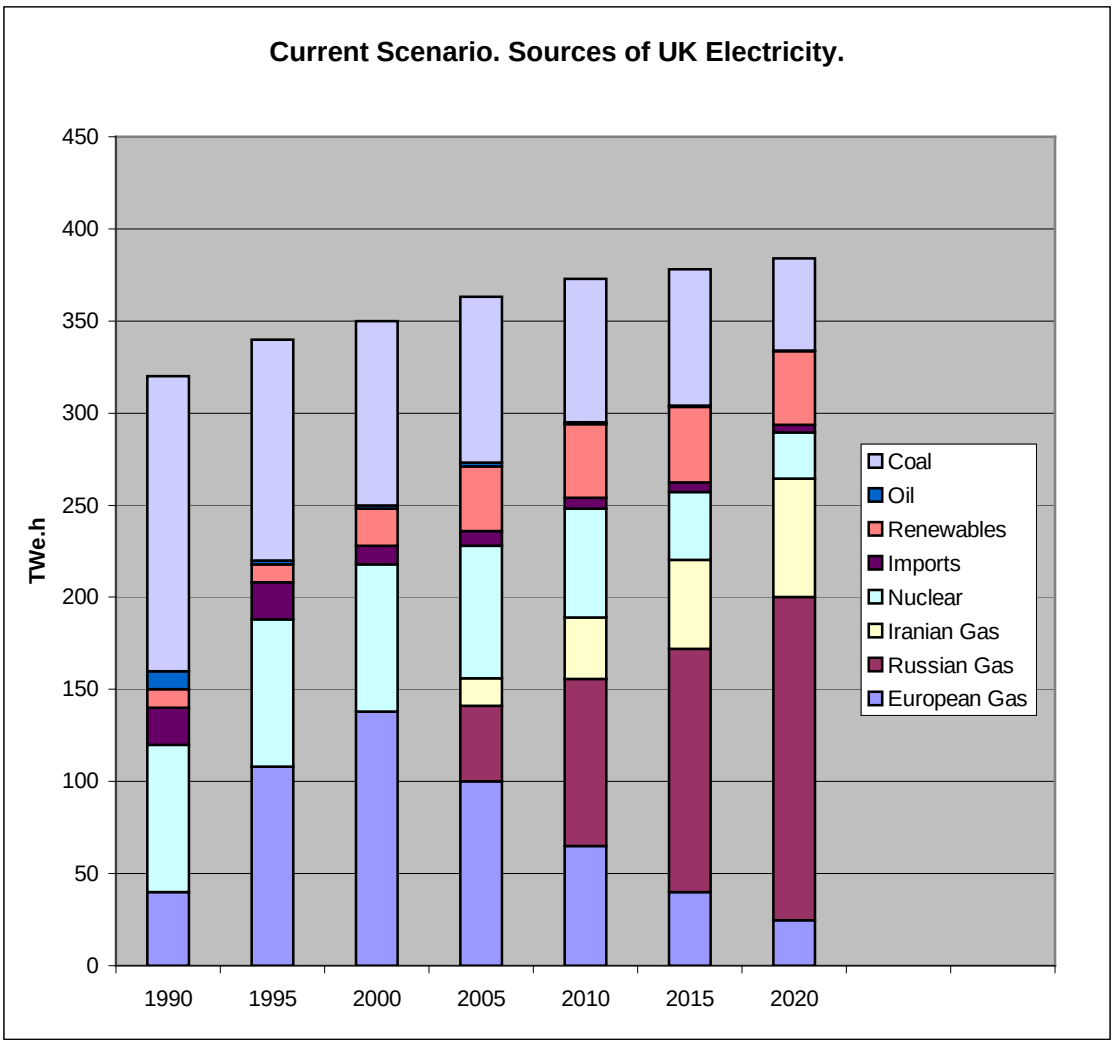
[1] For example, the EU's Energy Commissioner, Loyola de Palacio says, in *General Report: Energy And Economic Security: The Importance Of Energy In Transatlantic Economic And Strategic Security October 2001*: "… the more pipelines in the(Russian) region the better, as this will give exporters several means of moving gas and oil to market from this remote and unstable region. Several pipelines would help accommodate any large increase in production and ensure continued exports were any single line blocked for reasons of war or terrorism". Again Energy Minister Brian Wilson told the BBC *Today* program that… "The only way in which we could have security of supply without nuclear power would be to become 70% dependent on gas, 90% of which would be imported, some of it from places I don't think we would probably wish to stake our children's future on…the nuclear option must be kept open in case there is any problem with future gas supplies from volatile regions of central Asia" www.bbc.co.uk/radio4/today/re.../nuclear_energy.shtml

[2] Over 70% of the world's natural gas reserves are concentrated in the Middle East and the Former Soviet Union. Further analysis shows that two companies, Gazprom in Russia and the Iranian National Oil Company, control almost half of global gas reserves. These regions are subject to much political instability and uncertainty, yet oil companies wish to bring this gas to Europe with projects such as the $35 billion Yamal pipeline from Siberia. The UK, at the end of very long pipelines passing through

Currently the UK is self-sufficient in Gas, but our reserves will virtually have run out by 2020. By 2020 most of the UK's supplies of gas will be imported from Europe, Countries of the Former Soviet Union and countries near the Caspian Sea, of which Iran will be the main supplier.

PIU data indicates that UK gas reserves have fallen from 2,200 Mtoe in 1980 to 700 in 2000 and will be only 79 Mtoe in 2020. The following figure shows the forecast sources of the UK's electricity in the years to 2020:

**Figure 2 Present Forecasts of Sources of UK Electricity, to 2020.**




many countries, would be subject to the highest transportation costs and greatest risk of supply interruption if, as forecast, the nation was to become largely dependent on imported gas.

## *Russia, Iran and Qatar: Main Sources of Natural Gas, 2002* [3]

The following figure shows the natural gas reserves of the countries that had the biggest reserves in 2002.

Note that

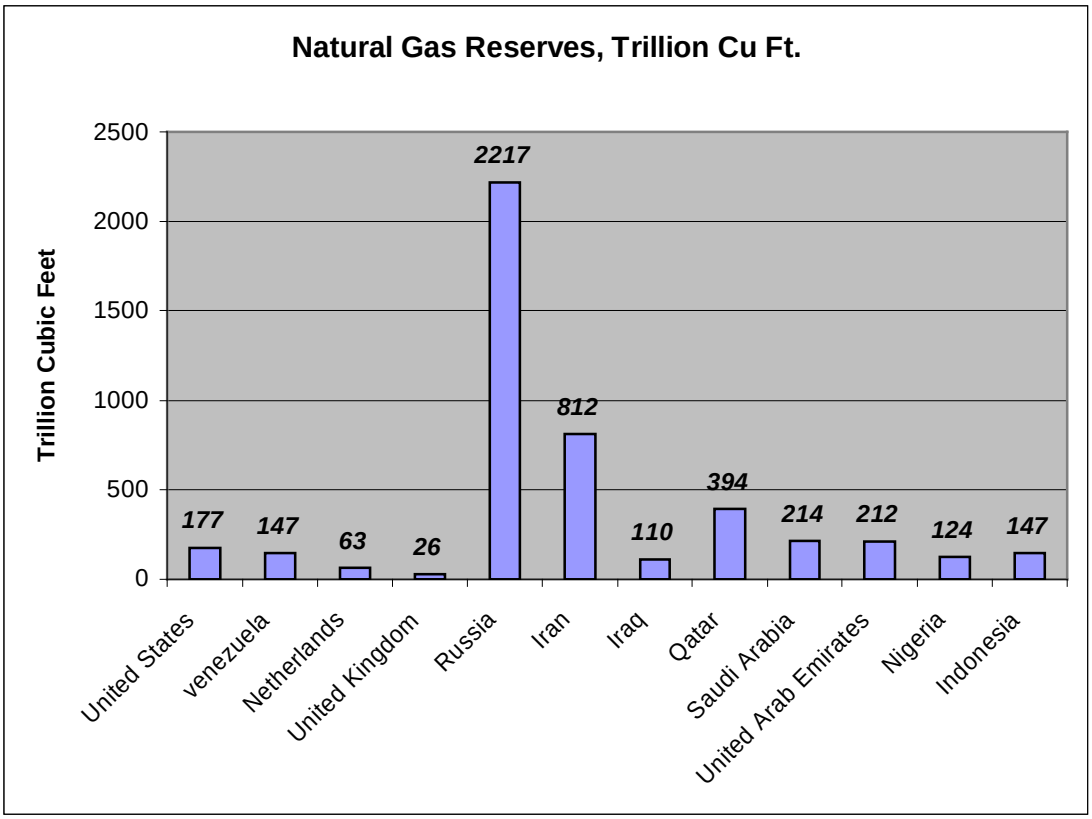
- Russia has overwhelmingly the largest reserves, at 2,217 trillion cubic feet (tcf).
- Those of Iran come next,
- The third highest reserves are held by Qatar, which in my analysis of LNG I identified as one of the main sources from which the UK will obtain natural gas in liquid form, i.e. as LNG. The UK is too far from Qatar for it to be feasible for a pipeline to be used to connect the two countries.

The natural gas reserves of the UK are tiny by comparison at only 26 tcf whilst those of the Netherlands, although still small, are now the largest in Europe at 63 tcf.

The total reserves of the Middle East, of which Iran, Qatar and Saudi Arabia have the most, are approximately equal to those of Russia at 1,900 tcf.

[3] *Last Updated on 3/20/03 By EIA Email: patricia.smith@eia.doe.gov*

**Figure 3: World's Natural Gas Reserves, Divided by Country.**




## Trade in Natural Gas in Eurasia.

The following figure shows forecasts for the natural gas trade within Eurasia in 2050 for a global scenario with rapid economic development and accelerated investments in gas production and transport infrastructures. Flows denote pipelines and LNG routes, width of trade "arrows" is proportional to gas-flows, numbers are in Mtoe, areas of Eurasian regions are proportional to primary energy consumption in 2050. Figures for 2020 are approximately half those shown in the Map below[4].

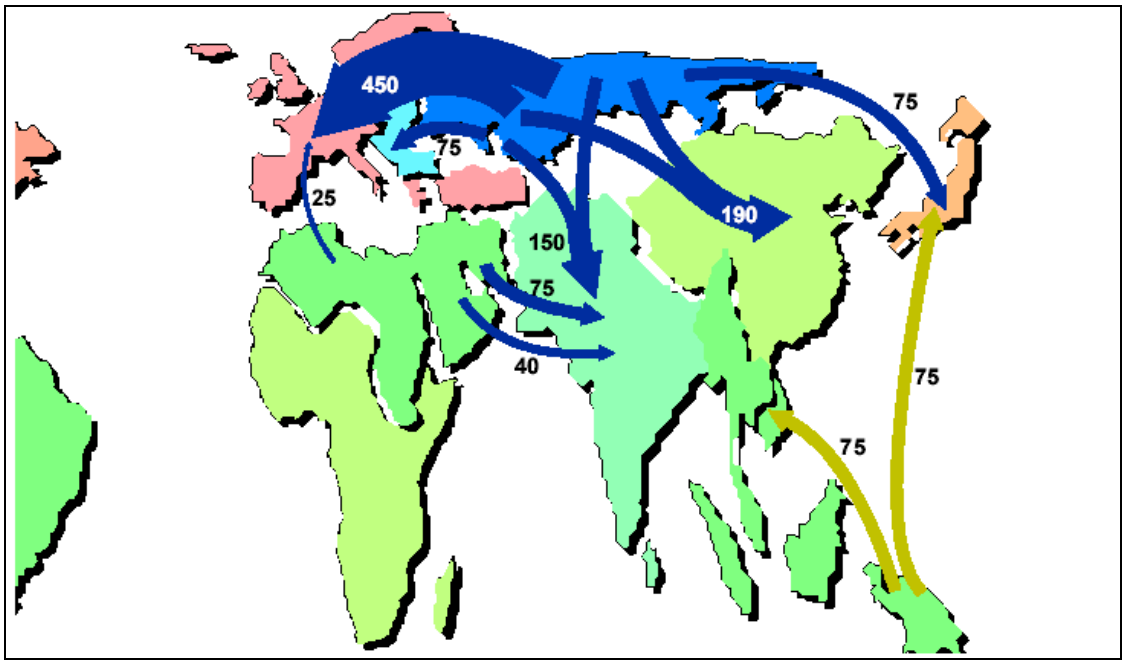
[4] Source: Naki´cenovi´c, N. (1999), Energy Perspectives for Eurasia and the Kyoto Protocol, Section II Chapter 5 in The Sustainable Future of the Global SystemI I, Fuchen Lo, K. Matsushita and H. Takagi (eds), Proceedings of the International Conference on Sustainable Future of the Global System, 23-24 February, Tokyo, Japan, 71-92. This work is essentially a follow up to a five-year study conducted jointly by the International Institute for Applied Systems Analysis (IIASA) and the World Energy Council (WEC). International Institute for Applied Systems Analysis, Schlossplatz 1 • A-2361 Laxenburg • Austria, Telephone: ( 43 2236) 807 342 • Fax: ( 43 2236) 71313. E-mail: publications@iiasa.ac.at • Internet: www.iiasa.ac.at

Note that the major flow of gas is through pipelines from Russia to Western Europe. This is not surprising, since the previous figure has revealed that Russia has by far the greatest reserves of natural gas in the world. Indeed the whole of Western Europe has natural gas reserves of about 160 trillion cubic feet, which is less than one tenth of the reserves of Russia (2,217 tcf).

A subsidiary flow is from the area in and around the Caspian Sea, which is where Iran has its gas reserves, second only to those of Russia as we have seen

- Russian gas is the supply of gas upon which the UK is to rely for most of its electricity from 2020 onwards, on present forecasts.
- The second most important source for the UK will be gas from the Caspian Sea sector and, since it has the largest reserves in that sector, Iran in particular.

**Figure 2: Forecast flows of natural gas in Eurasia, 2050.**



## *The Russian Yamalo-Nenetsky autonomous region, Source of Most of the UK;s Future Gas Supplies [5].*

The following Map shows the Yamalo-Nenetsky autonomous region of Russia, which will be the main source of the massive gas flows shown on the previous figure. The Yamalo-Nenetsky autonomous region of Russia is characterised by the largest deposits of gas in the world. The region is located in the Northern Eurasia. The extreme northern point of the region is on the Yamal peninsula 73°30' northern latitude, it is almost 800 km to the North from the Polar Circle. Islands of the Kara Sea, which are included in the group of the region, are located far to the North. Approximately a half of the region is located beyond the northern Polar Circle. In the West the region borders upon Arkhangelsk oblast, the republic of Komi; in the South - with Khanty-Mansiisk autonomous region; in the East - with Krasnoyarsk Krai.

The Yamalo-Nenetsky region supplies more than 90% of the natural gas and 12% of the oil extracted in Russia. Twenty seven percent of working population of Yamalo-Nenetsky region are employed in the industrial production: oil and gas extraction and transportation. Most of the gas production in Yamalo-Nenetsky is carried out by a number of "Gazprom" subsidiary companies and 96% of oil production is carried out by the Sibneft and Rosneft companies In addition to being a source of oil and gas the Ural mountains in Yamalo-Nenetsky are rich in precious, ferrous, non-ferrous metals. The mountains also have abundant deposits of chromite, phosphorites and barites.

For the coming decades a large number of gas pipelines is being proposed or planned in the Eurasian regions These new pipelines are intended to transport large volumes over long distances and consequently are expected to have high costs. The Yamal pipelines will transport much of the UK’s gas from Yamal through Poland and Belarus and/or Ukraine over a distance of more than 4,000 km. The Irkutsk-Japan gas pipeline will cross a stretch of over 3,500 km from Kovykytinskoye in Russia, through Mongolia, China, South Korea to Japan.

[5] Based on the results of a five-year study conducted jointly by the International Institute for Applied Systems Analysis (IIASA) and the World Energy Council (WEC). covered the period through 2020 with some extensions to 2100. This study describes three cases of alternative energy futures that diverge into a total of six scenarios, and their implications for 11 world regions. The objective was to examine more thoroughly the period beyond 2020, where the real potential for change lies. To that end the study integrates near-term strategies through 2020 with long-term opportunities to 2050 and beyond.

**Figure 3, The Yamalo-Nenetsky autonomous region.**


## *The Main Gas Pipelines from Yamal to Europe.* [6]

There will be two main groups of pipelines, from Yamal to Europe.

- The first “Yamal-Europe 1” natural gas export pipeline goes from Russia, across Belarus, through Poland, and on to Germany.

- The proposed "Yamal-Europe 2" pipeline would run from Russia through Belarus or the Ukraine and then connect Brzesc, Poland, to Velke Kapusany, Slovakia.

Gazprom currently supplies around 25% of European natural gas demand, and the company is eager to increase its penetration in the region. Approximately 90% of Russia's total natural gas exports to Europe are currently routed through Ukraine, which receives natural gas supplies as in-kind payment for allowing Russia's natural gas to transit its territory en route to European consumers (Ukraine purchases additional natural gas from Russia to meet its domestic demand).

[6] Russia: Oil and Natural Gas Export Pipelines. Energy Information Administration, DOE, UK, April 2002.

The first leg of the Yamal-Europe pipeline, which is routed through Belarus and Poland to Germany, is Russia's only natural gas export pipeline to Europe that is not routed through Ukraine.

Gazprom has sent conflicting signals on its intentions with the second leg of the Yamal pipeline (stipulated in a 1993 Russia-Poland intergovernmental agreement) and the related question of a possible bypass route around Ukraine. In February 2002, Gazprom board member Boris Fyodorov told investors that the company's board of directors had decided to increase the capacity of the Yamal-Europe pipeline and drop the project to build the natural gas pipeline through Poland, bypassing Ukraine. Gazprom officials, however, denied reports that the company has scrapped plans for a north-south pipeline from Belarus to Slovakia via Poland, avoiding Ukraine.

Russia has questioned Ukraine's reliability as a transit country, noting Ukraine's $2-billion debt for natural gas supplies. Several times in the past few years, Russia has accused Ukraine of illegally taking more natural gas from than the amount for which it had contracted. With Russia's long-term energy supply agreement with the European Union, Russian officials have said that they need additional export routes to be able to meet Russia's increased supply obligations. As a result of the strained relations between Ukraine and Russia over natural gas transit, in October 2000 Gazprom officials proposed a new pipeline that would bypass Ukraine. However, Ukraine pledged to stop siphoning natural gas from the transit pipelines, and in October 2001, the two countries agreed on a 12-year debt restructuring deal for Ukraine's natural gas debts.

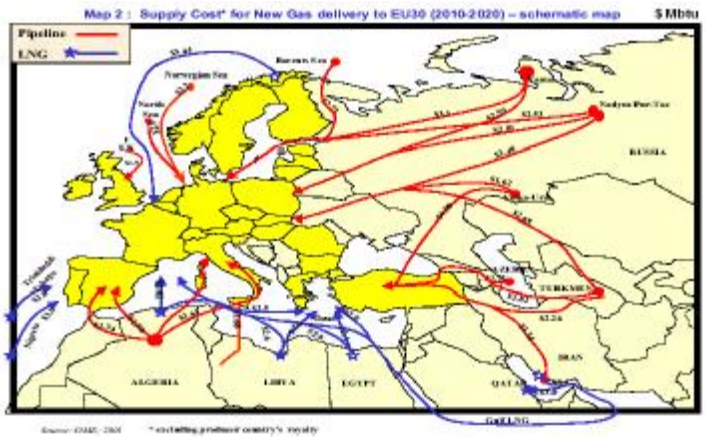
Although there has been confusion as to what Gazprom's position is, what is clear is that the company is still interested in boosting Russia's natural gas export capacity to Europe by diversifying its export routes. Currently, the Yamal-Europe pipeline annually carries about 600 Bcf of Russian natural gas, which is sold to the Russian-German trading company Weih, and the pipeline is expected to handle about 1.17 Tcf of natural gas per year by 2003 after new compressor stations have been built in Poland. Gazprom's plans for a second stretch of the Yamal-Europe pipeline through Poland would increase capacity to 2.1 Tcf of natural gas per year, but Russia and Poland have differed on the route for the second leg, and Russia's shorter route would still cost an estimated $2 billion to construct.

## *Yamal - Europe Gas Pipeline Being Brought into Service in Belarus*

On September 21, 1999 the first Belarussian section of the *Yamal - Europe* pipeline was brought into service. It stretches 209 kilometres from the *Nesvizhskaya* compressor station to Belarus' border with Poland. Between July 23 and August 1, 2002 the second section of the pipeline, from the *Smolenskaya* compressor station to the River Berezina, was filled with gas.

On March 19th 2003, it was announced that the third phase of the *Yamal - Europe* gas pipeline, which passes through Belarus, has begun to be brought into use. According to the press office of Belarussian state gas transport and supply company *Beltransgaz*, after completion of the construction of the 183-kilometre section of the pipeline, experts will work on expelling air and filling the pipeline with gas. Russian experts are preparing the pipeline for use. According to the press office, representatives of *Orgenergogaz* (Russia), the main contractor for preparatory work on the pipeline, are responsible for ensuring that junction valves on the pipeline work properly.

After preparatory work has been completed, the entire Belarussian stretch of the pipeline, from the Russian border in the east to the Polish border in the west, will be filled with gas. *Beltransgaz* believes that this 'will allow Russian gas to be transported to Germany through Belarus, which will improve the reliability of gas transport to Western consumers.



## *The Reliability of Supplies of UK Electricity Generated From Russian Gas.*

The reliability of the supplies of UK electricity generated from Russian gas will now be calculated from data on

- Political Risks[7] and
- Political Risk Insurance[8]
- Politically-motivated interruptions [9]that have, historically, occurred to fossil fuel supplies.

Political Risk information and Political Risk Insurance information are available for 137 countries:

**Figure 4: The 137 Countries for Which Political Risk and Political Risk Insurance Data are Available.**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Albania | Burkina Faso | Egypt | Hungary | Kuwait | Mozambique | Portugal | Suriname | United States |
| Algeria | Cameroon | El Salvador | India | Latvia | Myanmar | Qatar | Sweden | Uruguay |
| Angola | Canada | Estonia | Indonesia | Lebanon | Namibia | Romania | Switzerland | Uzbekistan |
| Argentina | Chile | Ethiopia | Iran | Liberia | Netherlands | Russian Federation. | Syria | Venezuela |
| Armenia | China, Peoples' Rep. | Finland | Iraq | Libya | New Zealand | Saudi Arabia | Taiwan | Vietnam |
| Australia | Colombia | France | Ireland | Lithuania | Nicaragua | Senegal | Tajikistan | Yemen, Republic |
| Austria | Congo, Dem. Republic | Gabon | Israel | Luxembourg | Nigeria | Serbia | Tanzania | Yugoslavia |
| Azerbaijan | Costa Rica | Gambia | Italy | Madagascar | Norway | Sierra Leone | Thailand | Zambia |
| Bahamas | Cote d'Ivoire | Germany | Jamaica | Malawi | Oman | Singapore | Tunisia | Zimbabwe |
| Bahrain | Croatia | Georgia | Japan | Malaysia | Pakistan | Slovak Republic | Turkey | |
| Bangladesh | Cuba | Ghana | Jordan | Mali | Panama | Slovenia | Turkmenistan | |
| Belarus | Cyprus | Greece | Kazakstan | Malta | Papua New Guinea | South Africa | UAE | |
| Bolivia | Czech Republic | Guatemala | Kenya | Mexico | Paraguay | Somalia | Uganda | |
| Botswana | Denmark | Guyana | Kyrgyzstan | Moldova | Peru | Spain | Ukraine | |
| Brazil | Dominican Republic | Honduras | Korea, D.P.R. | Mongolia | Philippines | Sri Lanka | United Arab Emirates | |
| Bulgaria | Ecuador | Hong Kong | Korea, Republic | Morocco | Poland | Sudan | United Kingdom | |

[7] •The Indices for Political Risk used in this work have been developed from a Data Base prepared by The PRS Group, Inc, 320 Fly Road, Suite 102, PO Box 248, East Syracuse, NY 13057-0248, USA. The forecasts extend to 2007 and have been extended to 2020 for the present study.

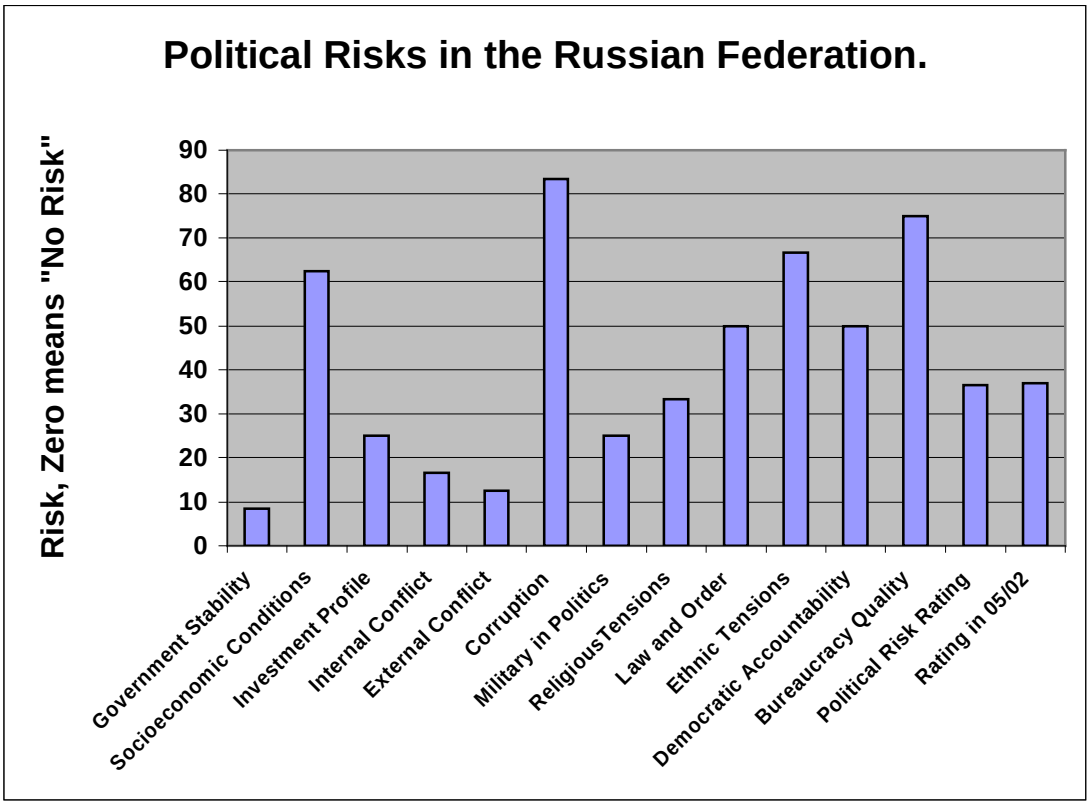
[8] •The Data on Political Risk Insurance Premiums have been developed from a Data Base prepared by AON Plc. 8 Devonshire Square, London EC2M 4PL. These Premiums are based on historic losses.

[9] The Data on interruptions to the UK's oil and coal supplies have been taken from news items that appeared in the media at the time of each interruption.

For each of these countries a range of political risk parameters are calculated, updated at regular intervals and extrapolated to give forecasts of future risks. The next figure shows values of these parameters for the Russian Federation, together with a combined Index that has been calculated from them all in combination.

The purpose of these Political Risk forecasts is to enable business to evaluate the risks that it will run in activities such as exporting to the Russian Federation, importing from it, entering into Joint Ventures with it etc etc. The Political Risk has no numerical significance except as a means of comparing one country with another or one component of the risk with another. So we note that of the various elements of risk in the figure for the Russian Federation, *Socioeconomic conditions*, *Corruption*, *Ethnic Tensions* and *Bureaucratic Quality* are the worst. The joint index of Political Risk, at about 35 points, does not appear high, since the scale goes up to 100, but in order to judge the meaning of this number we need to look at some other countries and that is done in the succeeding figure.

**Figure 5: Political Risks in the Russian Federation.**

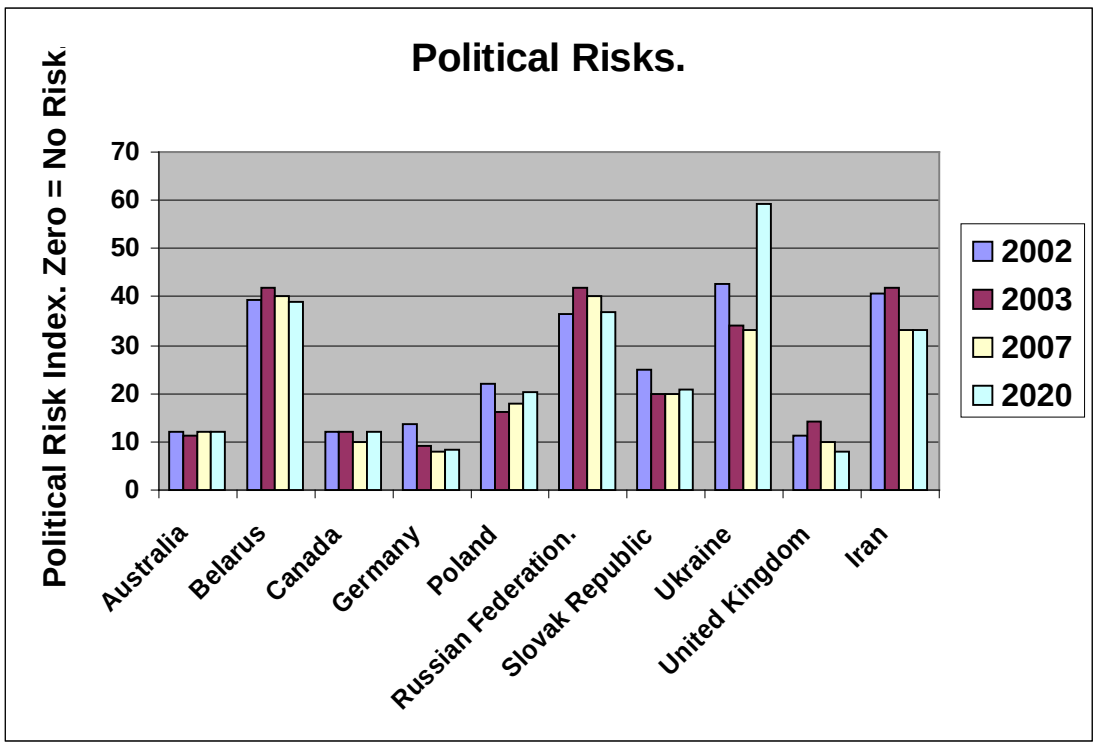


## *Relative Political Risks for the UK and for Gas and Uranium Supplier Countries.*

In the next figure the Political Risk Indices for the Russian Federation and Iran are compared with that for the UK and prove to be three times greater. Also shown are those for Ukraine and Belarus. These are countries through which the gas pipelines pass or will pass that will bring Russian gas to the UK. The Political Risk Indices of Belarus and Ukraine are also high—similar to those for the Russian Federation. Of course the absolute magnitude of the Indices has no particular numerical significance, but it lends perspective, particularly when it is realized that Australia, Canada (countries that supply the UK with uranium), Germany and Poland (countries through which gas from Russia will be piped on from Ukraine and Belarus *en route* for the UK) have low Political Risk Indices similar to that of the UK.

The figure gives estimates of Political Risk for the years ahead and clearly the further ahead we look the more uncertain the estimates. The data base on which these indices are based gives three values: the most likely, the highest thought likely and the lowest thought likely, for each value of the Political Risk Index. The most important conclusion is that no striking improvement or deterioration is expected over the next decade or so, for any of the countries considered.

**Figure 6: Political Risks Presented by Countries that Supply UK with Uranium compared to those presented by Countries that will supply the UK with natural gas.**



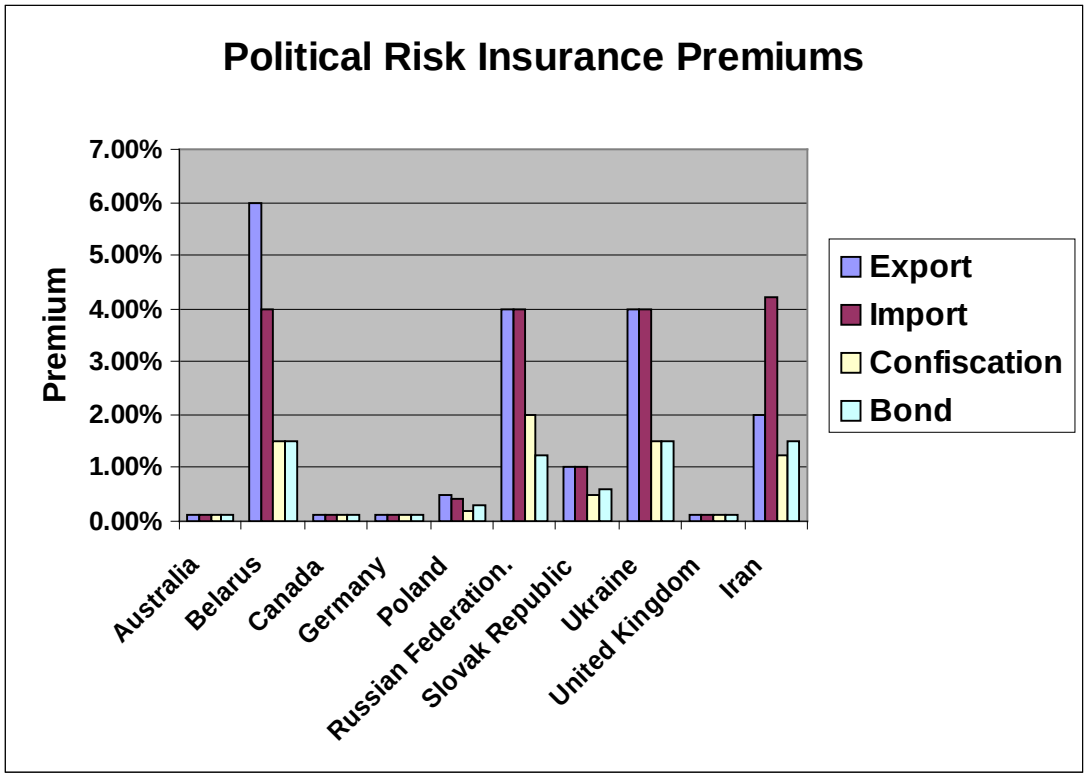
## *Political Risk Insurance Premiums.*

Having introduced the data base on Political Risk Indices, attention will now be directed to the parallel data base on Political Risk Insurance Premiums.

Amongst the aspects of Political Risk that are insured in the Lloyds of London market and elsewhere are the following:

1.Contract frustration (***export*** risks) including pre shipment and nonpayment risks on sales to, or guaranteed by, public entities.
2.Contract frustration (***import*** risks) including supplier non-delivery and failure to refund pre-payments.
3.On-demand ***bond*** unfair calling including calls arising from political force majeure events.
4.***Confiscation*** including expropriation and nationalization of foreign shareholdings.
5.Physical damage to land-based assets caused by war, civil war, ***terrorism***, rioters, malicious damage etc.In the next figure values of the Political Risk Insurance Premiums are given for the same countries as covered in the previous figure. It is immediately apparent that the premiums follow the same pattern as did the Political Risk Indices: Russia, Iran, Ukraine and Belarus attract the highest premiums, whether for Export, Import, Confiscation or Bond calling risks. The UK, Australia, Canada, Germany and Poland all attract low premiums.

**Figure 7: Political Risk Insurance Premiums for Russia, Iran, Ukraine, Belarus, UK Canada etc.**



## *Using Political Risk Indices to Forecast Political Risk Insurance Premiums.*

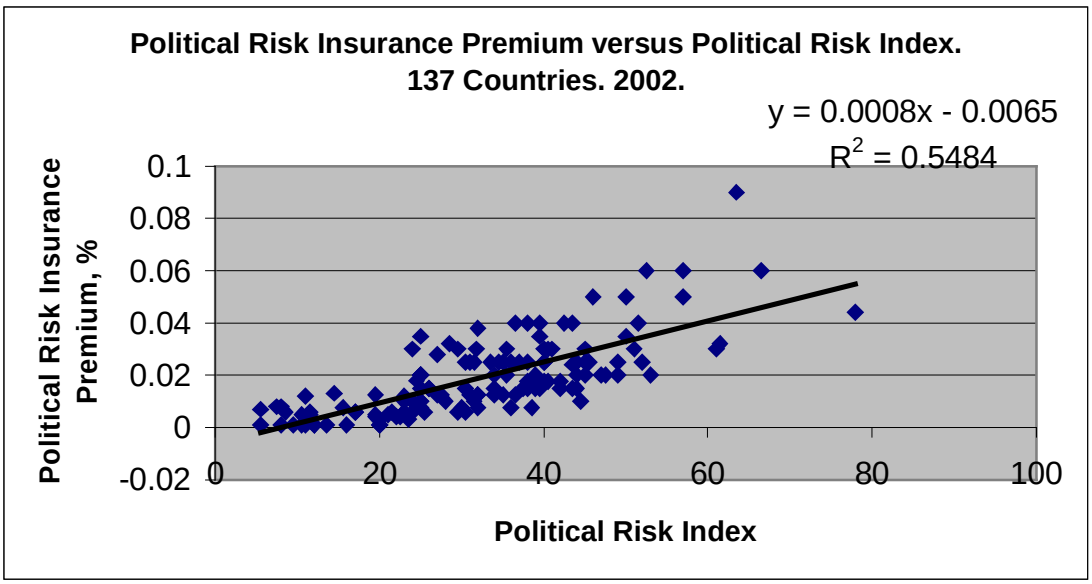
The important difference between the Indices and the Premiums for Political Risk is that the former are based on the actual losses that insurers have had to pay. The premiums are the actual, financial measure of Political Risk, in the sense that if these premiums had been saved then, over a long period of time, they would have sufficed to pay for the losses. The premiums are therefore based on historic data for losses sustained. What we want to know is this: how likely are we to suffer losses in the future if we go into business to import Russian and Iranian gas as a way of producing most of the UK's electricity?

The Political Risk database gives us a way of answering this question.

Thus we have seen that Russia, Iran, Belarus and Ukraine have the highest Political Risk Indices and the highest Political Risk Insurance Premiums.

As the next figure shows, this correlation extends to all the 137 countries in the two databases.

It means that the Political Risk Insurance Premiums for today and the years ahead, to 2020 and beyond, can be calculated from our estimates of the Political Risk Indices for those years. **Figure: Political Risk versus Political Risk Insurance Premium for 137 Countries in 2002.**

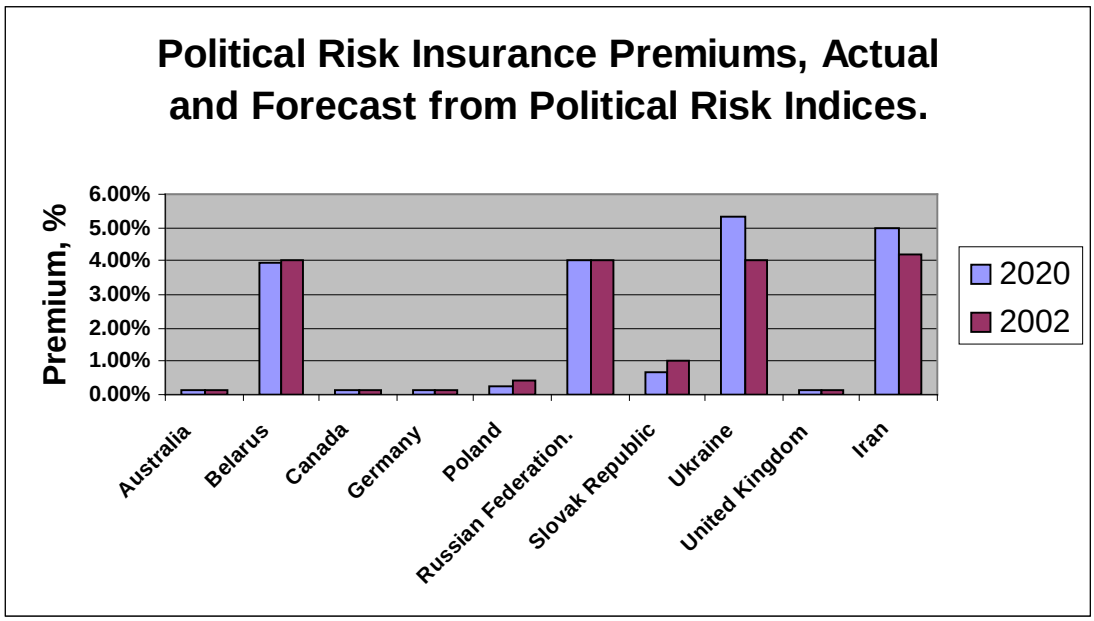


## *Actual and Forecast Political Risk Insurance Premiums for Gas and Uranium Producer Countries.*

To show what can be done, the correlation between Risk and Premium has been used to forecast the latter from values of the former deduced for 2020. The results are shown in the next figure. The changes, compared with today, are not great and the ranking of the different countries is still as before; that is to say the uranium producers are considerably less risky than the countries from and through which our gas will be arriving from Russia and Iran in 2020.

The Premiums are based, of course, on all sorts of politically-motivated losses to many different classes of business. In that sense they are superior to information based solely on the actual gas-industry, or more broadly the fossil fuel industry. We shall need to show, however, that they are of the order that would pay for politically-motivated fossil fuel supply-interruptions so that we can better justify using premiums to forecast the frequency and duration of gas-supply interruptions. That will next be addressed.

**Figure 8: Political Risk Insurance Premiums: Actual and Forecast, for Gas and Uranium Producing Countries.**

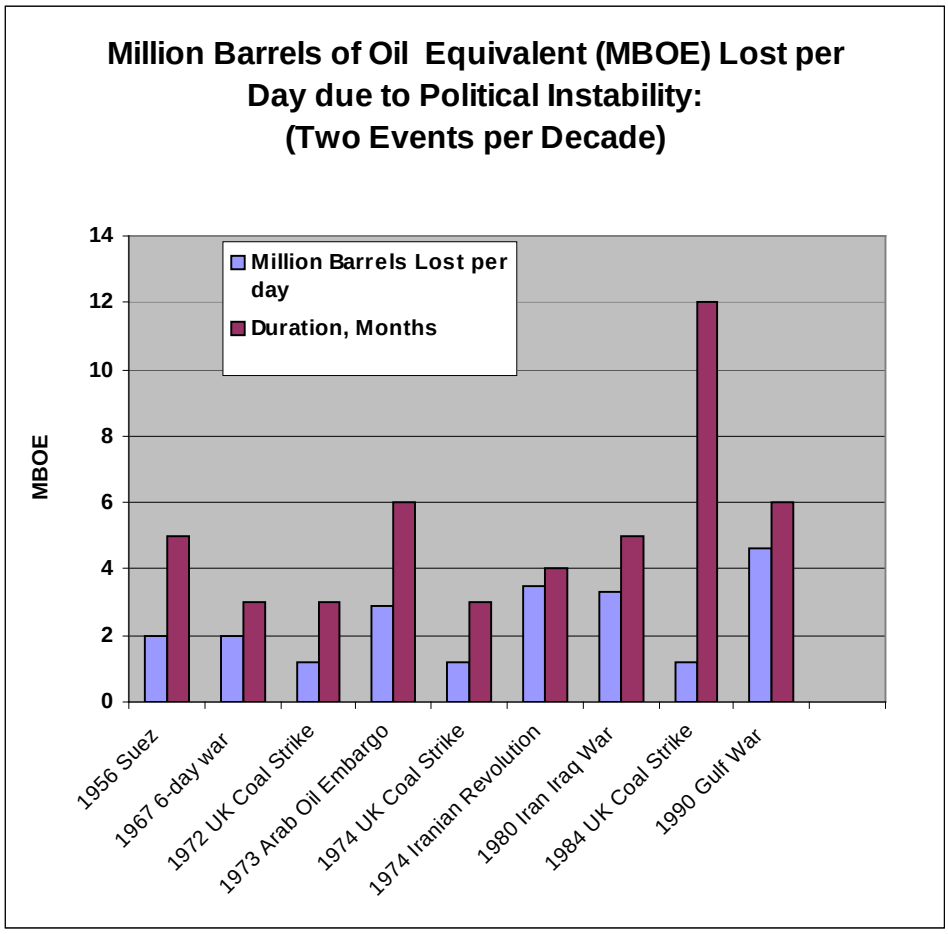


## *Political Disruptions of Fossil Fuel Supplies Have Occurred Twice per Decade in the last 50 Years.*

Disruption of oil and coal supplies due to political activities has occurred twice per decade in the last 50 years. The following graph illustrates this. (Britain used more than a million barrels of oil equivalent per day throughout the period of this graph).

Now not all of the oil was destined for the UK, but in the case of future deliveries of Russian gas, similar interruptions would deprive the UK of all the gas that it imports from Russia, for periods measured in months and of up to a years' duration or more. It may be objected that interruptions of this frequency and duration cannot be ***imagined,*** but the reality is that they have ***occurred*** for oil, that oil coming from countries that present similar Political Risks to Russia, the Ukraine and Belarus and for which the Political Risk Premiums are similar.

**Figure 9: Politically-Motivated Interruptions to UK Fossil Fuel Supplies, 1956-2002.**



If we ignore the coal strikes then oil supplies have been interrupted about 5% of the time. As explained this does not mean that the UK's oil supplies were entirely cut of for 5% of the period, since the loss was shared by several importers and the UK will have had other sources of supply. Nevertheless it led to important economic penalties on the UK economy, such as "The Suez Shilling" (an extra payment for oil) and "The Three Day Week" (because there was insufficient energy to keep the UK factories going for a ***five*** day week). When, in 2020 and beyond, gas supplies from Russia suffer similar interruptions, as this work leads us to forecast they will, the UK will have to bear the brunt with little or no planned diversity.

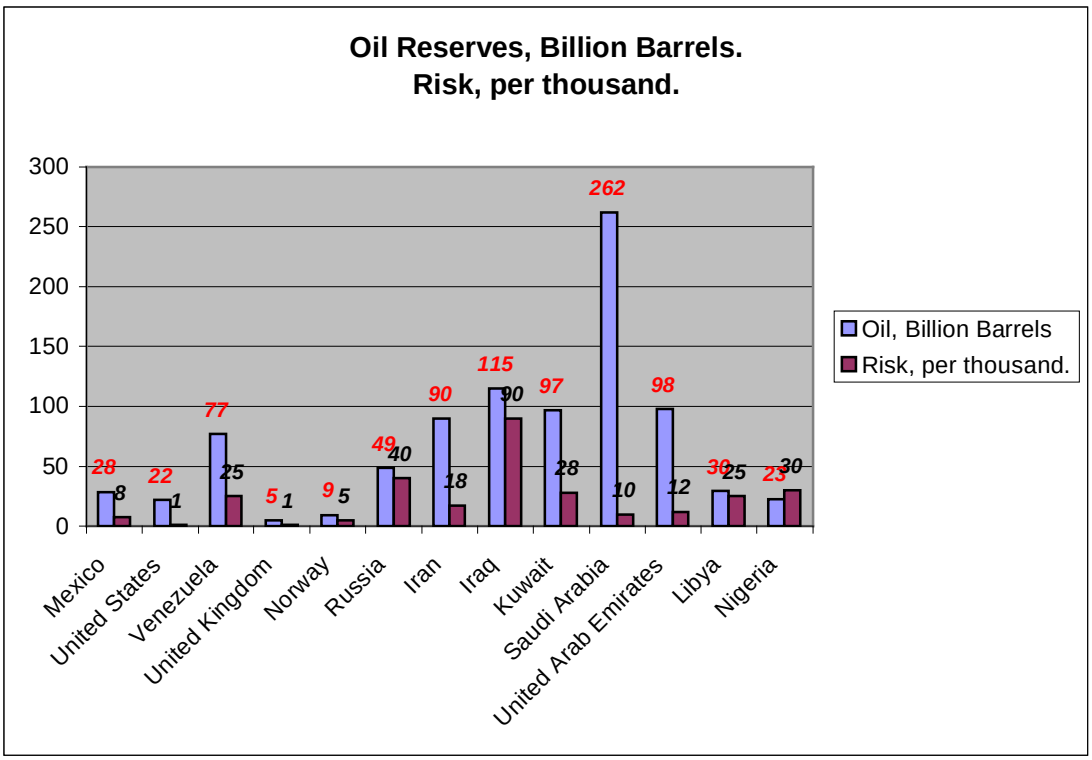
As we shall show in the next section, this figure of 5% is of the order of the Political Risk Premiums for the countries of the Middle East from which the oil came, which must be regarded as good agreement.

## *Political Risk for Oil Supplier Countries.*

First we shall illustrate(3) the locations of the world's main reserves of oil, coupled with the Political Risk Insurance Premium for 2002 for each of those countries.

These are shown in the following figure:

**Figure 10: Oil Reserves and Political/Business Risks for Various Countries.**



Clearly the UK's oil reserves are negligible and most of the world's oil is in the Middle East

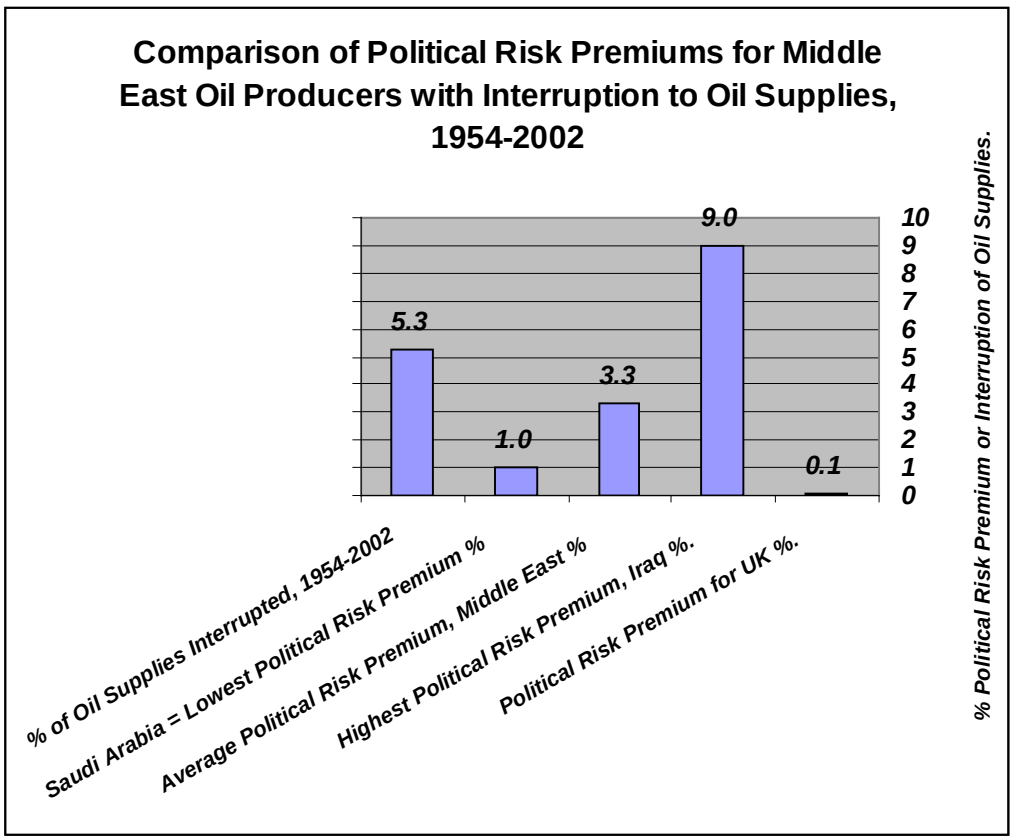
Indeed 700 billion barrels out of the world's 1,000 billion barrels of oil reserves are in the Middle East and the UK reserves amount to no more than 5 billion barrels.

When the UK's oil imports have been cut off, historically, it has been the countries of the Middle East that have cut them off.

For the countries of the Middle East that have the greatest oil reserves and which are shown in the above figure, the average Political Risk Insurance Premium in 2002 is 3.3% and the range is from 1% for Qatar to 9% for Iraq. This may be compared with a figure of 0.1% for the UK, Australia and Canada.

Clearly the Political Risk Insurance Premium for Middle East Oil States is similar to that for Russia, the source in coming years of the UK's gas and Ukraine and Belarus, the countries through which Russian gas will be piped to the UK.

**Figure 11: Political Risk Premiums for Main Middle East Oil Producers Compared to the Interruption of Oil Supplies, 1954-2002.**



The interruptions to oil imports were of similar ***daily magnitude*** to the UK's ***daily consumption*** of oil and occurred at a frequency of 6 in 46 years or one in eight years and this is the kind of pattern that we can expect for any politically-engineered interruption of fossil fuel supplies- the UK coal strikes generally lasted a significant part of a year- a whole year in the case of the last one, ***when significantly it was the country's nuclear power stations that helped to keep the economy alive***.

But what of pipeline interruptions in Russia, the Ukraine etc? Data on these is sparse, but several times in the first half of 2002, we have discovered that Russian companies cut off natural gas supplies to the Ukraine and Georgia to force payment of debts. Russian gas giant Gazprom is now suing Ukraine to pay for gas that Kiev has allegedly siphoned from the pipeline transiting its territory. Longer, less frequent stoppages may easily be envisaged, therefore.
We conclude, therefore, that:

- The actual Risk, in percentage terms, presented by Politically-motivated interruptions to oil supplies over the last half century is numerically similar to the Political Risk Insurance Premium for the countries of the Middle East from which this oil was imported.
- Those Premium-values are similar to the Premiums for the countries from (and through) which the UK will be importing most of its gas in 2020 and the years leading up to 2020.
- If interruptions of gas supplies follow the pattern of historic interruptions of oil and coal supplies in terms of duration and frequency, then we can expect them to occur at intervals of order 10 years and to last a significant part of a year on each occasion. The sparse data that are available show that politically-motivated interruptions of pipelines is already commonplace in Russia and in pipelines from Russia to Ukraine.
- In what follows we shall assume, therefore, that the frequency, per year, of interruptions to Russian gas will be proportionate to the Political Risk Insurance Premium. We shall make use of the correlation that we have found, between this Premium and the Political Risk Index to forecast Premiums for future years to 2020. A Premium of 5% would then imply, in the simplest case, that interruptions of 6 months could be expected every 10 years. This, as we have shown, is essentially the historic pattern for supplies of oil imported by the UK from countries for which the Political Risk Premium is around 5%[10].

[10] More exactly, we can expect a few longer periods of interruption and the greater the length of a given class of interruption, the less frequent such interruptions will be. This implies that if we fix on interruptions of a given length, say six months, then their frequency will be proportionate to the total annual risk, that is to say to the Political Risk Insurance Premium

# Forecast of Interruptions to Supplies of Russian Gas.

By 2020 most of the UK's natural gas, on present forecasts, will come from Russia. The main gas reserves are in the Yamal region (Yamal means "end of the earth") and they will arrive in Western Europe via two pipelines, Yamal-Europe 1 and Yamal-Europe 2. In this section we apply a combination of probability theory and Kirchof's laws to calculate the frequency with which one or both of these pipelines will be interrupted because of politically inspired events.

## Yamal-Europe 1, 2002.

Clearly the Political Risk to the Yamal-Europe 1 Pipeline, as indicated by the actual, incurred losses that have led to the Political Risk Insurance Premiums for 2002, will be concentrated in ***Russia***, where the Pipeline originates and ***Belarus*** through which Yamal-Europe 1 passes.

## Yamal-Europe 1 & 2, 2020.

The Future Political Risk to the Yamal-Europe 1&2 Pipelines, as indicated by the Political Risk Insurance Premiums forecast from Political Risk Indices for 2020, will be concentrated in ***Russia***, where the Pipelines originate, ***Belarus*** through which Yamal-Europe 1 passes and ***Ukraine***, through which Yamal-Europe 2 may pass.

## Principal of the Calculations.

Stripping away all mathematical complexity, the principal of the calculation can easily be understood by considering the following, simple examples, *in which the actual numbers used have no significance*:

Imagine that, at average intervals of 25years, the flow of gas from Yamal into the Yamal-Europe 1 pipeline is interrupted for 6 months due to political action, such as government intervention or terrorist attack.

The value of the gas lost would be $1/50^{th}$ of the total amount that should have been supplied in 25 years, since 6 months is $1/50^{th}$ of 25 years.

Suppose that we decide to put aside, in the bank, money so as to accumulate enough savings to recompense ourselves for the loss of 6 months' gas supplies: if we save this in installments over the 25 year period during which we expect a 6-month interruption in gas supplies then we shall have to save one twenty-fifth of the value of 6 months gas supply for each of the twenty-five years. This will give us a sum equal to the value of 6 months' gas supply at the end of 25 years. The annual sum that we save is, in fact, an ***insurance premium*** of $1/50^{th}$ of the value of one years' gas supply. That is to say, a Political Risk Insurance Premium of 1/50 or 2%. A commercial premium would be greater than this since it would include expenses and profits, but we shall

ignore these additions. Using the vocabulary of insurers, we are going to assume a ***Loss Ratio*** of 100%.

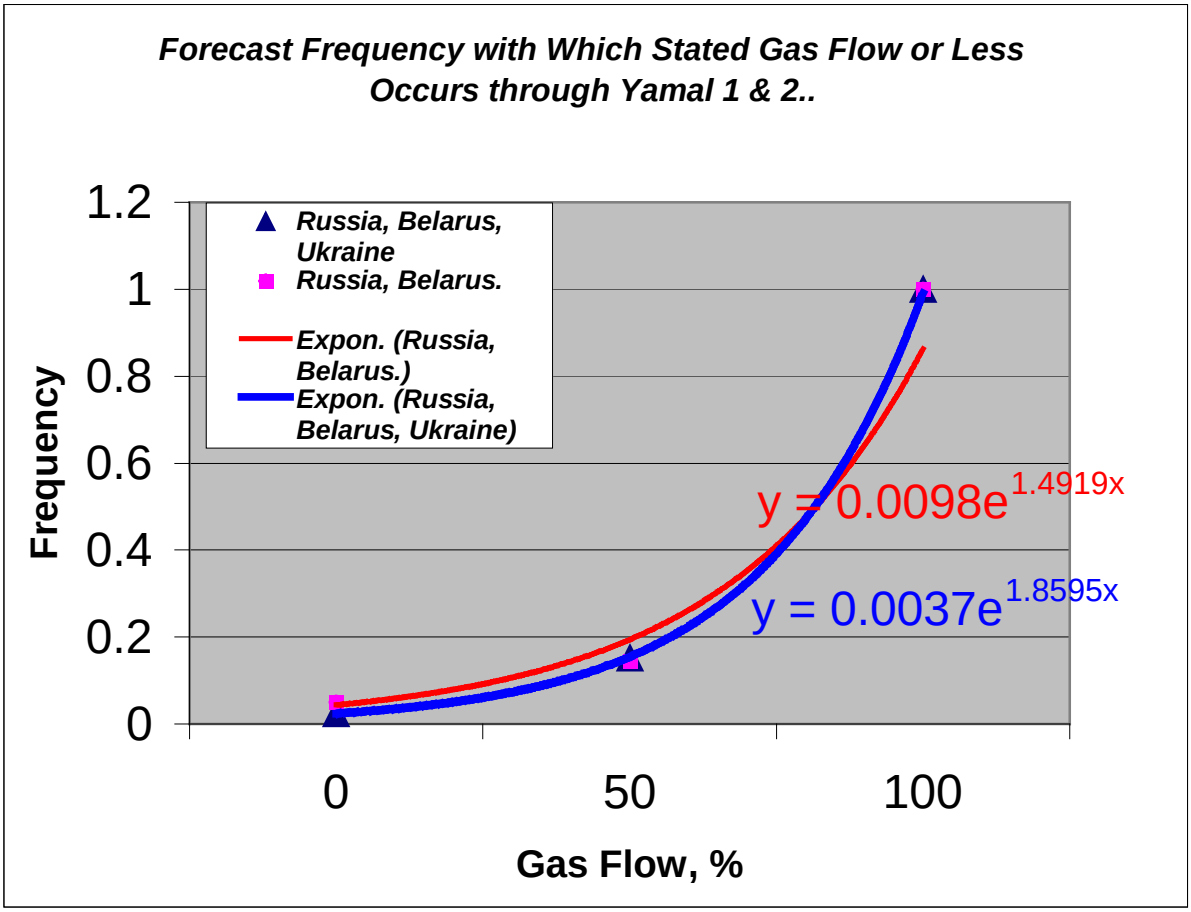
From the frequency and magnitude of the interruptions to Oil supplies that have occurred over the last half-century we infer that a Political Risk Insurance Premium of 2% means that major interruptions to gas flow will occur due to political intervention with a frequency of 2% or once every 50 years.

*More precisely, ignoring expenses and profit,*

- *The Premium is equal to the sum of **all products** such as the product of (Loss) x (Frequency of a Loss of this particular Magnitude).As large losses occur less frequently than small ones, there is some sort of inverse relationship between (Loss) and (Frequency) and so Premium can be taken as an indication of the Frequency of a Loss of a given size: say a Major Interruption to Gas Flow.*Two further examples help illustrate the effects of interruptions to the sections of the two Yamal-Europe pipelines that pass through Russia, Belarus and Ukraine:

- If gas flows into the Russian section of Yamal 1: 75% of the time and if it then flows on through the Belarus section 50% of the time, then it flows out of the Belarus section of Yamal 1: 75% x 50% = 37.5% of the time.If no gas flows through Yamal 1: 25% of the time and none through Yamal 2: 50% the time then no gas flows through either Yamal 1 or Yamal 2: 25% x 50% = 12.5% of the time.Applying these methods we arrive at the following relationships between frequency and the flow of natural gas from Yamal through the two Yamal-Europe pipelines in 2020:

**Figure 12: Figure: Forecast Frequency with Which the Stated Gas Flow, or Less, will Occur from Yamal in 2020.**

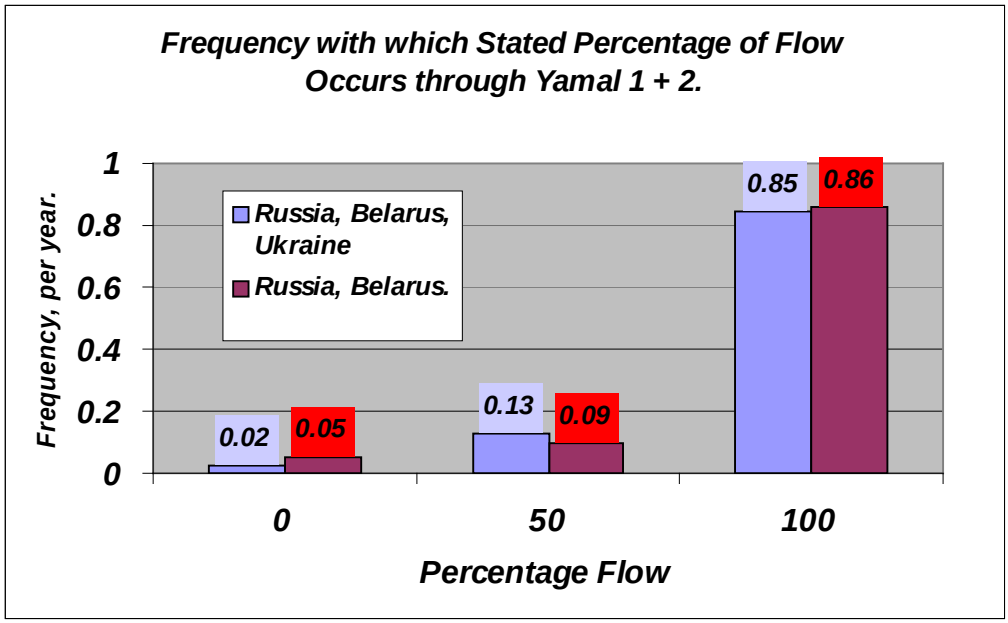



In each of the two cases in the above figure the gas-flow occurs through both of the Yamal-Europe pipelines. Each of the two cases is a forecast of the total of the flows through Yamal 1 and Yamal 2. In one case it is assumed that both pass through Russia and Belarus. In the other case it is assumed that one pipeline follows this route through Belarus, but the other is routed through Ukraine instead of Belarus.

Exponential curves prove to give a good representation of the forecast frequencies.

Another view of these same forecasts is given in the next figure. Here instead of plotting the frequency with which the stated flow, ***or less***, is forecast to occur, the forecast frequency of the stated flow is plotted.

**Figure 13: Forecast Frequency with which the Stated Percentage Flow Occurs through Yamal-Europe 1 & 2.**




Above, as before, in each of the two cases in the figure the gas-flow occurs through both of the Yamal-Europe pipelines. Each of the two cases is a forecast of the total of the flows through Yamal 1 and Yamal 2.

The forecasts show the advantage of ***diversity:*** Thus if one pipeline goes through Belarus and the other through Ukraine, then, compared with the case where both go through Belarus the frequency of zero flow has fallen from 5% to 2%. The reason for this is as follows: if ***both*** pipelines pass through Belarus, Belarus is likely to close ***both*** pipelines simultaneously to achieve some political end. We have assumed that if Belarus closes one pipeline then there is one chance in three that it will close the other as well. It is likely that there will be more than one chance in three, so this assumption is conservative. If one pipeline passes through Ukraine and the other through Belarus, then unless Ukraine colludes with Belarus, the chance that the Ukraine section will be closed when the Belarus section is closed is purely random.

As we have assumed that Belarus will tend to close ***both*** pipelines, rather than just one, on occasions when it seeks to achieve some political end, we have in this way reduced the frequency with which Belarus would close ***just one*** of the two pipelines. The frequency with which there is 50% flow is therefore lower, at 9%, for the case where both pipelines go through Belarus than for the case in which one goes through the Ukraine and the other through Belarus, where it is 13%.

Note, however, that when we consider the frequency with which the flow is ***50% or less*** these two opposing effects cancel out. Thus the frequency with which the flow is

50% or less is 15% when one pipeline goes through Belarus and the other through Ukraine. It is almost the same, at 14%, when both pipelines go through Belarus.

### *Conclusions about the Flow of Gas From Russia in 2020.*

It is forecast that, irrespective of whether or not one of the two Yamal-Europe gas pipelines passes through Ukraine:

- There will be no Yamal gas flow to the UK for a few percent of the time.For about 15% of the time, Yamal gas will flow to the UK at 50% or less than the intended rate.

## Forecasts of Interruptions to Gas from Iran and Russia.

In this section of the Report we give the results of a similar analysis for the flow of natural gas by pipeline from Iran to the UK.

Iran has been chosen as it has the second largest reserves of natural gas in the world, second only to Russia. Iran and Russia are making preparations to supply Europe with natural gas. However, in order to boost oil and natural gas exports from the Caspian Sea region, a number of issues will need to be addressed. During the Soviet era, all of the oil and natural gas pipelines in the Caspian Sea region (aside from those in northern Iran) were designed to link the Soviet Union internally and were routed through Russia.

From the forecast Political Risk indices and Political Risk Insurance Premiums for Iran in the years up to 2020 the following forecasts are produced, and are here tabulated and plotted together with those already presented for Russia to permit a comparison.

We shall assume that the UK imports natural gas from Russia and from Iran.

As has been explained Russia has the largest reserves of natural gas in the world and Iran has the second largest.

We have also seen that Russia and Iran are making preparations to become the world's biggest and second biggest suppliers of natural gas.

We assume that the UK imports natural gas from Iran and Russia in amounts that are proportionate to the natural gas reserves of the two countries.

This means, that of the natural gas which the UK will import from (Iran plus Russia):

- 27% will come from Iran and the balance of
- 73% will come from Russia.

Russia is keen that the gas pipelines from Iran should be routed through Russia. However Iran and its potential customers are aware that there will be a risk that Russia will then interrupt the flow of Iranian gas in order to obtain political or business advantages. There are therefore moves to install pipelines to Europe from Iran that do ***not*** pass through Russia and in the present analysis I have assumed that gas to the UK from Iran flows exclusively through pipelines that pass through countries that present a political risk small enough to be neglected compared to that evidently presented by Iran itself.

In each of the three cases in the following Table and Figure the gas-flow occurs through both of the Yamal-Europe pipelines. Each of the cases contains a forecast of the total of the flows through Yamal 1 and Yamal 2.

The three cases considered in Figure 14 and Figure 15 are as follows:

A. Gas comes to the UK through two pipelines from Russia, one via Belarus and Ukraine; the other via Ukraine,
B. It comes from Russia through two pipelines both of which are routed via Belarus or
C. It comes through three pipelines, one from Iran, the second from Russia via Belarus and Ukraine; the third from Russia via Ukraine

Cases A and B have already been considered in the earlier part of this Report and are here included for the purposes of comparison.

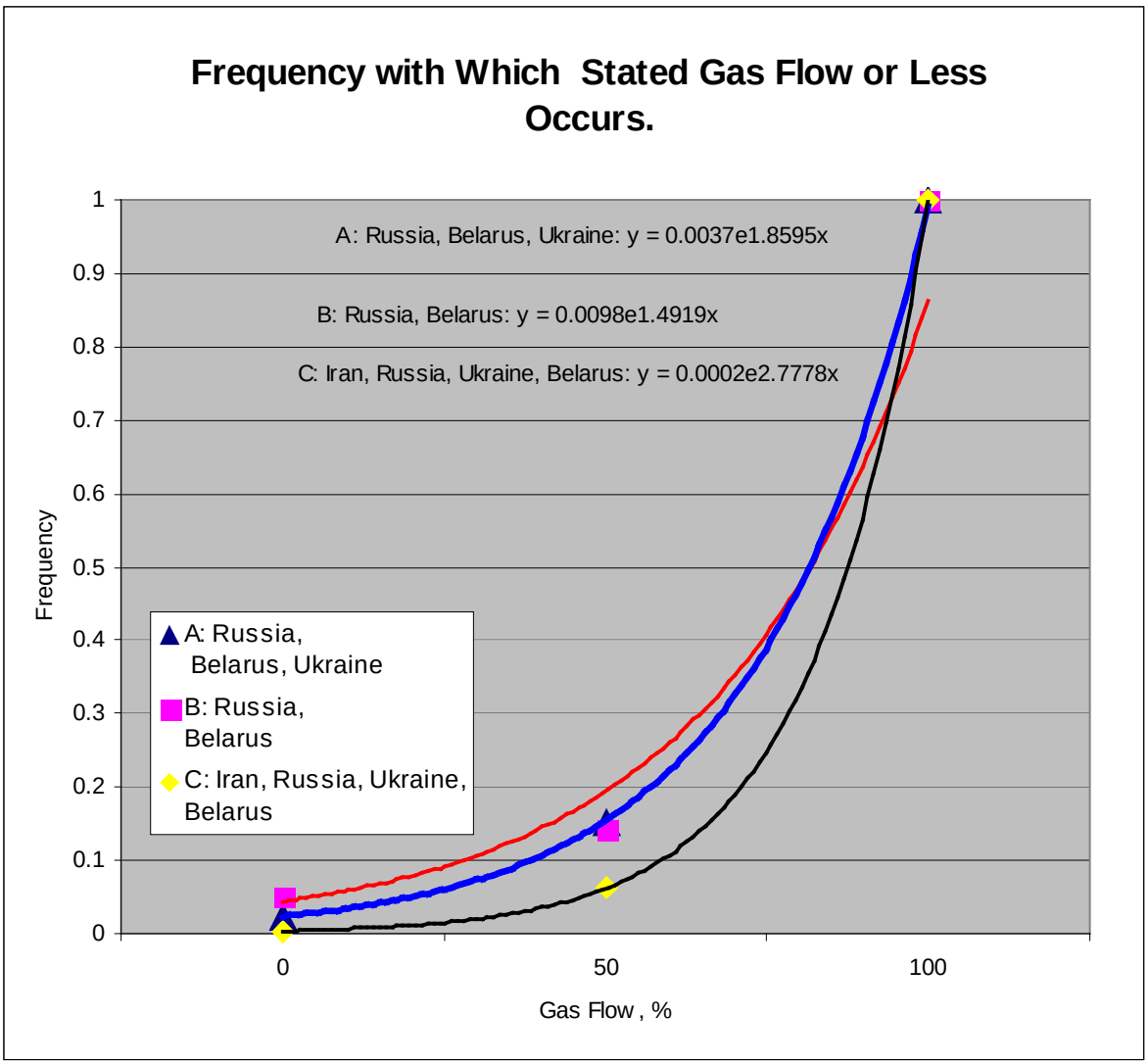
## *Figure 14: Frequency with which the stated % of Gas or less arrives in UK either*

- **A. Through two pipelines from Russia, one via Belarus and Ukraine; the other via Ukraine, or**
- **B. from Russia through two pipelines both of which are routed via Belarus or**
- **C. through three pipelines, one from Iran, the second from Russia via Belarus and Ukraine; the third from Russia via Ukraine**

| % of Flow | 0% | 50% | 100% |
|---|---|---|---|
| A. Russia, Belarus, Ukraine | 0.024256 | 0.151744 | 1 |
| B Russia, Belarus | 0.0506 | 0.1446 | 1 |
| C Russia, Belarus, Ukraine, Iran | 0.004 | 0.062 | 1 |

## *Figure 15: Frequency with which the stated % of Gas or less arrives in UK either*

- **A. Through two pipelines from Russia, one via Belarus and Ukraine; the other via Ukraine, or**
- **B. from Russia through two pipelines both of which are routed via Belarus or**
- **C. through three pipelines, one from Iran, the second from Russia via Belarus and Ukraine; the third from Russia via Ukraine.**




The improvement in Security of Supply produced by diversity, of pipeline-routes and countries of supply, is immediately evident.

In Figure 1 I assume case C, the most diverse case.

### *Russia and Iran to cooperate in fuel and energy sector*

In this analysis I have assumed that if Iran interrupts our gas supplies, then Russia will not decide to join-in. However there will be a chance that this will occur.

Thus, an Iranian-Russian task force will be in charge of negotiations on the possible participation of Russian enterprises in joint projects in the fuel and energy sector. An agreement on the creation of this group was achieved at a meeting of Russian Energy Minister Igor Yusufov and Mohammad Froozandeh, the Chairman of the Mostazafan Foundation, on April 8th 2003. Froozandeh declared the foundation was ready for active collaboration with Russian enterprises. In particular, he mentioned concrete proposals concerning participation of Russian companies in the foundation's large projects aimed at constructing electrical power stations, modernizing thermoelectric power plants, conducting drilling activities on oil and gas fields and supplies of Russian oil and oil products to Iranian northern regions.

## Minor Terrorist Activity.

Here the scenario that I consider is this: A terrorist blows up a gas pumping station or severs gas pipe(s). The design of the equipment is such that the frequency with which this happens will be the frequency with which a weak Line of Defence (LOD) fails, in this case under terrorist action. A weak LOD includes Human Failures, in this case the failure to identify and prevent a terrorist threat.

The frequency with which a weak LOD fails is of order 0.01/year. The design intent is that no single cause shall contribute more than one tenth of this frequency. In the Report on Nuclear Energy, produced under this Contract, as in my work on Terrorism for HMG, I have argued that the terrorist threat is an order of magnitude higher today than it was when (for example) nuclear power reactors were designed. The outcome of this analysis is that the minor-terrorist risk to gas transmission is now 0.009/year.

## Major Terrorist Activity.

Here the scenario that I consider is this: Terrorists "do a World Trade Centre", sabotaging not just one pipe (c.f. one WTC tower) but all the Yamal 1 pipes, for example.

The design of the equipment is such that the frequency with which this happens will be the frequency with which a strong Line of Defence (LOD) fails, in this case under terrorist action. A strong LOD comprises engineered safeguards, designed inter alia to prevent terrorists damaging the plant.

The frequency with which a strong LOD fails is of order 0.0001/year. The design intent is that no single cause shall contribute more than one tenth of this frequency. In the Report on Nuclear Energy, produced under this Contract, as in my work on Terrorism for HMG, I have argued that the terrorist threat is an order of magnitude higher today than it was when (for example) nuclear power reactors were designed. The outcome of this analysis is that the major-terrorist risk to gas transmission is now 0.00009/year.

## Minor Equipment Failure.

The scenario that I consider here is minor equipment failure due to internal or external events: fatigue or earthquake for example. It includes such things as serious damage to existing, operational pipes during digging the trench for adjacent new pipes.

The design of the equipment is such that the frequency with which this happens will be the frequency with which a weak Line of Defence (LOD) fails, i.e. 0.01/year.

## Major Equipment Failure.

Here the scenario is that, due to internal or external events, there is a release of gas from a small fracture followed by fire that renders pumps inoperative.

The design of the equipment is such that the frequency with which this happens will be the frequency with which a strong Line of Defence (LOD) fails, i.e. 0.001/year.

## Diversion of gas by Ukraine and Belarus.

Ukraine and Belarus are allowed to take gas from the pipeline to pay them for allowing it to cross their countries. They commonly take too much. If they take a lot, then by the time Germany and France have had their share, there may be a small shortfall in the amount reaching the UK.