# The Future Security of UK Electricity Supplies: An Analysis.

Prepared By

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

August 17th 2002.

## 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 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 and other companies in the Lloyd's of London nuclear insurance market 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 the strongest of the early "Nimonic" 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, he 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.

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**
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# Contents.

# The Future Security of UK Electricity Supplies: An Analysis.

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## Summary

There are mounting concerns that supplies of Russian gas, the main source of UK electricity in 2020 and thereafter, will prove unreliable. The UK has experienced half a dozen politically-motivated interruptions in its imports of ***oil***, leading for example to the "Three Day Week"; Russia seems no more likely to be reliable as a source of the UK's gas than the Middle East has been a reliable source of oil, but how are these concerns to be ***quantified***?

A means of quantification does exist:

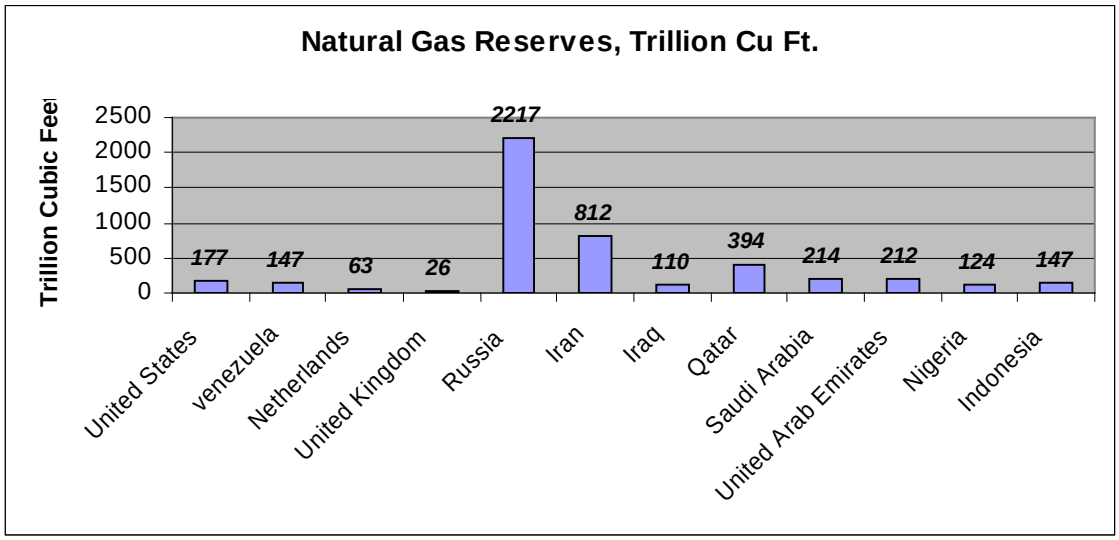
- the business world has developed data-bases on ***political risk*** for most of the countries of the world and
- within the business world, the insurance companies have extensive data on the losses that have been sustained due to political action in all countries since they insure many of those risks.

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 gas supplies in the years to 2020 and beyond. The same approach is used to examine the likely reliability of supplies of the other two fuels that the UK imports to produce electricity: coal and uranium. This enables the reliability of the UK's electricity supplies in the years up to 2020 and beyond to be analyzed.

The analysis is repeated for scenarios in one of which, instead of allowing nuclear power to die out, new nuclear power stations are built to replace the old ones as the latter reach the end of their lives. In a more radical scenario it is assumed that, as supplies of UK gas are exhausted, additional nuclear stations are built instead of importing Russian gas, to keep pace with rising demand for electricity.

## By 2020 Most UK Electricity will be Generated from Russian Gas.

It is forecast that, by 2020, most of the UK's electricity will be generated from gas.[1] Currently the UK is self-sufficient in Gas, but our reserves will virtually have run out by 2020. 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




The Yamal peninsula 73°30' northern latitude, almost 800 km to the North from the Polar Circle contains the largest natural gas field in the world and by 2020 it will be the main source of the massive gas flows to Europe, with the UK at the far end of the pipelines. It is situated in the Yamalo-Nenetsky autonomous region of Russia.

## Russian Gas will Travel 4,000km Along Pipelines from Yamal to the UK.

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

[1] The 1998 White Paper *Energy Sources for Power Generation* (Cm 4071) states that the UK will become a net importer of gas at some point between 2003 and 2009, and import 55-90% of our gas by 2020.

## Reliability of UK Electricity Generated from Russian Gas.

The reliability of the supplies of UK electricity generated from Russian gas are, in this Report, calculated from data on

- Political Risks
- Political Risk Insurance and
- Politically-motivated interruptions that have, historically, occurred to fossil fuel supplies.

The purpose of the 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 forecasts are routinely used, by business, for that purpose and in this Report they are used to help analyse the likely reliability of gas imports from Russia.

***Political Risk*** information and ***Political Risk Insurance*** information are available for 137 countries, including Russia, Ukraine, Belarus, Poland and other countries through which Russian gas will be piped to the UK. This information is also available for all the countries of the Middle East from which, before the discovery of North Sea Oil, Britain was reliant for its oil supplies. It is also available for all the countries that export coal and all that export uranium, the UK's other main sources of energy.

***Political Risk Insurance Premiums*** from one data base are here compared with ***Political Risk Indices*** from a second, independently-produced data base: Russia, Ukraine and Belarus attract some of the highest premiums and have the highest Risk Indices, whether for Export, Import, Confiscation or Bond-Calling risks. The UK, Australia, Canada, Germany and Poland all attract low premiums and have the lowest Political Risk Indices.

This correlation extends to all the 137 countries for which the databases provide information. It means that we can calculate future values of Political Risk Insurance Premiums from future estimates of Political Risk Indices. In this way values of Political Risk Indices and Political Risk Insurance Premiums have been calculated for 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 go on to show that the premiums are of the order that would have paid to insure the politically-motivated interruptions that have, historically, occurred to the UK's imports of fossil fuel. This gives confidence that we can use such premiums to forecast the frequency and duration of future interruptions to Russian gas imports.

## Historic Disruption of the UK's Fossil Fuel Supplies.

Disruption of oil and coal supplies due to political activities has occurred twice per decade in the last 50 years. This does not mean that the UK's oil supplies were entirely cut off, since several importers shared the loss 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). 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.

If we ignore the coal strikes then oil supplies have been interrupted about 5% of the time and in this Report we show that 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. 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 similar also to those for Ukraine and Belarus (the countries through which Russian gas will be piped to the UK).

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, 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.

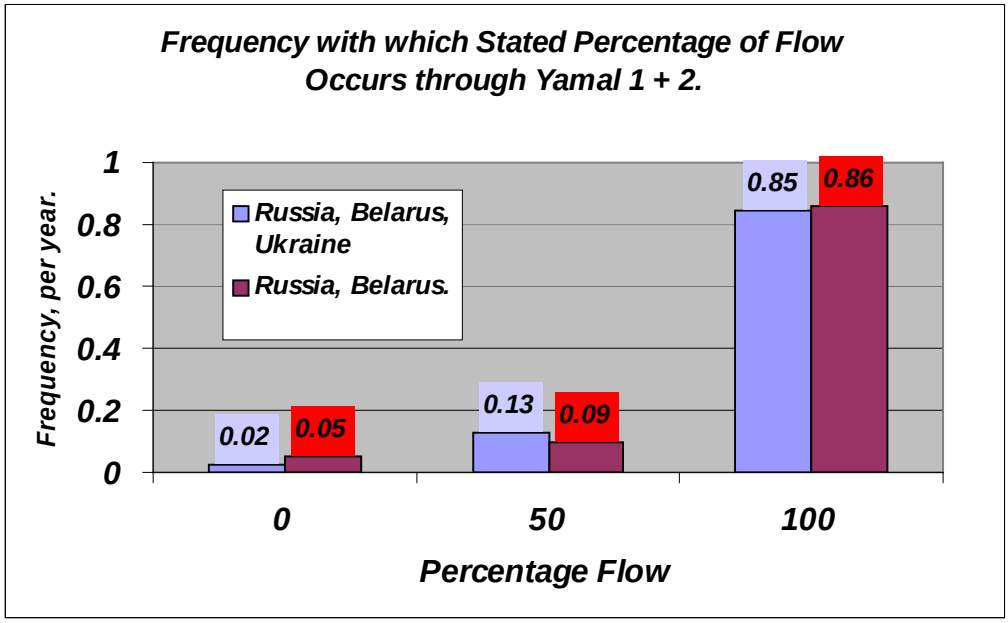
## Risk of Interruption of UK's Gas Imports from Russia.

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 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 are already commonplace in Russia and in pipelines from Russia to Ukraine.
- We shall assume, therefore, that the frequency, per year, of interruptions to Russian gas will be proportionate to the Political Risk Insurance Premium. We 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%[2].

We apply a combination of probability theory and Kirchoff's laws to calculate the frequency with which one or both of the pipelines that will bring Russian gas from Yamal to the UK will be interrupted because of politically inspired events. 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:




Two cases are shown above: in one case Yamal 1 and Yamal 2 both pass through Belarus and in the other case Yamal 1 passes through Belarus and Yamal 2 passes through Ukraine. In the above figure, each of the two cases is for the combined flows of both pipelines.

The analysis forecasts that there will be no flow of gas through either pipeline for a period lasting several months with a frequency of 0.02 to 0.05 per annum, depending on the routes of the pipelines. There will only be a 50% flow with a frequency of 0.09 to 0.13. Full flow will occur the balance of the time, that is with a frequency of 0.85 to 0.86 per annum.

## Reliability of the UK's Coal Supplies.

[2] 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

The same analytical approach that has been developed for gas has been, in this Report, applied also to UK coal imports. In view of the low Political Risk presented by the UK and by four or more other countries, each of which is separately capable of supplying all the UK's coal imports, together with the UK's stocks and production potential, it is concluded that there is about a chance in a million of the UK's coal supplies drying up.

## Reliability of the UK's Supplies of Nuclear Fuel.

Following the same procedure, the following conclusions are drawn concerning the reliability of the UK's supplies of nuclear fuel:

- The UK has nuclear fuel and uranium stocks sufficient for more than one year.
- The UK has adequate domestic enrichment facilities.
- Australia and Canada, two uranium exporters that present low Political Risks, are amongst the several countries capable of supplying the UK's uranium needs.There is, therefore, perhaps a chance in a million of inadequate supplies of nuclear fuel for the UK's reactors.

## The Renewables.

In 2020, in the UK, wind generators will provide most of the "renewable" energy. On average wind generators supply 30% of their rated capacity. In general, winds exceeding 5 m/s (11 mph) are required for cost-effective application of small grid-connected wind machines, while wind-farms require wind speeds of 6 m/s (13 mph) There is a finite chance that they will all be stationary and supply no electricity at all but the important thing in the present context is that the wind will certainly not stop blowing altogether for a continuous period lasting several months, once or twice in every decade. Oil supplies have dried up for several months every decade and this Report concludes that, for the same type of political reasons, Russian gas will too.

We do not, therefore, take account of the intermittency of wind power and the other new renewables: it is important but it is not to be compared with the much less frequent, much more protracted intermittency stemming from political interruption of, say, Russian gas (or Middle Eastern oil) imports.

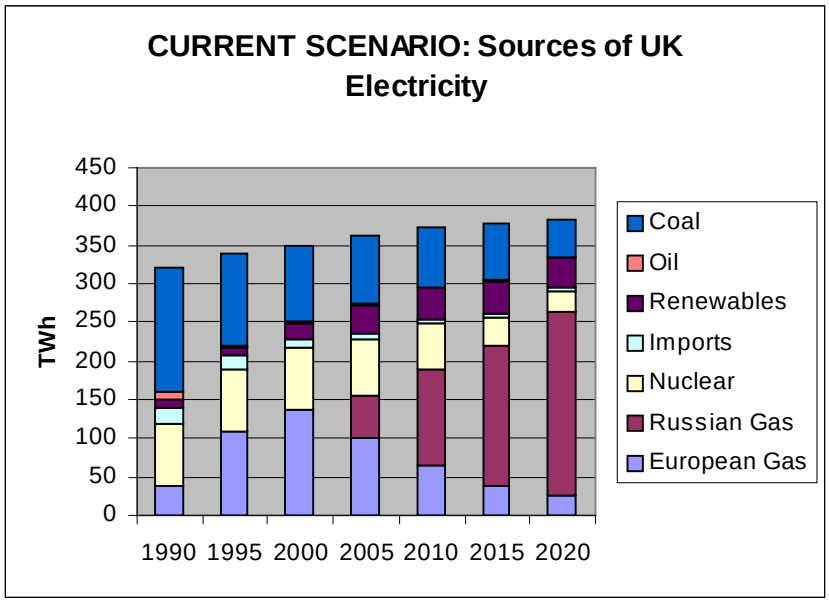
## Reliability of Electricity Supplies.

As summarized above, the reliability of each of the main contributions to UK electricity supplies in the years up to 2020 has been analyzed. Combining these estimates, the reliability of UK electricity supplies in total, up to 2020 has been forecast for the three scenarios: "current", "new nuclear for old" and "nuclear instead of Russian Gas".

As presently envisaged, the sources of UK electricity from now until 2020 will be as shown in the following figure. The division of gas between European supplies and supplies from Russia plotted in this figure does not appear in the DTI forecasts. It has been derived here from forecasts of the way in which European gas reserves will decline in the next few years.

This Scenario is characterised by:

- The inexorable rise of Russian gas, to become by far the most important source of the UK's electricity
- The virtual disappearance of nuclear power by 2020
- The steady reduction, to about one third of the present level, in the use of coal to generate electricity
- The virtual elimination of oil as a source of electricity
- The emergence of the renewables, which effectively take over most of the capacity relinquished by nuclear




The frequency of availability of electricity in the UK has been calculated for this, the present Scenario and the results are as follows:

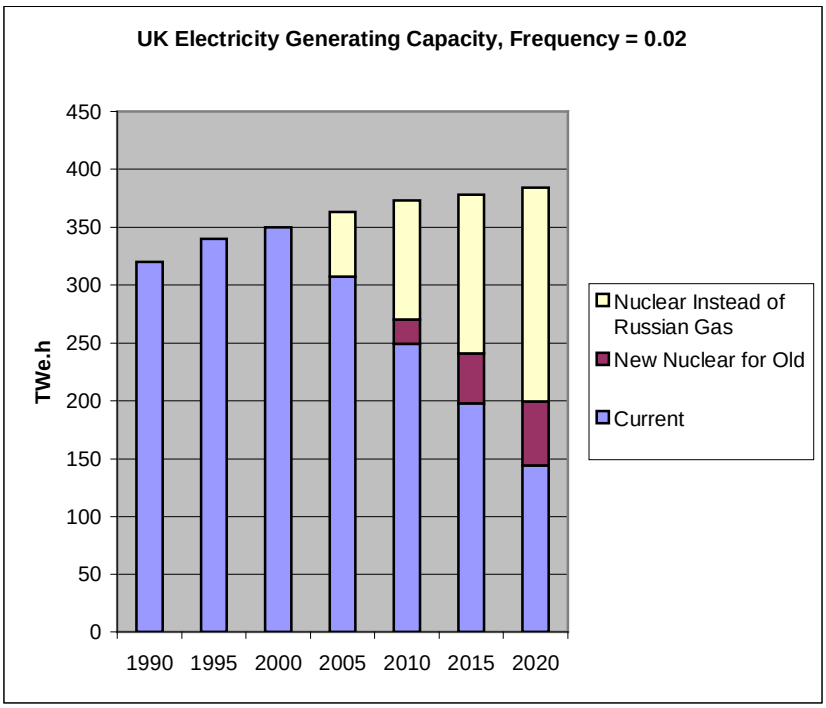
- With a frequency of 0.86/year, if Yamal-Europe 2 goes through Ukraine and 0.85/year if, like Yamal-Europe 1, Yamal-Europe 2 goes through Belarus, the full capacity for electricity generation will be available.
- With a frequency of 0.09 (0.13 if Yamal 2 goes through Belarus) per year, only approximately three quarters of the UK's generating capacity will be available, the balance being offline due to politically-inspired interruptions of supplies of gas from Russia.
- With a frequency of 0.05 (0.02) per year, only approximately one third (actually 37.5%) of the UK's generating capacity will be available, the balance being offline due to politically-inspired interruptions of supplies of gas from Russia.

The second Scenario, in which new nuclear power stations are built to replace the old ones as the old ones are shut down, offers improvements in the reliability of supplies, largely because imports of Russian gas are reduced. Now:

- With a frequency of 0.05 (0.02) per year, approximately one half (actually 51.82%) of the UK's generating capacity will be available, the balance being offline due to politically-inspired interruptions of supplies of gas from Russia.

In the third Scenario, additional nuclear stations are built to replace the old and provide for the increasing demand: no Russian gas needs to be imported. Now the full generating capacity is available, with a high level of security.

The following diagram summarizes these forecasts.




## Concluding Remarks.

It is concluded that reliance upon Russian gas as the main source of the UK's electricity in the years ahead will lead to the same kind of politically-driven interruptions that characterized Britain's Middle Eastern oil imports, in the days before our North Sea oil came on stream. Thus, the Political Risk to business, in Russia, as forecast by two business-oriented databases, is high and similar to that in Middle Eastern countries. It correlates, numerically, with the losses of oil imports suffered as a result of political intervention by these Middle East countries.

A solution to this problem would be to make more use of nuclear power, since the countries that supply nuclear fuel present very much lower Political Risks: up to one hundred times lower than those presented by countries that supply oil and gas.

Of two scenarios examined, "new nuclear for old" offers a useful improvement in electricity supplies but the full benefit is obtained by building nuclear stations instead of importing Russian gas: then the UK's electricity supplies become virtually immune to politically-motivated interruption.

***(End of Summary)***

# The Future Security of UK Electricity Supplies: An Analysis.

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## Introduction.

*4.32 Of the main fuels available to the UK – coal, oil, gas and uranium and renewable energy – only gas and oil raise major strategic risks. Uranium is plentiful, widely distributed throughout the world and currently cheap. Even more important, it is a very small proportion of the cost of nuclear power generation, so the economic impact of price risk is small. Storing future uranium needs is straightforward in physical and economic terms. Proven world coal reserves are very large and well spread geographically: some estimates suggest that there are more than 200 years worth of world use at current production levels. Coal is currently available on world markets, and from domestic sources, either deep-mined or open cast. The world industry is generally competitive, though there have been some indications of market consolidation into a few large companies, in efforts to reduce over capacity, and possibly to increase prices. The UK has a large indigenous renewable energy resource.*

*4.33 The main strategic risks of imports have traditionally concerned oil and now, prospectively, gas…*

*4.2. Concerns about imports focus on the exercise of market power, the political unreliability of possible suppliers or lack of investment overseas. The UK is currently more than self-sufficient in gas and oil, but over the next decade it will become a net importer of gas. Net oil imports are likely to follow in the 2010s. The precise dates by which the UK will become a net importer are a matter of some dispute: progress in energy efficiency, and market and technology conditions will have significant effects on timing, and projects such as PILOT are likely to yield extra exploitable UKCS resources.*[3]

There are mounting concerns that Russian gas, the main source of UK electricity in 2020 and thereafter, will prove unreliable. The UK has experienced half a dozen politically-motivated interruptions in its imports of ***oil***, leading for example to the "Three Day Week"; Russia seems no more likely to be reliable as a source of the UK's gas than the Middle East has been a reliable source of oil[4]. But how are these concerns to be ***quantified***?

[3] Excerpt from The Energy Review A Performance and Innovation Unit Report - February 2002

[4] For example, the EU's Energy Commissioner, Loyola de Palacio says, in his *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

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 gas supplies in the years to 2020 and beyond. The same approach is used to examine the likely reliability of supplies of the other two fuels that the UK imports to produce electricity: coal and uranium. Combined with an appreciation of the contribution of renewable sources of electricity, this enables the reliability of the UK's electricity supplies in the years up to 2020 and beyond to be analyzed.

As will be seen below, the forecast so arrived at is not encouraging and this leads to the question: what should be done to ensure that future UK electricity supplies are as reliable as today's? For we have grown accustomed to reliable supplies ever since the UK became self sufficient in all three fossil fuels: gas, oil and coal. The UK's other main source of electricity is nuclear power, which can rely on imports of uranium from such friendly countries as Canada and Australia and which is seen to have played a major role in "keeping the lights burning" during the year-long UK miners' strike.

To answer that question, other scenarios are analyzed, chosen for their practicality but with an eye to economics, since if we are to retain our seat with the G8 the UK must have reliable supplies of ***affordabl***e electricity; there is no point in having secure supplies if they are so costly that we cannot afford to use them and if they make our exports unaffordable.

## Sources of the UK's Electricity.

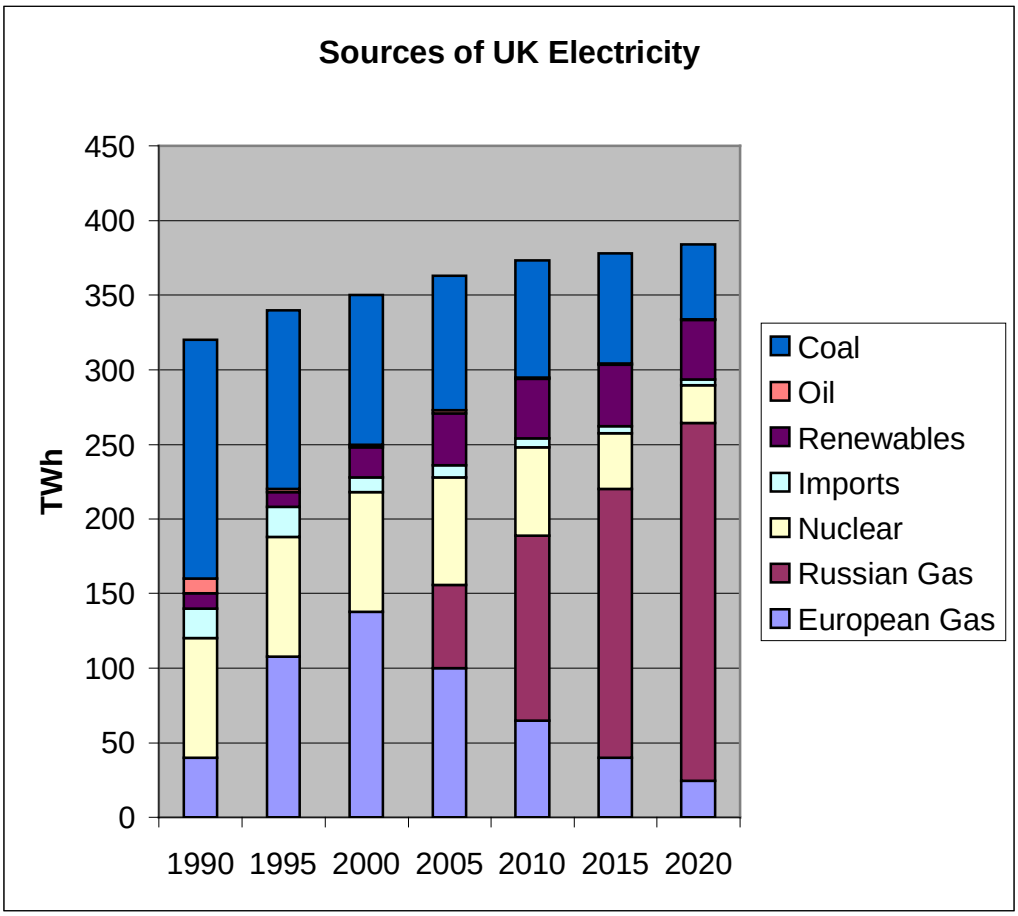
It is forecast that, by 2020, most of the UK's electricity will be generated from gas. [5]

*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

[5] 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 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.

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 and Countries of the Former Soviet Union. 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: Present Forecasts of Sources of UK Electricity, to 2020.**



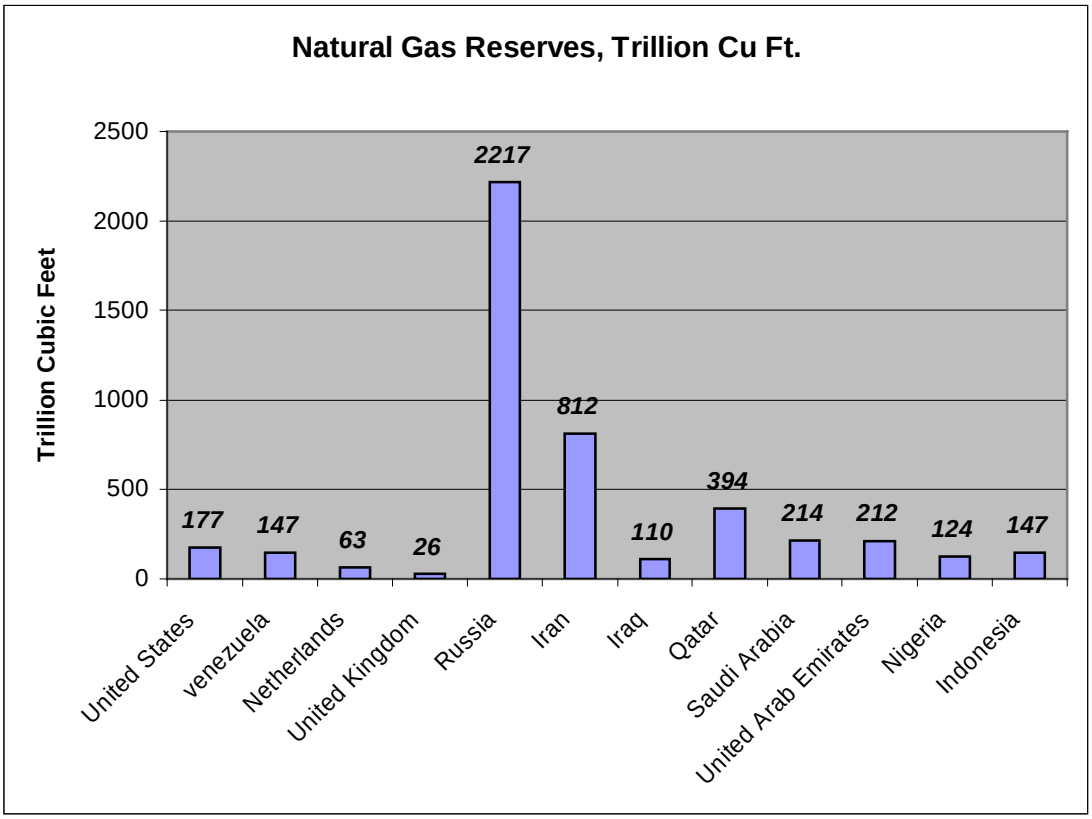

[6] Taken from the PIU Report, with the division of gas between European and Russian sources inferred from information in that Report about the decline in UK and European gas supplies in the coming 20 years or so.

## Sources of Natural Gas, 2001 [7]

The following figure shows the natural gas reserves of the countries that had the biggest reserves in 2001.

Note that Russia has overwhelmingly the largest reserves, at 2,217 trillion cubic feet (tcf). Those 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.




[7] *Last Updated on 4/23/02 By EIA Email: patricia.smith@eia.doe.gov*

## Trade in Natural Gas in Eurasia.

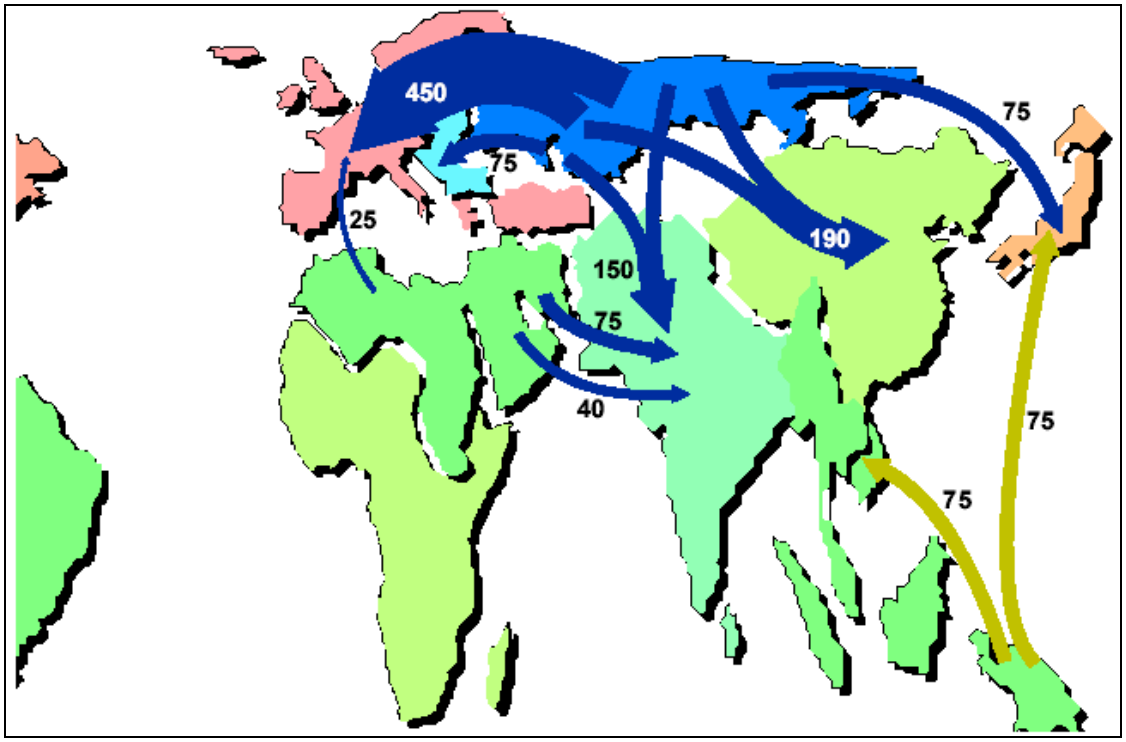
The following figure shows forecasts for the natural gas trade within Eurasia in 2050 for a global scenario with rapid economic development and accelerated investments in gas production and transport infrastructures. Flows denote pipelines and LNG routes, width of trade “arrows” is proportional to gas-flows, 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[8].

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).

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.

[8] 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

**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 [9].

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.

Data on natural gas reserves in relation to production make it clear that the long term future of gas supply belongs to the Former Soviet Union (FSU) and Middle East (MEA) since they account for 35 and 30 percent, respectively, of proven recoverable and estimated additional reserves of conventional natural gas. The sum of conventional, as well as unconventional, natural gas reserves and resources in the FSU are estimated to amount more than 2,000 times world annual gas consumption.

[9] 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. [10]

There will be two main pipelines, or 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).

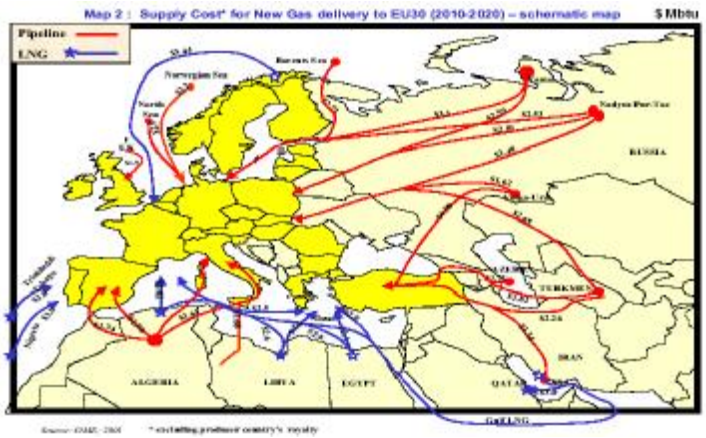
The first leg of the Yamal-Europe pipeline, which is routed through Belarus and Poland to Germany, is Russia's only natural gas export pipeline to Europe that is not routed through Ukraine.

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

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. As a result, Yamal-Europe II appears to be on hold.



# 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[11] and
- Political Risk Insurance[12]
- Politically-motivated interruptions [13]that have, historically, occurred to fossil fuel supplies.

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

## Table: 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 | |

[11] •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.

[12] •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.

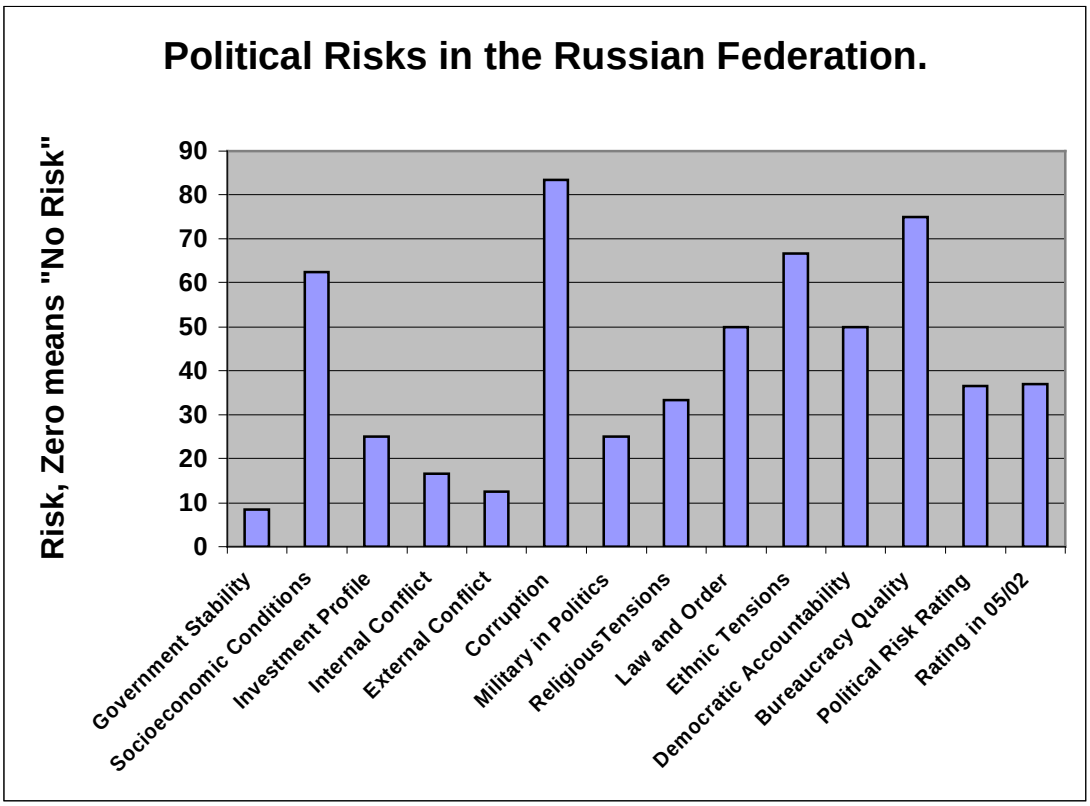
[13] The Data on interruptions to the UK's oil and coal supplies have been taken from news items that appeared in the media at the time of each interruption.

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 last two bars on the right hand side of this figure represent values for the Political Risk calculated for January and May 2002.

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: Political Risks in the Russian Federation.**



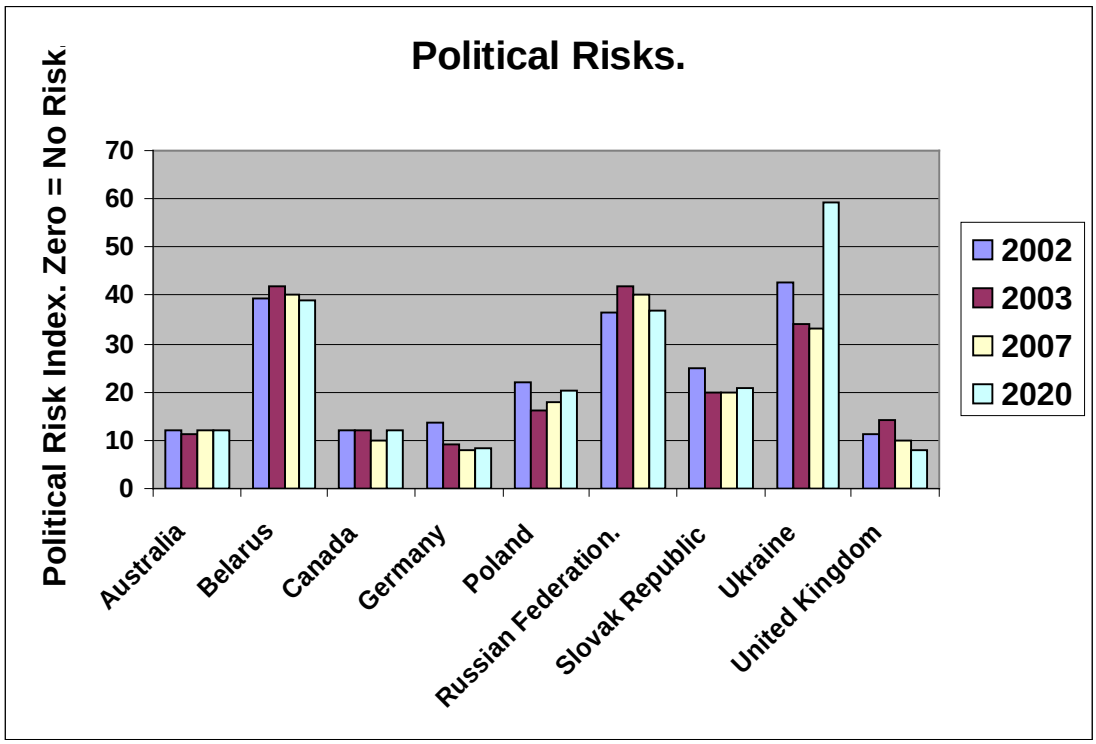
## Relative Political Risks for UK and Gas and Uranium Supplier Countries.

In the next figure the Political Risk Index for the Russian Federation is compared with that for the UK and proves to be three times greater. Of course the absolute magnitude of the difference 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 to the UK) have low Political Risk Indices similar to that of the UK.

By way of contrast, Ukraine and Belarus, countries next to Russia through which Russian gas will first pass on its way to the UK, are as bad as Russia.

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: Relative Political Risks.**



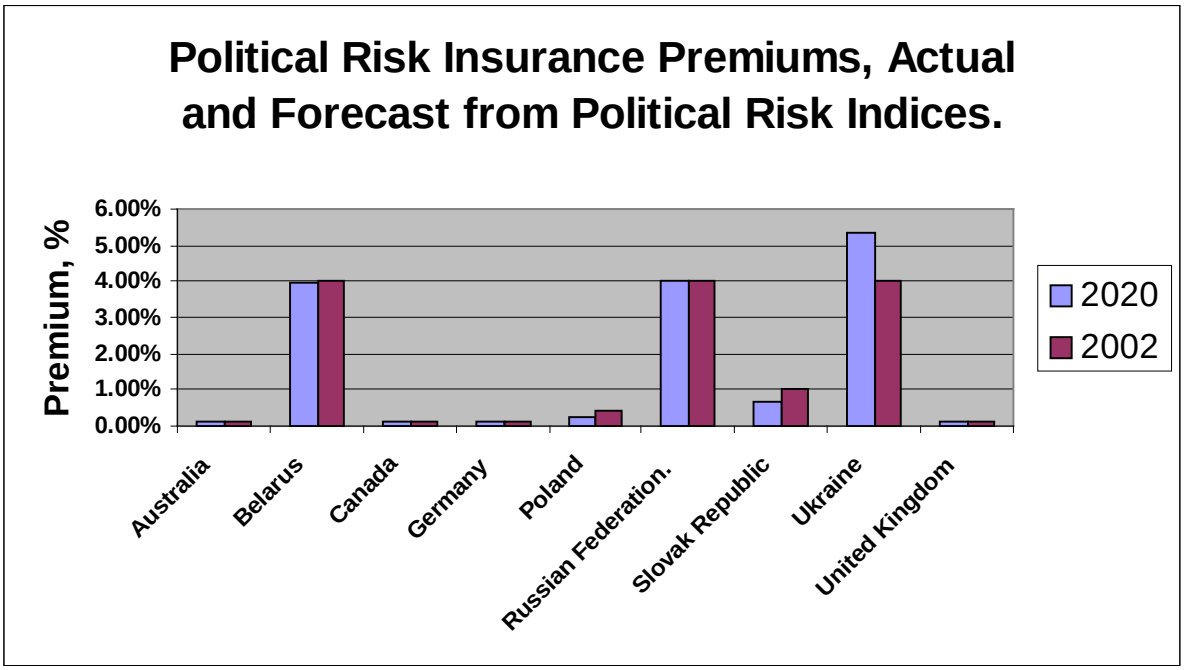
## Political Risk Insurance Premiums.

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, 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: Political Risk Insurance Premiums.**



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

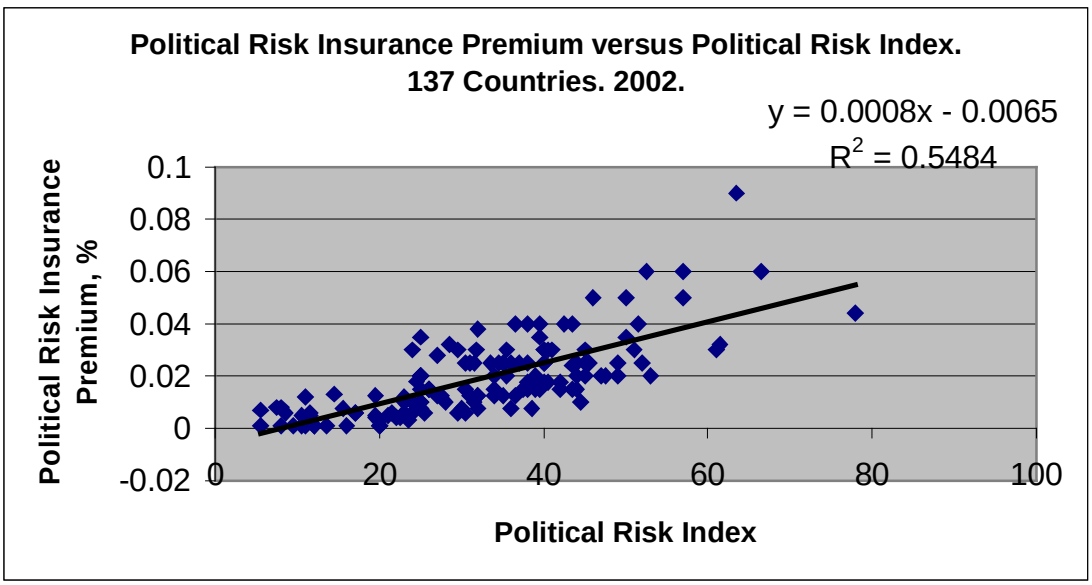
The important difference between the Indices and the Premiums for Political Risk is that the former are based on the actual losses that insurers have had to pay. The premiums are the actual, financial measure of Political Risk, in the sense that if these premiums had been saved then, over a long period 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 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, 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.**

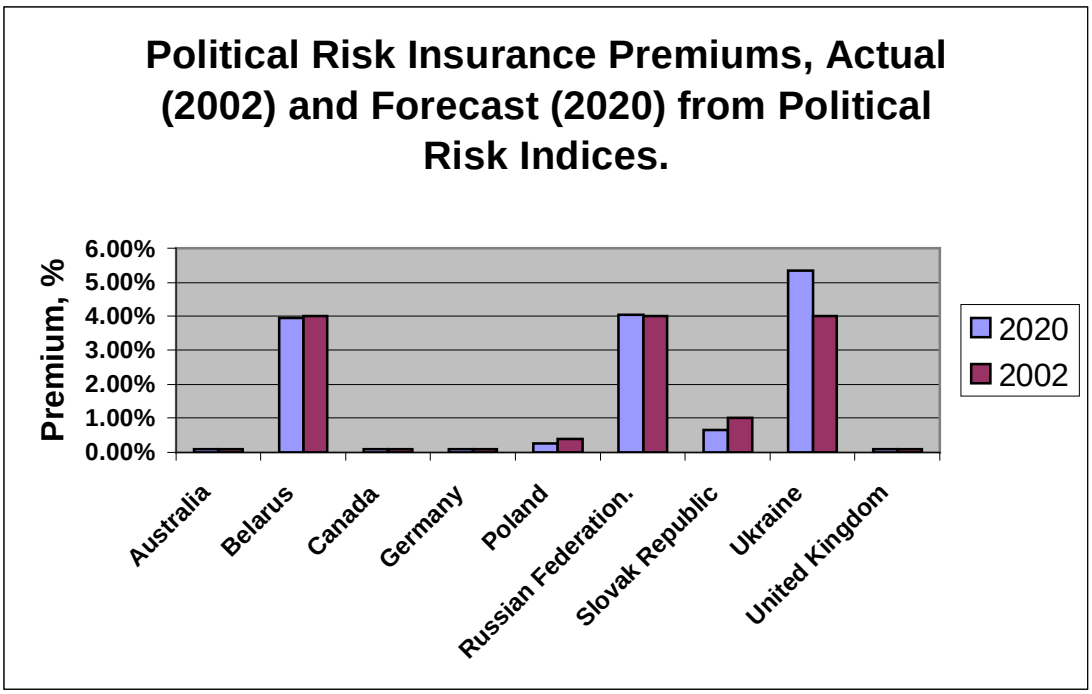


## Actual and Forecast Political Risk Insurance Premiums for Gas and Uranium Producer Countries.

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 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.

**Political Risk Insurance Premiums for 2002 and Forecast for 2020.**

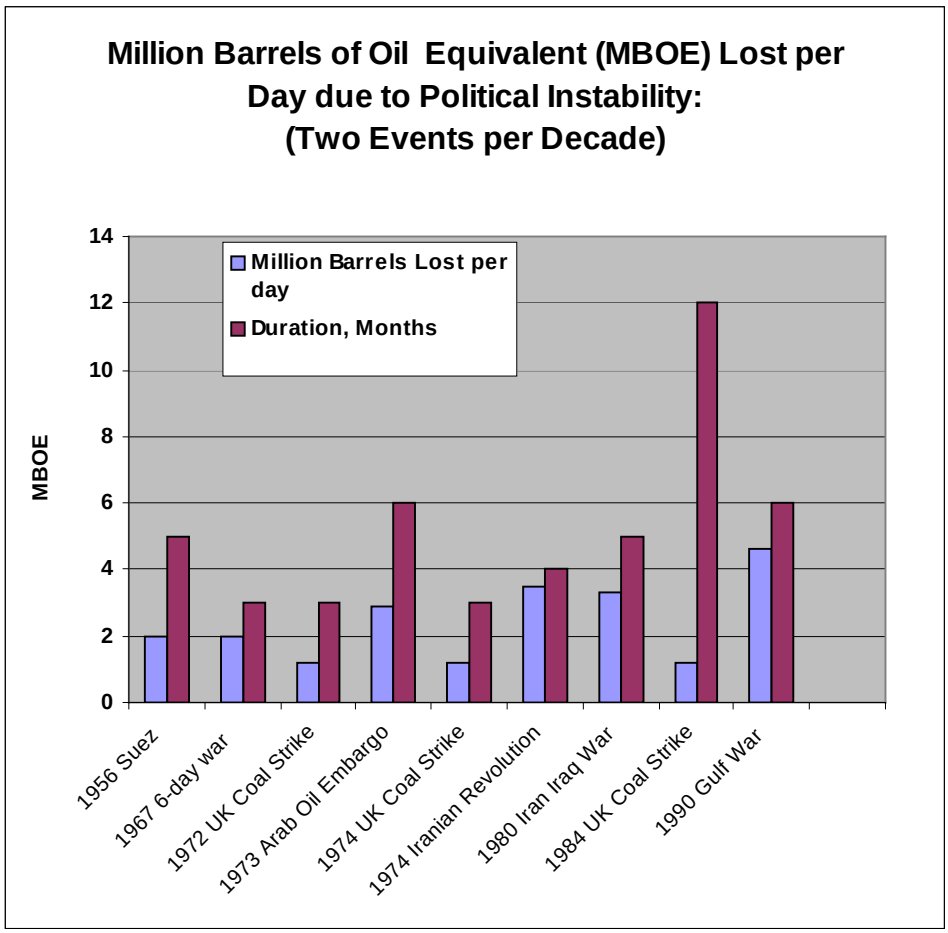


## Political Disruptions of Fossil Fuel Supplies Have Occurred Twice per Decade in the last 50 Years.

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



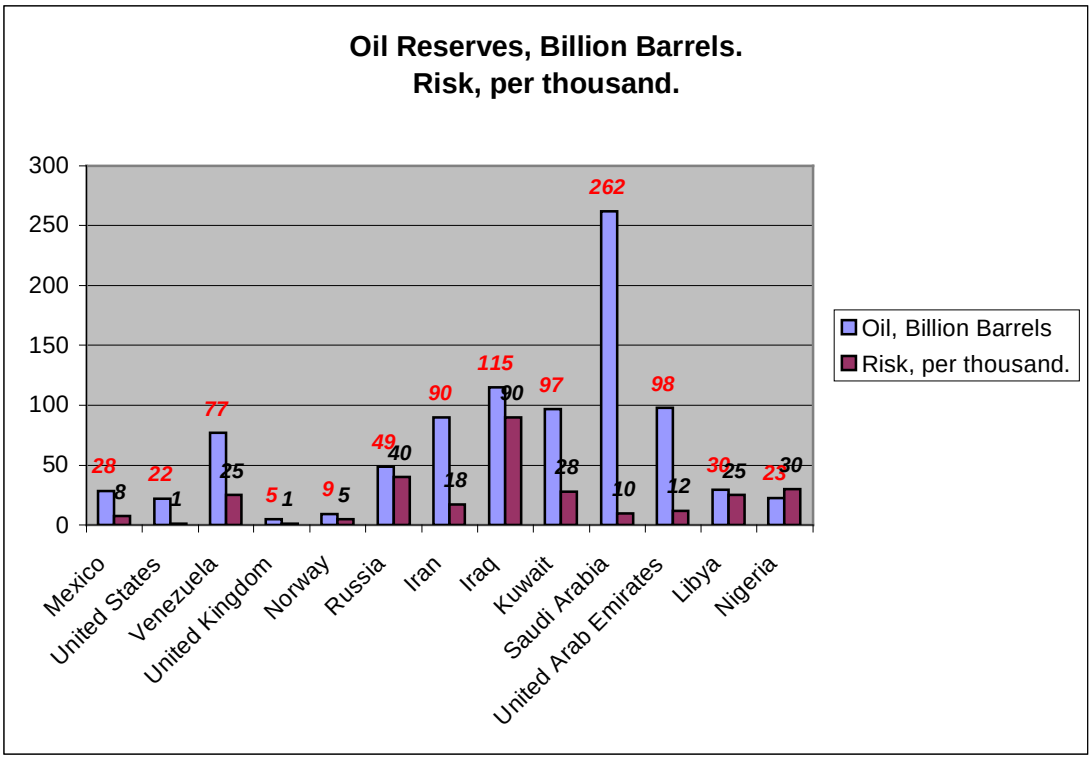
If we ignore the coal strikes then oil supplies have been interrupted about 5% of the time. As explained this does not mean that the UK's oil supplies were entirely cut of for 5% of the period, since the loss was shared by several importers and the UK will have had other sources of supply. Nevertheless 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 the locations of the world's main reserves of oil [14]., coupled with the Political Risk Insurance Premium for 2002 for each of those countries.

These are shown in the following figure:




[14] *Last Updated on 4/23/02 By EIA Email: patricia.smith@eia.doe.gov*

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

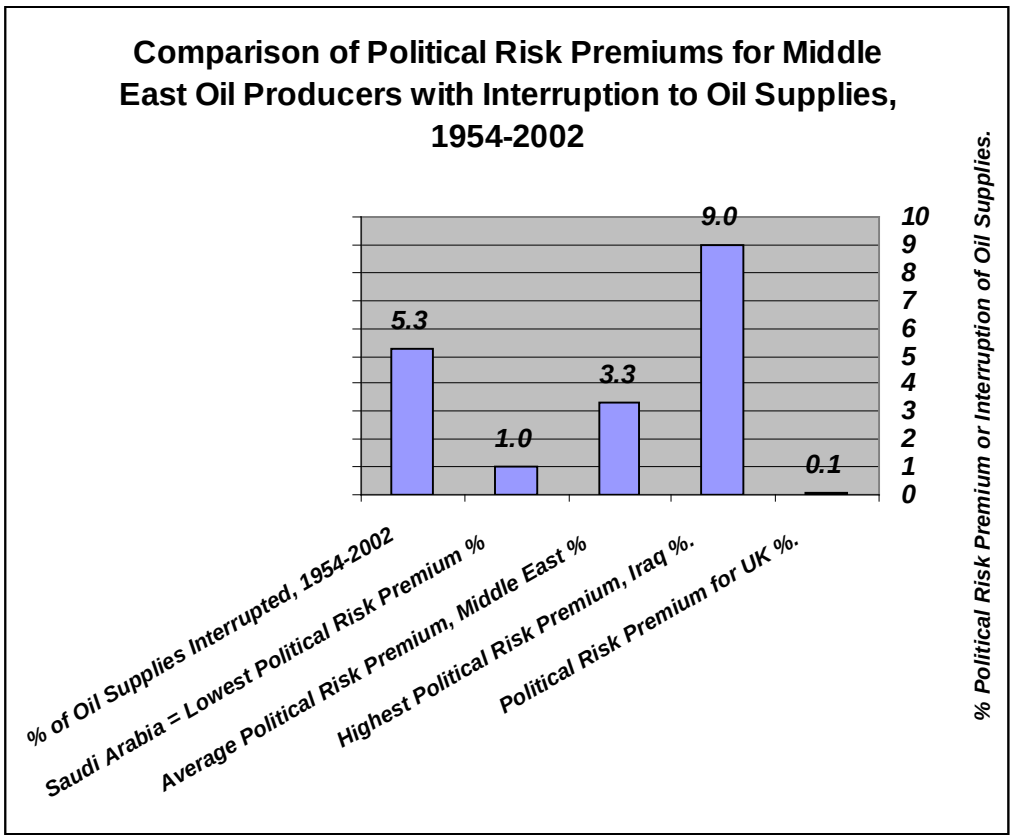
Indeed 700 billion barrels out of the world's 1,000 billion barrels of oil reserves are in the Middle East and the UK reserves amount to no more than 5 billion barrels.

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 Iran. 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: Political Risk Premiums for Main Middle East Oil Producers Compared to theh 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%[15].

[15] 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%.

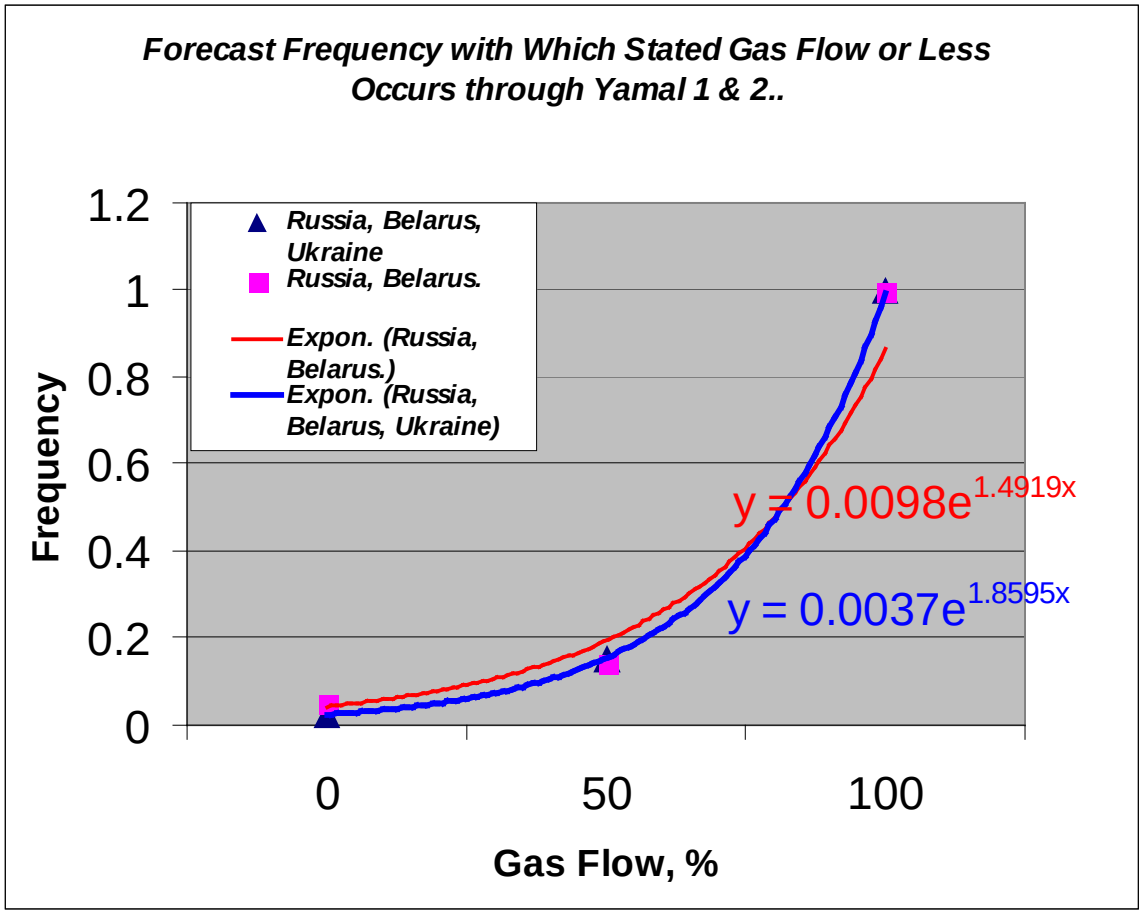
From the frequency and magnitude of the interruptions to Oil supplies that have occurred over the last half-century we infer that a Political Risk Insurance Premium of 2% means that major interruptions to gas flow will occur due to political intervention with a frequency of 2% or once every 50 years.

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

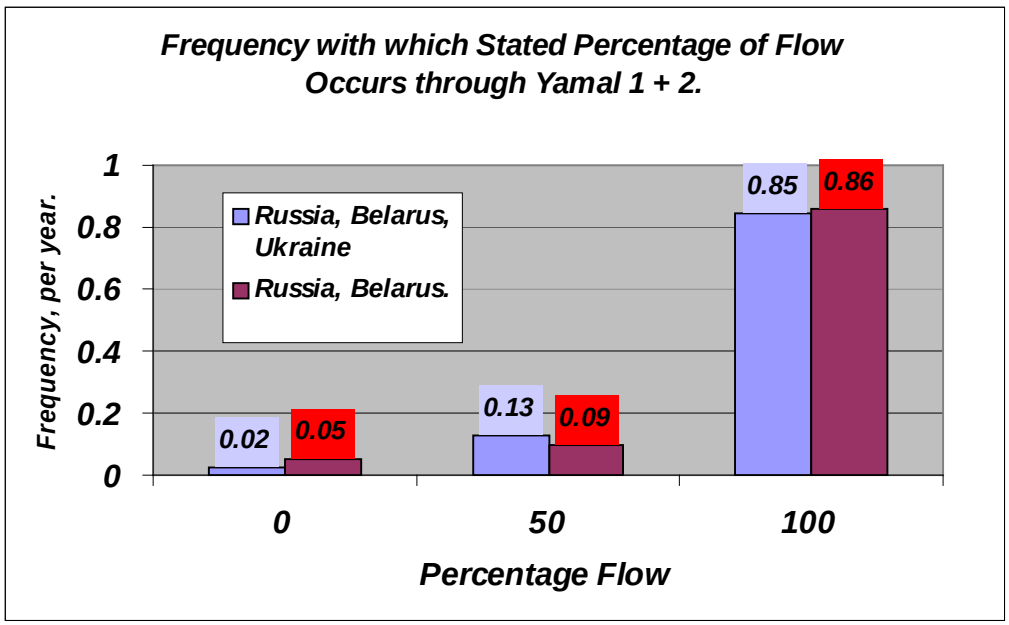



In each of the two cases in the above figure the gas-flow occurs through both of the Yamal-Europe pipelines. Each of the two cases is a forecast of the total of the flows through Yamal 1 and Yamal 2. In one case it is assumed that both pass through Russia and Belarus. In the other case it is assumed 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: 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.

## 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:

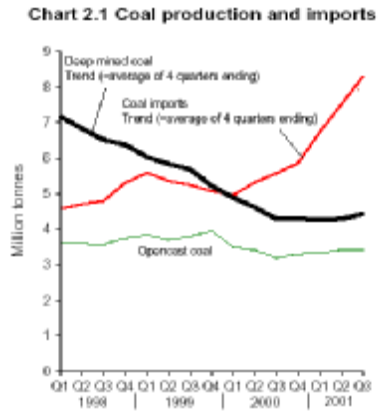
- There will be no Yamal gas flow to the UK for a few percent of the time.For about 15% of the time, Yamal gas will flow to the UK at 50% or less than the intended rate.

# Politically-Inspired Interruption of the UK's Coal Supplies.

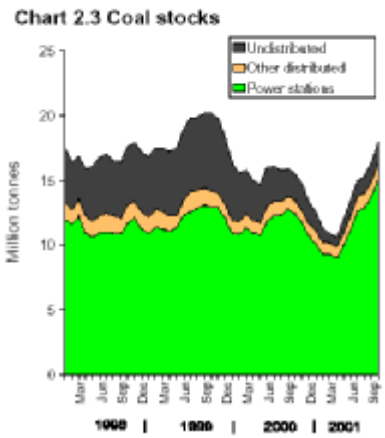
In the 1972, 1974 and 1984 Britain had major coal strikes. Each was a politically-motivated interruption of all domestic coal supplies that lasted, in the case of the 1984 strike, for more than 12 months.

Currently, Britain's coal stocks will last three months if supplies are interrupted, as illustrated in the following figures: [16]

## Figure: UK Coal Production and Imports.

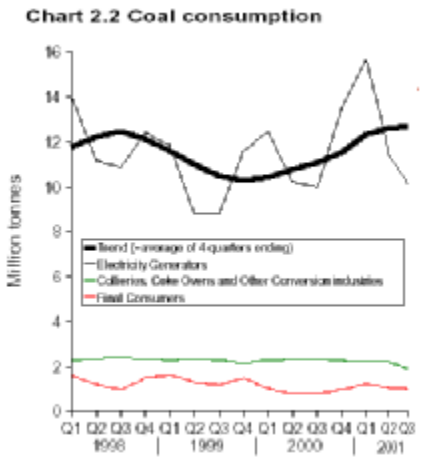



## Figure: UK Coal Stocks.




[16] Energy Trends, DTI 2002. Sets of tables can be found at www.dti.gov.uk/energy/energystats/energystats.htm.

**Figure: UK Coal Consumption.**



Although UK domestic coal production is falling, this is because imports are cheaper.

The UK could, given time, be once again self-sufficient in coal.

The following figures show that eight foreign countries each ***export*** more coal than the UK ***imports***. Four of these exporters offer a low Political Risk of reneging on contracts.

From these facts it is calculated that there is perhaps a chance in a million of Britain's coal supplies drying up.

**Figure: Exports of Coal, Trillion BthU.**

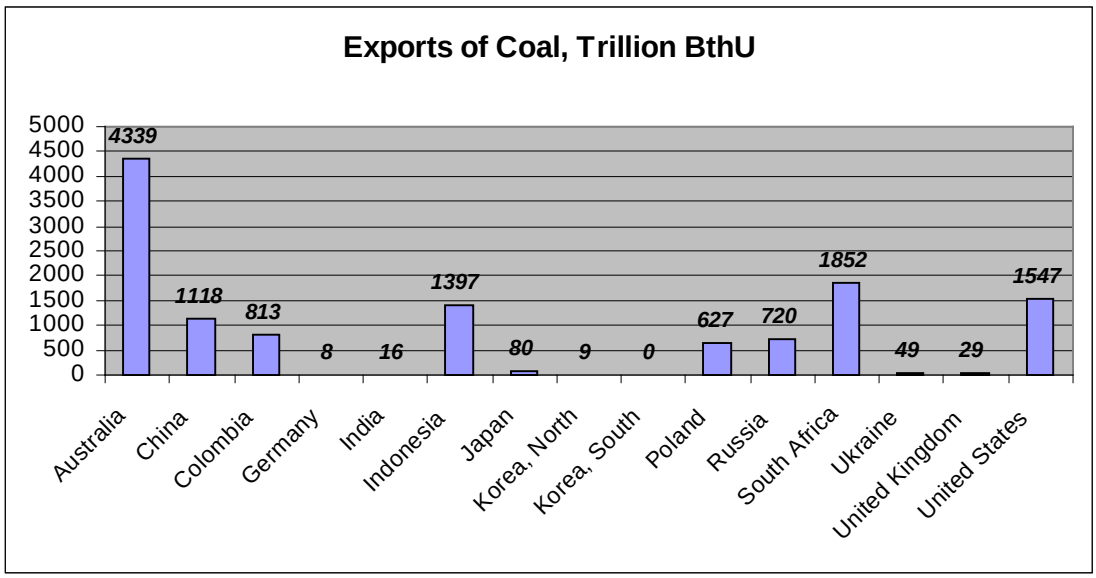


**Figure: Political Risk Premium, %, for Coal Exporting Countries and the UK.**

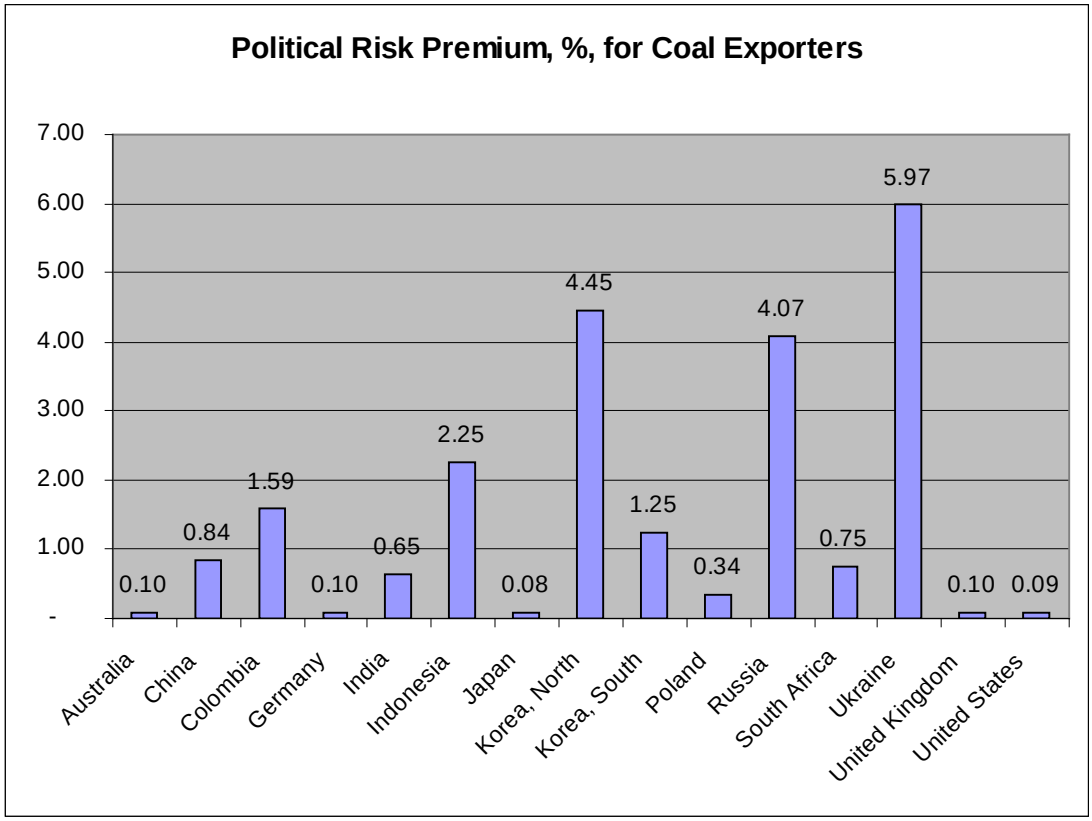
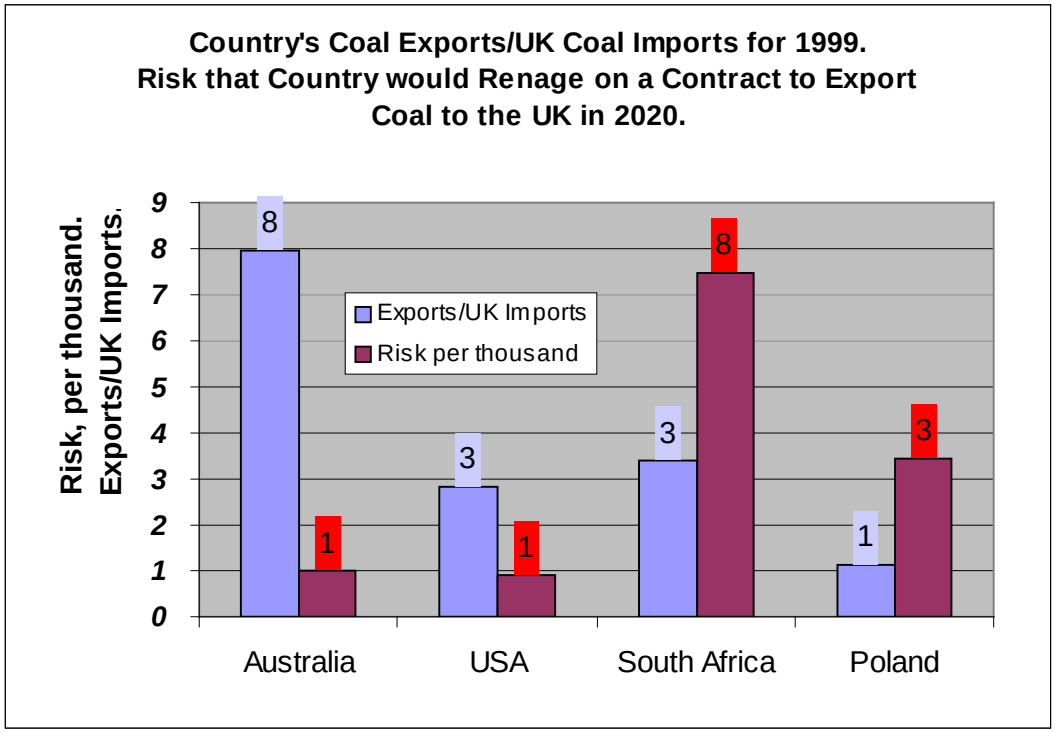


**Figure: Country's Coal Exports/UK Coal Imports for 1999. Also the Risk that a Country would Renage on a Contract to Export Coal to the UK in 2020 for Political Reasons.**




## Conclusion Concerning the Reliability of UK Coal Supplies.

In view of the low Political Risk presented by the UK and by four or more other countries, each of which is separately capable of supplying all the UK's coal imports, together with the UK's stocks and production potential, it is concluded that there is about a chance in a million of the UK's coal supplies drying up.

## Reliability of the UK's Nuclear Fuel Supplies.

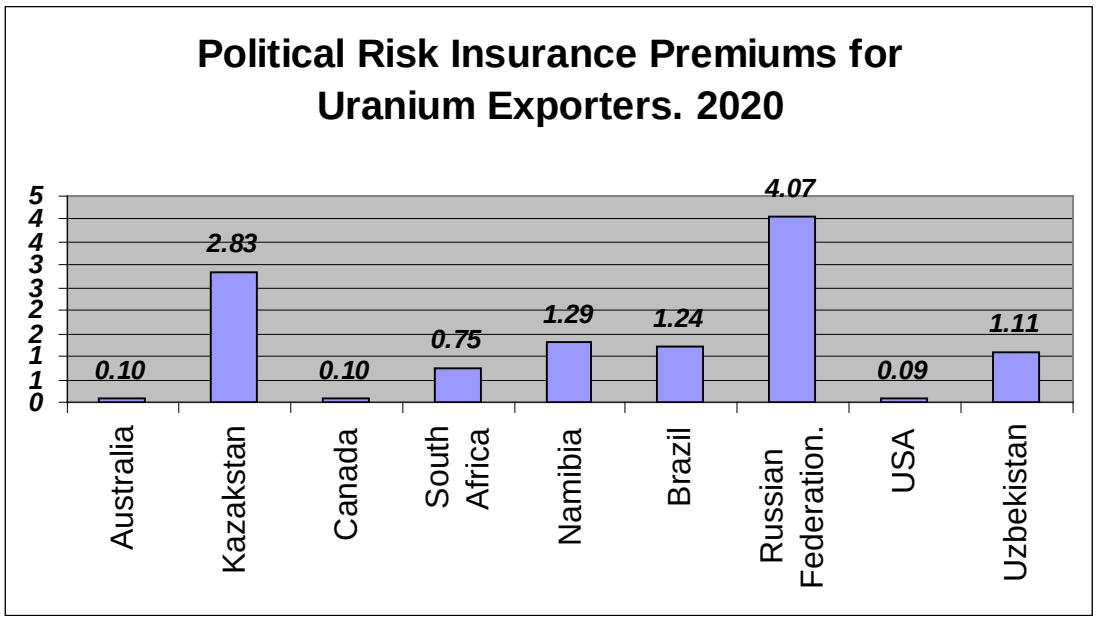
The UK has stocks of uranium and nuclear fuel sufficient for more than a year.

There are nine or more countries from which the UK can import uranium.

The UK has enrichment facilities that are capable of meeting its domestic requirements.

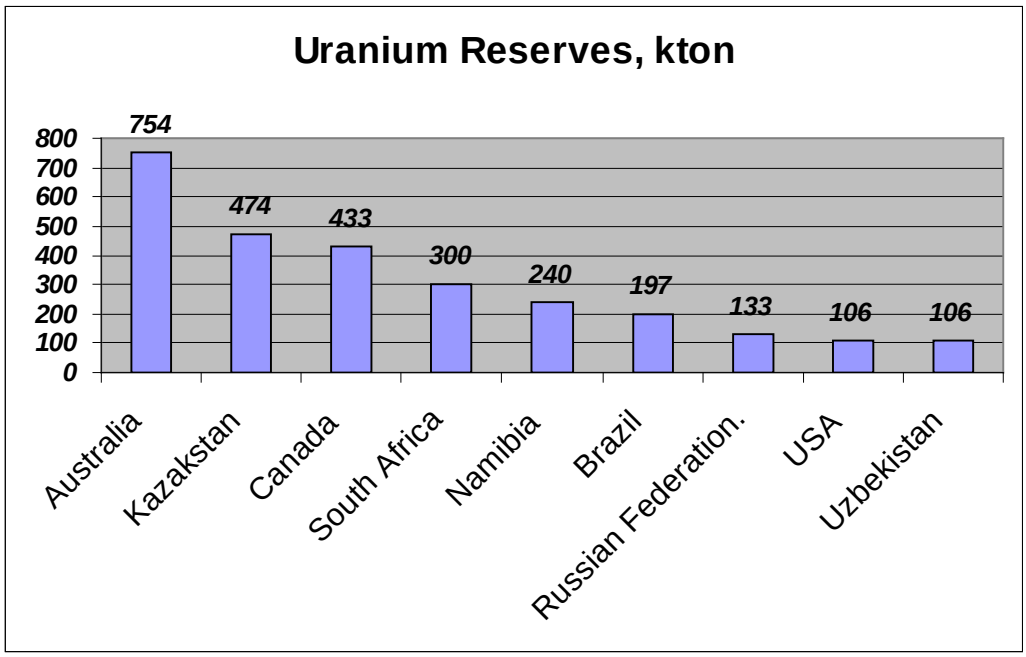
It is concluded that the chance of the UK running out of nuclear fuel is about one in a million.The following figures illustrate these points:

**Figure: Political Risk Insurance Premiums for Uranium Exporting Countries, forecasts for 2020.**



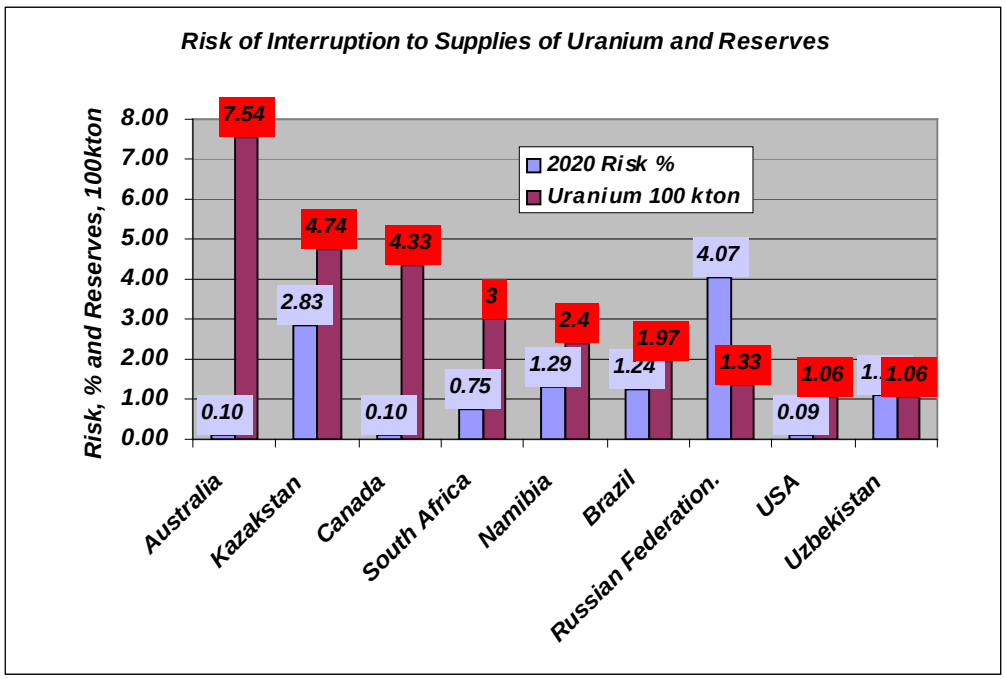

This figure shows that the Political Risk Insurance Premium, which we equate with the Risk of politically-inspired interruption to supplies of uranium destined for the UK, is low for Australia, Canada and the USA. It is high for Kazakhstan and the Russian Federation.

**Figure: Reserves of Uranium, kilo ton.**




Australia and Canada are revealed as the countries that have, respectively, the largest and the third largest reserves of uranium in the world. They are countries that present very low political risks, making it unlikely in the extreme that they would renege on contracts to supply uranium to the UK.

**Figure: Risk of Interruption of Supplies of Uranium and Uranium Reserves.**




## Conclusions Concerning the Reliability of the UK' s Supplies of Nuclear Fuel.

The following conclusions are drawn concerning the reliability of the UK's supplies of nuclear fuel:

- The UK has nuclear fuel and uranium stocks sufficient for more than one year.
- The UK has adequate domestic enrichment facilities.
- Australia and Canada, two uranium exporters that present low Political Risks, are amongst the several countries capable of supplying the UK's uranium needs.There is, therefore, perhaps a chance in a million of inadequate supplies of nuclear fuel for the UK's reactors.

## Risk of Politically-Motivated Interruption of the Operation of UK Nuclear Installations.

The Political Risk Premium for the UK is 0.1% and it implies a Risk of one in a thousand that the operation of a key nuclear installation in the UK will be interrupted in any given year by politically-motivated events. Analysis suggests that the frequency will be substantially less than this.

## The New Renewables.

Wind, wave-power, tidal power, solar energy are "new, renewable" sources of energy. They are intermittent, as the wind is variable, the sun does not shine at night, the sea is often calm and the tide does not come in continuously but only twice daily.

Analysis for the PIU assessed the costs of intermittency on the assumption that system services required to deal with increasing levels of intermittency would be provided using electrolytic storage plants. In practice, lower cost options may be available, such as holding older plant available on stand-by. The analysis suggests that:

- costs are negligible at low levels, indeed small amounts of intermittent generation cannot be detected by the system operator;
- costs are less than 0.1p/kWh for 10% of electricity from intermittents
- costs are less than 0.2 p/kWh for 20% of electricity from intermittents.

The analysis also suggests that at large penetrations (45% or more of peak demand) costs of intermittency could rise to 0.3p/kWh or more. However, as such high penetrations are unlikely to be reached for many years, such costs are very uncertain.

We note here that the assumption that electricity will be stored electrolytically will presumable have had a substantial bearing on these deductions and that, in the absence of storage the cost of intermittency would be considerably more substantial.

The PIU concluded that:

- The addition of another 0.5GWe to the existing 1.5 GWe of Hydro is possible.
- Wind energy, photo-voltaics and biomass have good short/medium term prospects.
- Of these wind energy has the most potential and is already being well developed and tested on a world scale, over 14,000MW world wide, including some 9000MW in Europe, and doubling every 3 years.

In 2020, in the UK, wind generators will provide most of the "renewable" energy. On average wind generators supply 30% of their rated capacity. In general, winds exceeding 5 m/s (11 mph) are required for cost-effective application of small grid-connected wind machines, while wind-farms require wind speeds of 6 m/s (13 mph)[17]. There is a finite chance that they will all be stationary and supply no electricity at all but the important thing in the present context is that the wind will certainly not stop blowing for a continuous period of several months once or twice in every decade. Oil supplies have dried up for several months every decade and this Report concludes that, for the same type of political reasons, Russian gas will too.

[17] American Wind Association,

We shall not, therefore, take account of the disbenefit due to the intermittency of wind power and the other new renewables: it is an important disbenefit but it is not in the same ***category*** as the much less frequent, much more protracted intermittency stemming from political interruption of, say, Russian gas (or Middle Eastern oil) imports. It is the latter that the present Report is concerned with.

## The Reliability of UK Electricity Supplies in the Years 2002 to 2020.

In the foregoing, the reliability of each of the main contributions to UK electricity supplies in the years up to 2020 has been analyzed. Now these estimates will be combined to forecast the reliability of UK electricity supplies in total, up to 2020. Three scenarios will be examined: “current”, “new nuclear for old” and “nuclear instead of Russian Gas”.

### The Three Scenarios Considered:

The three scenarios considered in this work are as follows:

#### CURRENT SCENARIO:

This is the scenario advanced by the DTI.

#### NEW NUCLEAR FOR OLD:

Here, with some delay whilst the first new nuclear power station is approved and built, nuclear capacity is restored to its present level and maintained at that level by building new nuclear power stations through 2020.

#### NUCLEAR INSTEAD OF RUSSIAN GAS:

Here Britain builds new nuclear stations at the same rate as EdeF did, in France. In this way generating capacity keeps pace with demand without the need to buy gas from Yamal.

## Current Scenario.

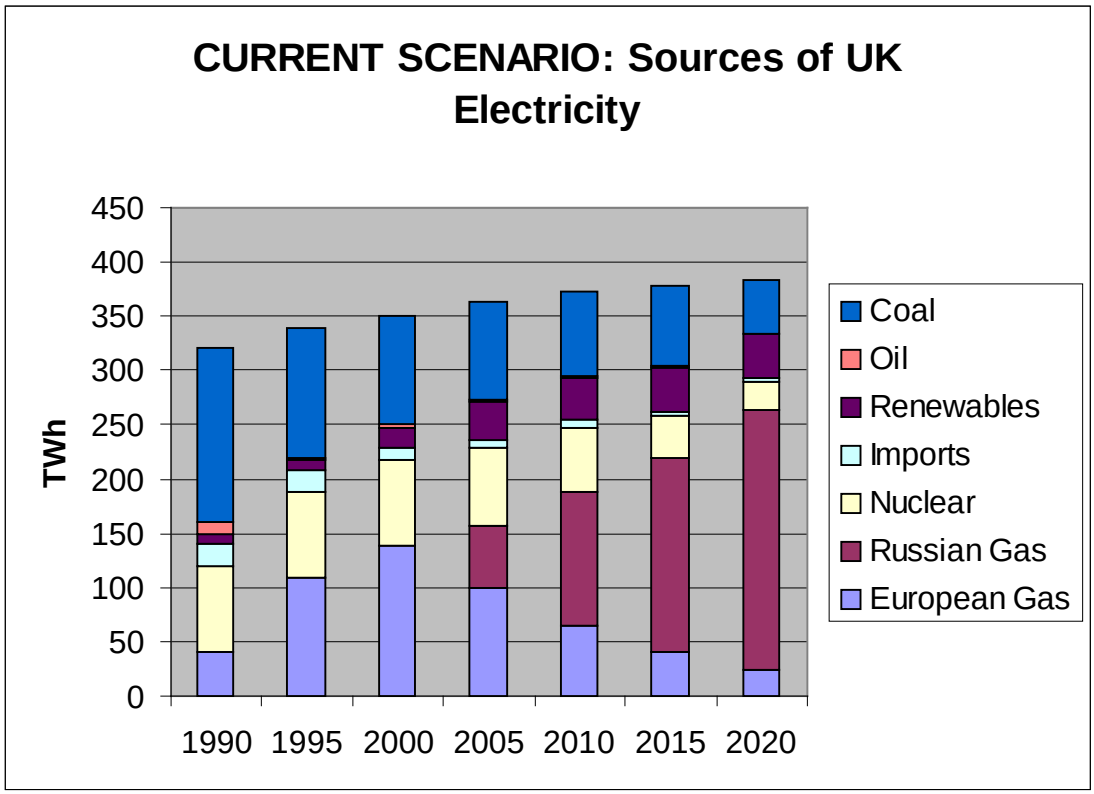
The next figure shows the DTI forecast of the mix of different fuels, which, together with the renewables, will be used to generate electricity in the UK until 2020.

The division of gas between European supplies and supplies from Russia plotted in this figure does not appear in the DTI forecasts. It has been derived here from forecasts of the way in which European gas reserves will decline in the next few years. These forecasts were summarized earlier in this Report.

This Scenario is characterised by:

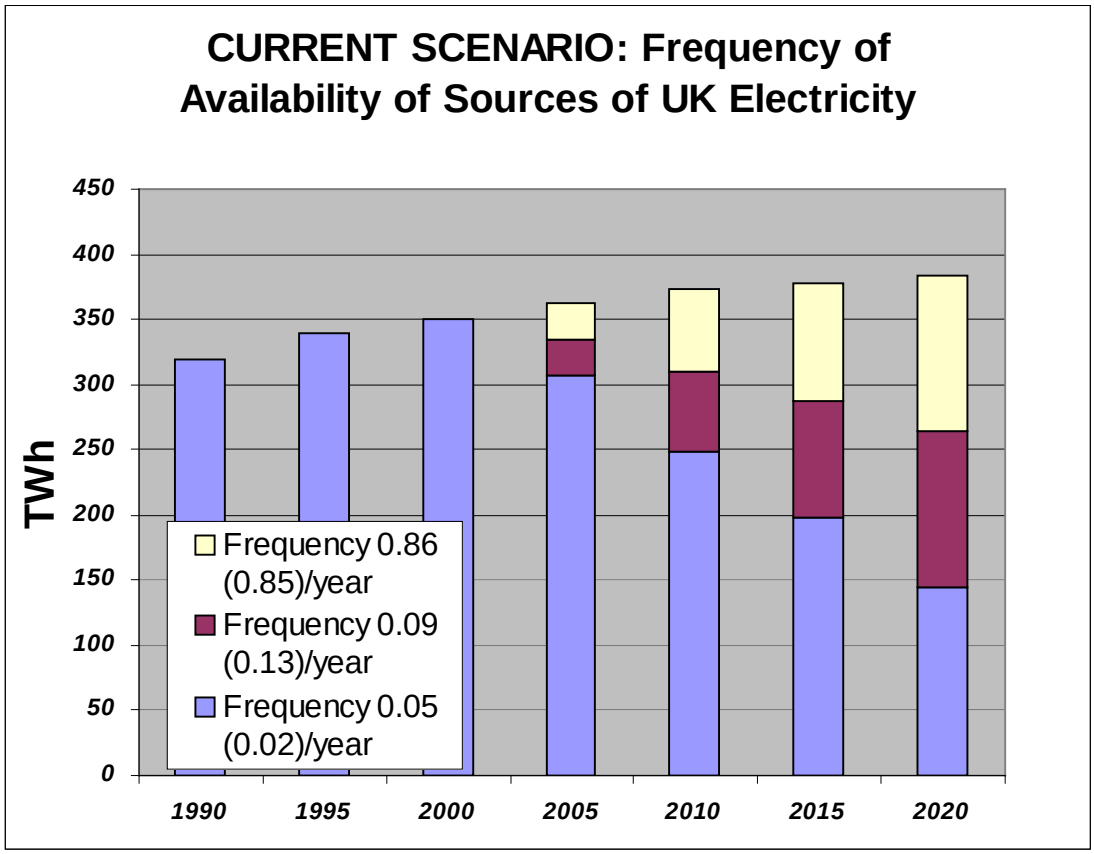
- The inexorable rise of Russian gas, to become by far the most important source of the UK's electricity
- The virtual disappearance of nuclear power by 2020
- The steady reduction, to about one third of the present level, in the use of coal to generate electricity
- The virtual elimination of oil as a source of electricity
- The emergence of the renewables, which effectively take over a substantial proportion of the capacity relinquished by nuclear

**Figure: Current Scenario- Sources of UK Electricity to 2020.**




The frequency of availability of electricity in the UK has been calculated for this, the present Scenario and the results are shown in the next figure:

**Figure: Current Scenario. Frequency of Availability of Sources of Electricity.**



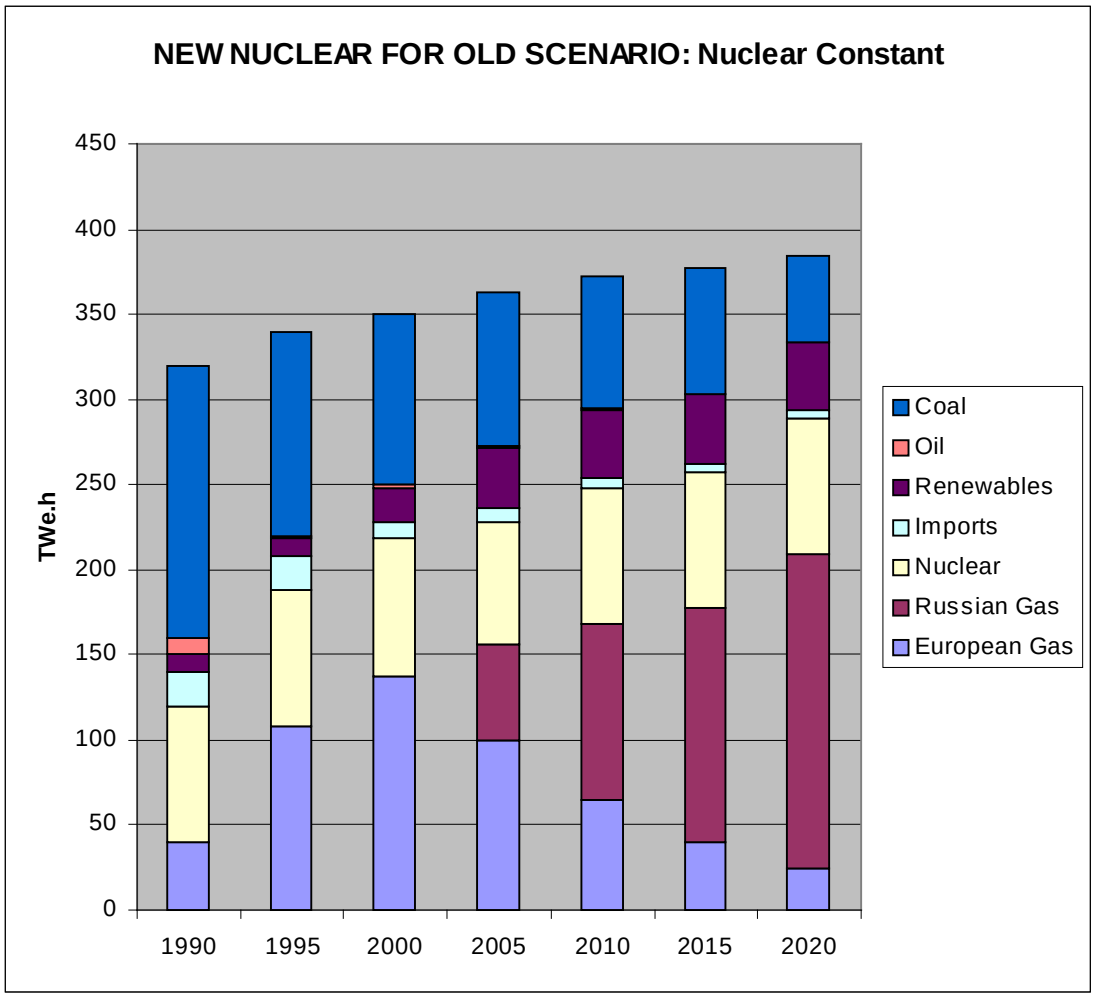

This figure leads to the following conclusions for the present Scenario:

- With a frequency of 0.86/year, if Yamal-Europe 2 goes through Ukraine and 0.85/year if, like Yamal-Europe 1, Yamal-Europe 2 goes through Belarus, the full capacity for electricity generation will be available.
- With a frequency of 0.09 (0.13 if Yamal 2 goes through Belarus) per year, only approximately three quarters of the UK's generating capacity will be available, the balance being offline due to politically-inspired interruptions of supplies of gas from Russia.
- With a frequency of 0.05 (0.02) per year, only approximately one third of the UK's generating capacity will be available, the balance being offline due to politically-inspired interruptions of supplies of gas from Russia.

# New Nuclear for Old Scenario.

The following figure shows the contributions of the various fuels and the renewables to electricity generation for the second of the three scenarios considered in this Report. In this Scenario, after a period during which ***preparations*** are made to build new nuclear power stations, they are built at a rate adequate to make up for the capacity lost when the old nuclear stations are taken out of service.

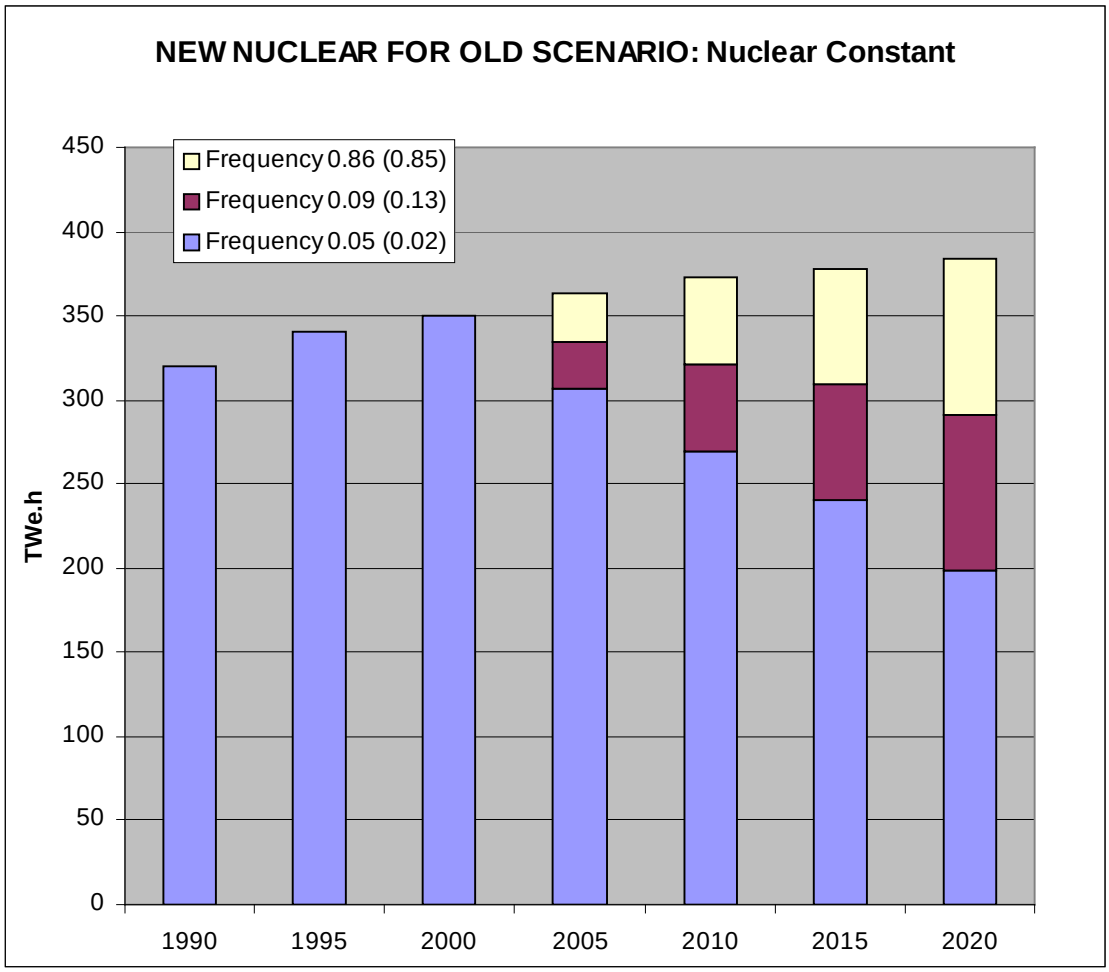
**Figure: Mix of Sources of UK Electricity for the Scenario in which new Nuclear Power Stations are built to replace old ones.**




In this scenario, the amount of Russian gas that the UK imports is reduced, being replaced by new nuclear generating capacity. Gas still plays an increasingly important role as time goes by and so additional gas-fired power stations have to be built throughout the period, as well as new nuclear power stations.

The trends for coal, oil, renewables and imports (from France in the main) remain the same as in the first scenario.

**Figure: Reliability of UK Electricity Supplies for the Second Scenario, in which New Nuclear capacity is built to replace old, retired nuclear capacity: "New Nuclear for Old"**




The above figure shows the impact of building new nuclear for old upon the reliability of the UK's electricity supplies.

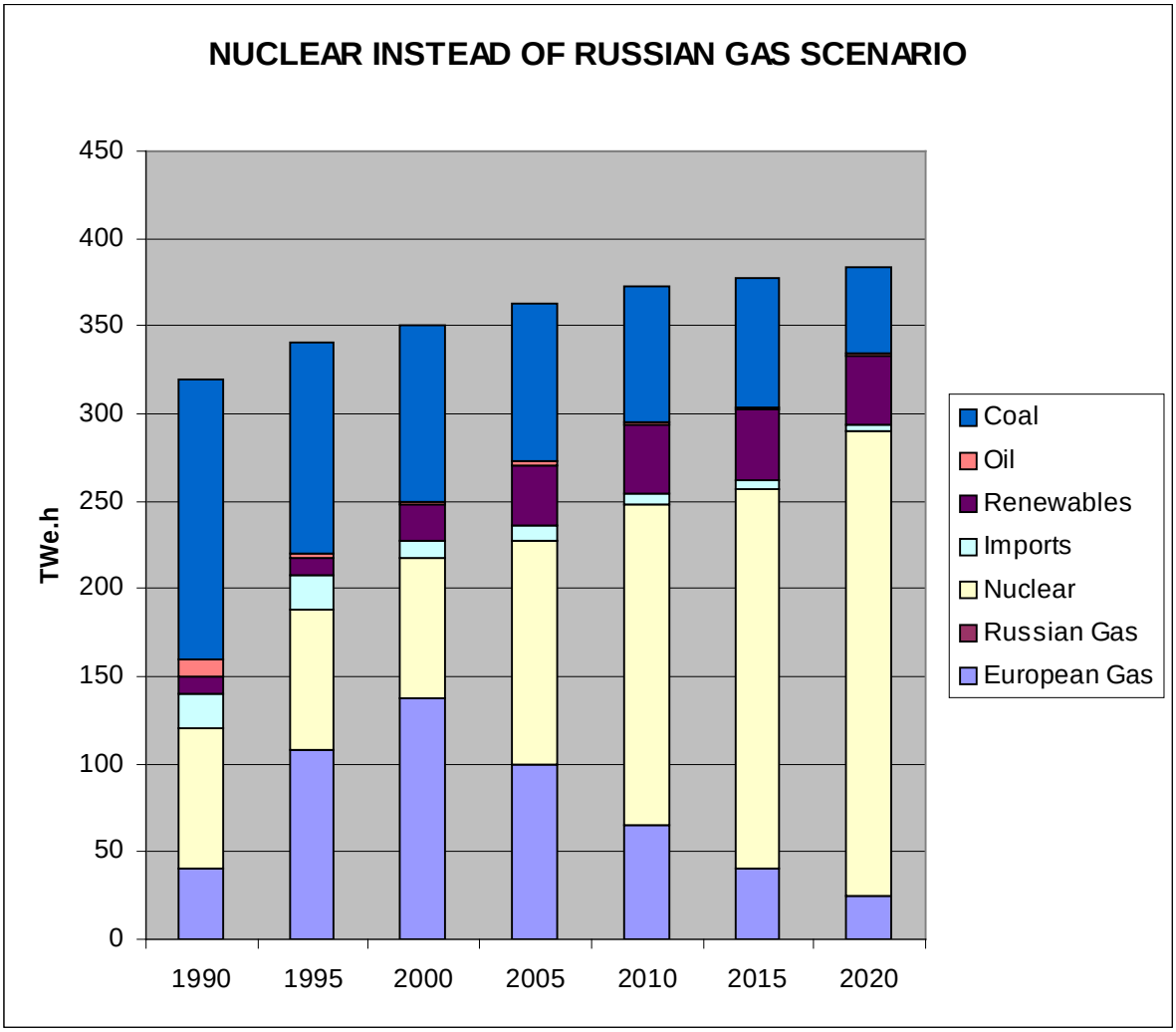
Compared with the first Scenario, in which nuclear was allowed to die out, the reliability of supplies has been significantly increased, but still leaves much to be desired.

Thus in the year 2020, when the requirement is 384 TWe.h, there is a 2% chance of only generating 200 TWe.h. This will be a 5% chance if Yamal-Europe 2 goes through Belarus, like Yamal-Europe 1.

# Third Scenario: Nuclear instead of Russian Gas.

In this Scenario the UK builds nuclear power stations at the same rate as did France twenty-five years ago. In this way the need to import gas from Russia is eliminated and with it the insecurity associated with supplies of Russian gas. The following figure shows the mix of sources of electricity under this Scenario:

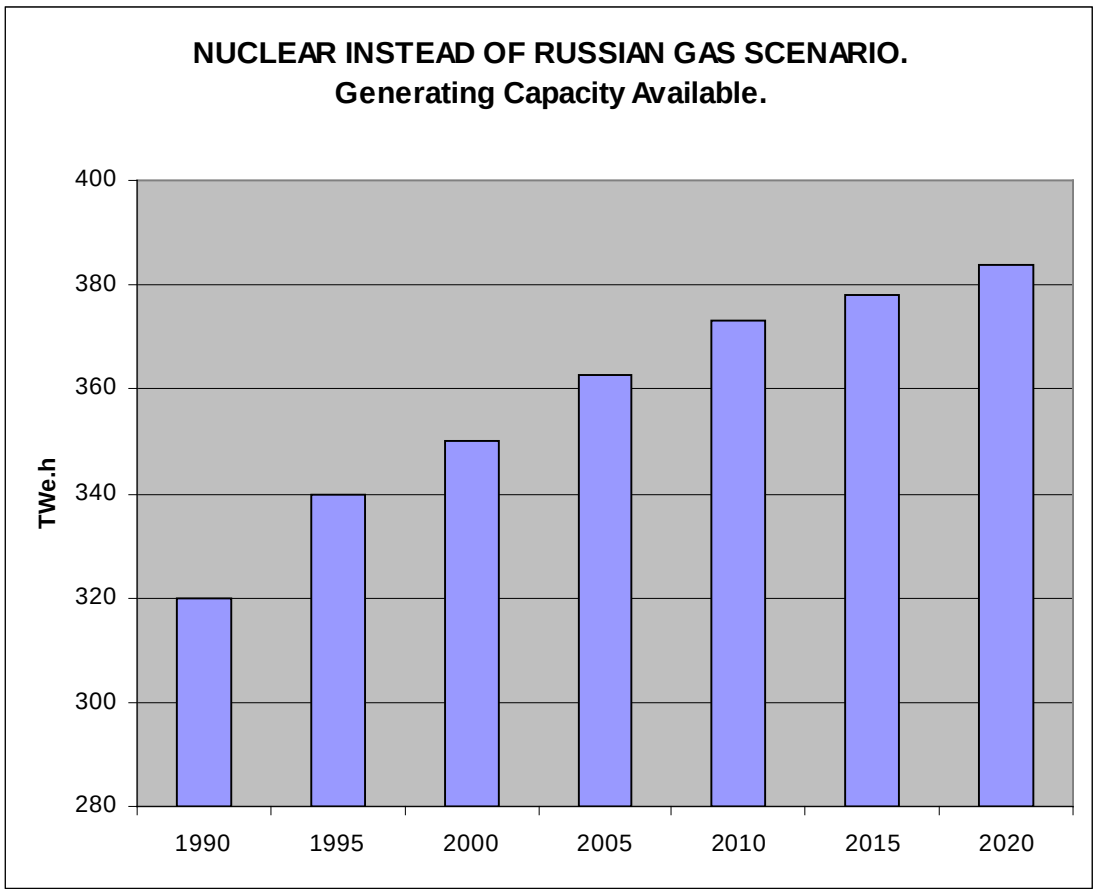
**Figure: Third Scenario: Nuclear Instead of Russian Gas.**




In this scenario coal, oil, renewables, European gas and imports are the same as in the two previous scenarios. Instead of importing Russian gas the UK builds nuclear power stations. Gas fired stations are retired after approximately a twenty year lifespan. If this is extended to 40 years then limited imports of Russian gas will be required.

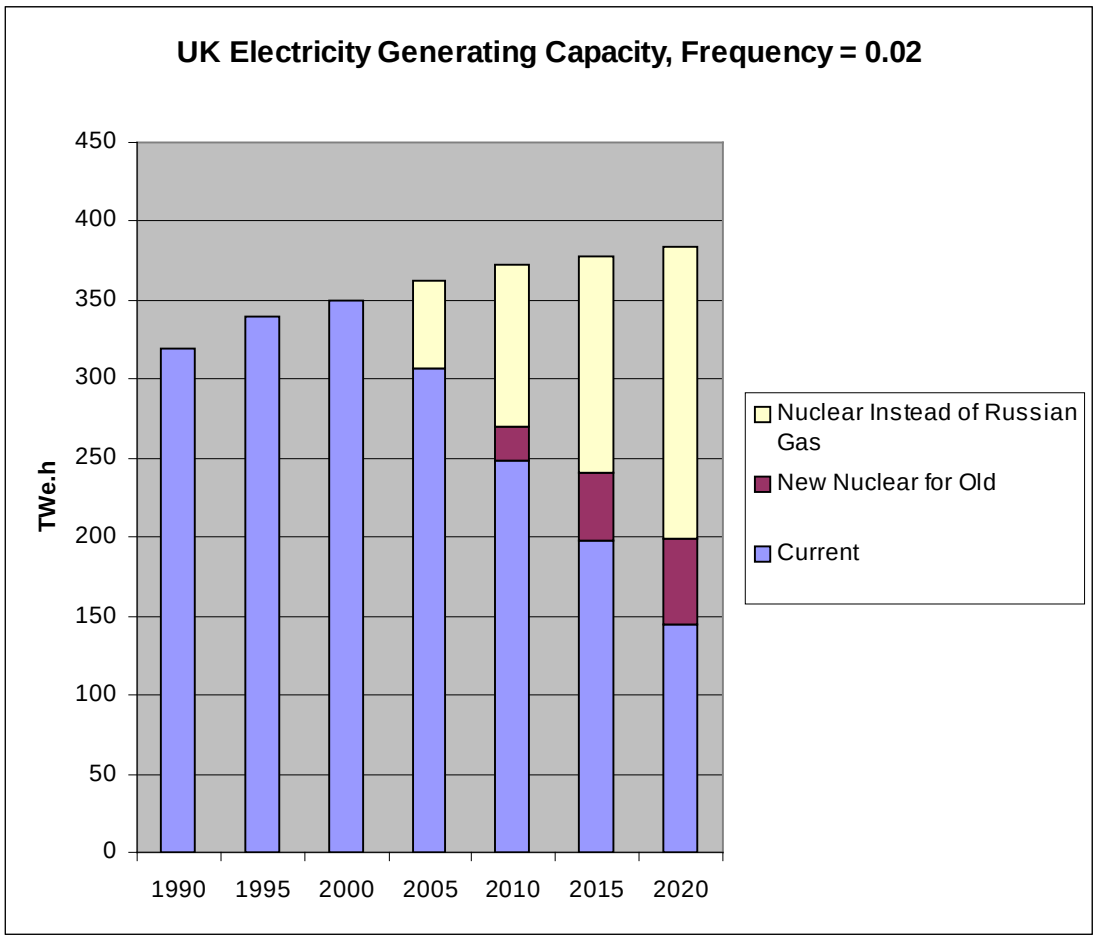
## Figure: Nuclear instead of Russian Gas Scenario. Generating Capacity Available.

In the following figure, by eliminating Russian gas as a source of electricity, we have rendered supplies of UK electricity reliable. Now there can be no question of political interruptions of gas supplies and so the full amount of electricity is generated, as required, with approaching 100% reliability, insofar as political parameters are concerned.



## Comparison of the Reliability of UK Electricity Supplies for the Three Scenarios.

In the next figure, the reliability of UK Electricity Supplies is compared for the three scenarios.




Now the benefits of nuclear are clear: new nuclear for old gives a significant improvement in the reliability of supplies but to retain the reliability of supplies that the UK has enjoyed for the last decade or more it is necessary to build new nuclear power stations instead of importing Russian gas.

## Comparison with PIU Recommendations.

The above conclusions may be compared with those of "The Energy Review A Performance and Innovation Unit Report - February 2002", which are as follows:

*There is no case for restricting the share of gas in the power sector at this time.*

*However, the WGSS should monitor this situation, in particular to assess the market signals surrounding gas prices (4.27).*

*10. DTI should carry out an assessment of the cost-effectiveness of policy responses that could enhance security of the system. These results should inform decisions on any contingency action taken in response to the monitoring (4.28 and 4.60).*

*Key measures which should be considered include: increased availability of UK gas storage and Liquid Natural Gas (LNG): Departments should examine barriers to private sector construction of either option, in particular at how these projects are represented in planning guidance; if sufficient private sector investment is not forthcoming, then consideration may have to be given to the imposition of mandatory obligations on storage.the development of electricity and gas interconnectors (see recommendation 11 and 12). improving the prospects of keeping existing coal-fired capacity open, possibly by: altering the basis on which business rates are charged; or keeping some plant as a strategic reserve, to be operated only if there was an imminent danger of widespread power cuts (4.25 and 4.26). requiring the owners of some generation sets to have dual-fired capacity (most obviously, oil and gas). action on the demand side.*

## Conclusions.

There are mounting concerns that supplies of Russian gas, the main source of UK electricity in 2020 and thereafter, will prove unreliable. The UK has experienced half a dozen politically-motivated interruptions in its imports of ***oil***, leading for example to the "Three Day Week". This work forecasts that Russia is no more likely to be reliable as a source of the UK's gas than the Middle East has been a reliable source of oil.

The business world has developed databases 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 have been used to produce the first numerical estimates of the likely reliability of Russian gas supplies in the years to 2020 and beyond. The same approach has been used to examine the likely reliability of supplies of the other two fuels that the UK imports to produce electricity: coal and uranium. This has enabled the reliability of the UK's electricity supplies in the years up to 2020 and beyond to be forecast.

The analysis has been repeated for scenarios, in one of which, instead of allowing nuclear power to die out, new nuclear power stations are built to replace the old ones as the latter reach the end of their lives. In a more radical scenario it is assumed that, as supplies of UK gas are exhausted, additional nuclear stations are built instead of importing Russian gas, to keep pace with rising demand for electricity.

These calculations show 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: approximately 5%.
- 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 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.
- We have deduced, therefore, that the frequency, per year, of interruptions to Russian gas will be proportionate to the Political Risk Insurance Premium. We 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%[18].

We apply a combination of probability theory and Kirchof's laws to calculate the frequency with which one or both of the pipelines that will bring Russian gas from Yamal to the UK will be interrupted because of politically inspired events.

The analysis forecasts that there will be no flow of gas through either pipeline for a period lasting several months with a frequency of 0.02 to 0.05 per annum, depending on the routes of the pipelines. There will only be a 50% flow with a frequency of 0.09 to 0.13. Full flow will occur the balance of the time, that is with a frequency of 0.85 to 0.86 per annum.

The same analytical approach that has been developed for gas has been, in this Report, applied also to UK coal imports. In view of the low Political Risk presented by the UK and by four or more other countries, each of which is separately capable of supplying all the UK's coal imports, together with the UK's stocks and production potential, it is concluded that there is about a chance in a million of the UK's coal supplies drying up.

Following the same procedure, the following conclusions are drawn concerning the reliability of the UK's supplies of nuclear fuel:

- The UK has nuclear fuel and uranium stocks sufficient for more than one year.
- The UK has adequate domestic enrichment facilities.
- Australia and Canada, two uranium exporters that present low Political Risks, are amongst the several countries capable of supplying the UK's uranium needs.There is, therefore, perhaps a chance in a million of inadequate supplies of nuclear fuel for the UK's reactors.

We have not taken account of the intermittency of wind power and the other new renewables: it is important but it is not in the same category as the much less frequent, much more protracted intermittency stemming from political interruption of, say, Russian gas (or Middle Eastern oil) imports. It is only with these potentially crippling interruptions that the present work is concerned.

As summarized above, the reliability of each of the main contributions to UK electricity supplies in the years up to 2020 has been analyzed. Combining these estimates, the reliability of UK electricity supplies in total, up to 2020 has been forecast for the three scenarios: "current", "new nuclear for old" and "nuclear instead of Russian Gas".

[18] 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

The frequency of availability of electricity in the UK calculated for the Current Scenario is as follows:

- With a frequency of 0.86/year to 0.85/year the full capacity for electricity generation will be available.
- With a frequency of 0.09 to0.13 per year, only approximately three quarters of the UK's generating capacity will be available, the balance being offline due to politically-inspired interruptions of supplies of gas from Russia.
- With a frequency of 0.02 to 0.05 per year, only approximately ***one third*** (actually 37.5%) of the UK's generating capacity will be available, the balance being offline due to politically-inspired interruptions of supplies of gas from Russia.

The second Scenario, in which new nuclear power stations are built to replace the old ones as the old ones are shut down, offers improvements in the reliability of supplies, largely because imports of Russian gas are reduced. Now:

- With a frequency of 0.02 to 0.05 per year, approximately ***one half*** (actually 51.82%) of the UK's generating capacity will be available, the balance being offline due to politically-inspired interruptions of supplies of gas from Russia.

In the third Scenario, additional nuclear stations are built to replace the old and provide for the increasing demand: no Russian gas needs to be imported. Now 100% of the UK's generating capacity is available, with a high level of security.

# Annex: GENERAL PROFILE OF YAMALO-NENETSKY AUTONOMOUS REGION

**LOCATION**
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. From the North and the North-West it is bathed by the Kara Sea.

**TERRITORY:**
The territory of Yomalo-Nenetsky autonomous region is 750.6 thousand of square km which means that the region is in 1.36 times larger in area than France.

**CLIMATE:**
The climatic conditions in Yamalo-Nenetskyautonomous region are unfavourable because the region is located far away from the Atlantic and Pacific oceans. This fact must be considered as the reason for extremely continental climate. All the year round the Arctic ocean is covered with ice that is why it does not make the climate more moderate. Continental climate can explain a very well-defined distinction between the zones from the north to the south, which are tundra, forest-tundra and forest zones. The winter is very long and severe. In January average temperature is 23-27 degrees below zero with an absolute maximum of 3 degrees above zero and an absolute minimum of 59 degrees below zero. The summer is warm but short. In July average temperature is 5-16 degrees with an absolute maximum of 37 degrees above zero and an absolute minimum of 5 degrees below zero.

**POPULATION:**
On January 1, 1998 there are 498 105 people residing Yamalo-Nenetsky autonomous region . Rural population amounts for 85 869 people and urban population for 412 236 people. The number of minority indigenous peoples amounts for approximately 30 thousand, most of whom represent the Nenets people(4%), the Khanty people(1,5%) and the Komi people (1%). There are approximately 1,5 thousand of the Selkups residing Krasnoselkupsk district. Average population density is 0,7 persons per sq km (ranks 79$^{th}$ in the Russian Federation). The number of pensioners is 56 956 people.

**ADMINISTRATIVE AND TERRITORIAL STRUCTURE:**
As an independent subject of the Russian Federation the autonomous region is included in Tyumen oblast on August 14, 1994. Moreover, it has 22 administrative and territorial entities,of which are 7 districts,6 towns of regional subordination and 9 industrial settlements.

**MINERAL RESOURCES:**
Great hydrocarbon raw reserves is the largest part of the natural resources in Yamalo-Nenetsky autonomous region. Yamalo-Nenetsky autonomous region is characterised by the largest deposits of gas in the world. Yamalo-Nenetsky autonomous region supplies more than 90% of total natural gas and 12% of total oil extracted in Russia. 27 % of working population of Yamalo-Nenetsky autonomous region are employed in the industrial production: oil and gas extraction and transportation. As a result the industrial sector of Yamalo-Nenetsky autonomous region still has the largest gross output where oil and gas production industry has 97%. Mostly natural gas production in Yamalo-Nenetsky autonomous region is carried out by a number of "Gazprom" subsidiary companies and 96% of oil production is carried out by 'Sibneft' and' Rosneft.' companies In addition to being a source of oil and gas the Ural mountains in Yamalo-Nenetsky autonomous region are rich in precious, ferrous, non-ferrous metals. The mountains also have abundant deposits of chromite, phosphorites and barites.

**THE BRANCHES OF THE TERRITORIAL SPECIALISATION:**
Oil and gas complex, mining industry, fishing, reindeer-breeding.

**INDUSTRY:**
Yamalo-Nenetsky autonomous regions is one of raw materials mining regions. In 1996 the production volume of the fuel industry in the region was 94.6%, gas industry constituted 55.7%, power industry - 0.91%, food industry - 0.55%. In 1996 a share of Yamalo-Nenetsky autonomous region in industrial production was 2.17%. In January 1997 the volume of industrial production of the region was 3076 billion roubles.
The most important forms of industrial production in the region are: natural gas (51,5 billion cubic metres produced in January 1997); oil including gas condensate (2,8 million tons produced in January 1997) and electric power (42 million kW/h produced in January 1997). Thanks to the monopoly position of gas industry in the economy of the region the total crisis of the production practically has not effected Yamalo-Nenetsky autonomous region. In 1996 the volume of industrial production on average was 75% compared to that of 1990 (throughout Russia it was 48%).
Capital investments in the region in 1996 were 6.17% of total investments to Russia.71.7% of capital investments in Yamalo-Nenetsky autonomous regions were made to industrial sector. It is a
high index because on average in Russia the figure is 37%. 88% of all capital investments are sent to the building production. This is the highest level in the country. 96% of the capital investments in the industry are made to the fuel industry and 73% to the gas industry.
One more index is worth mentioning: the volume of capital investments per capita in the region exceeds that of Russia in 18.3 times. In 1996 the main share of capital investments of 83.7%, fell on the enterprises with mixed ownership and for the state enterprises this figure was 52%.

**ECONOMICS:**
The "donor" term is applied to the budget of the autonomous region with regard to "an income part". The budget of Yamalo-Nenetsky autonomous region ranks 5$^{th}$ among

the budgets of 89 regions region with regard to volumes of assignations to the federal budget in Russia. 60% of an income's source connected with natural resources extraction are at the region's disposal. Yamalo-Nenetsky autonomous region was very active in implementation of Privatisation Program. According to some estimates, apart from contributions to the Budget of Yamalo-Nenetsky autonomous region Privatisation Program will allow to improve the resources management. The recent reforms have expanded service sector, which constitutes now 12.6% of the region's gross output.

## Annex: Statement From Gazprom.

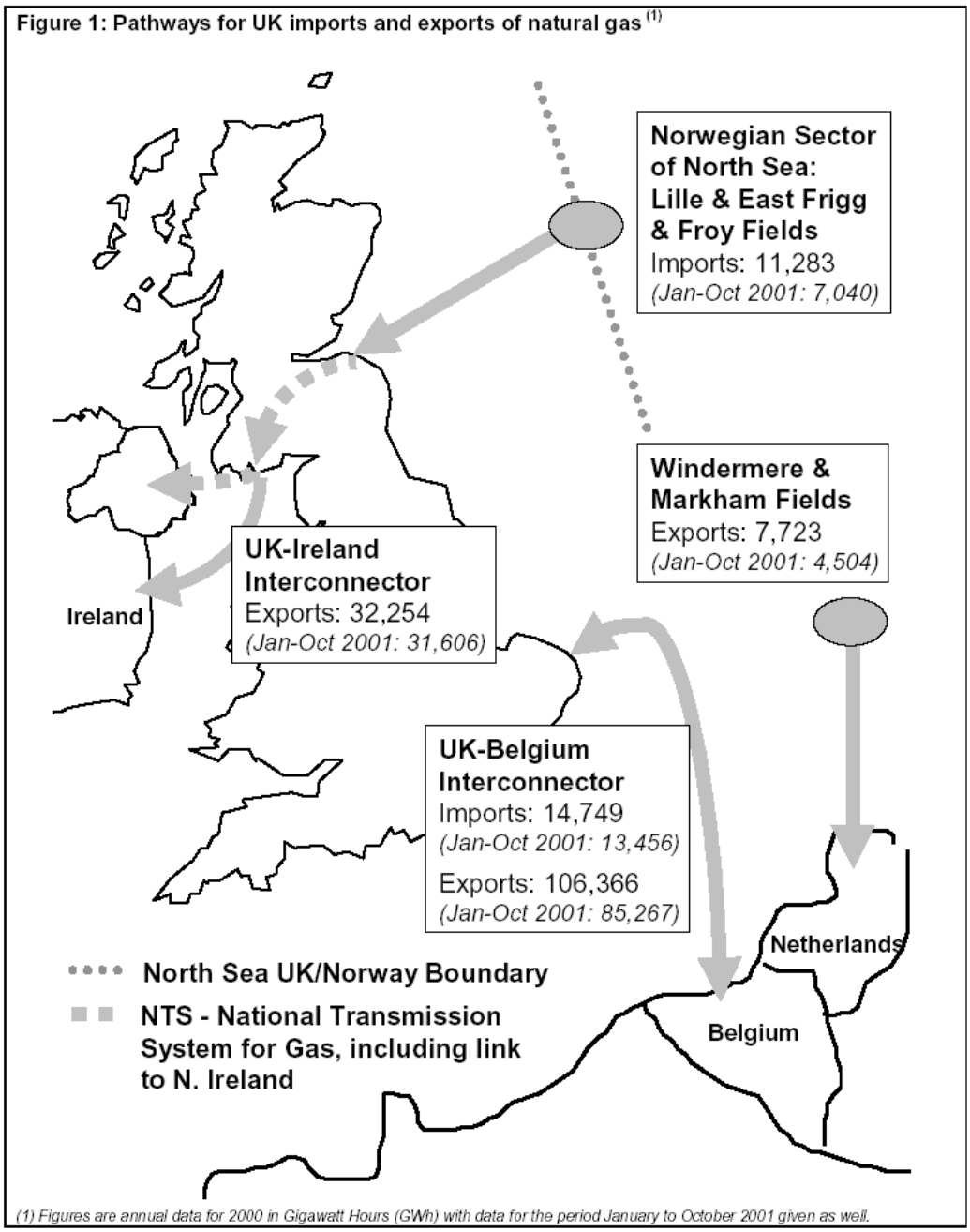
Gazprom is the world's biggest gas exporter. Its deliveries cover about 20% of the natural gas requirements of Western Europe and almost all the needs of Eastern Europe. The Company is continuing to build up its exporting arm. Other types of economic and technological cooperation with foreign partners are developing simultaneously. What ensures Gazprom's successful integration into the world gas market is the recently set up network of its foreign economic enterprises engaged in the direct sale of Russian gas. The problem of ensuring energy sources has acquired global importance, and Gazprom realizes the need to coordinate efforts between the world's leading power companies. The number of international projects with the participation of the Company and the number of its partners is constantly growing.. Practically all our agreements and contracts with foreign partners are concluded on the basis of the long-term perspective. Historically, Russia's gas industry was oriented to the European market. Russian gas is supplied to 19 European countries, excluding the CIS nations. In keeping with contracts already concluded and due to expire in 2010-2015 and beyond, our gas deliveries will increase, provided market conditions prove to be favourable. The liberalization of gas markets requires a more flexible export policy on the part of Gazprom.

In particular, this provides for the stage-by-stage development of the Yamal-Europe gas transporting system. Apart from that, the construction of a North European gas pipeline across the Baltic countries is also possible. This will increase the reliability and efficiency of gas deliveries, improve conditions for gas sales in Germany, facilitate entry into the Belgian market and in future, through the Interconnector system, also to that of Britain.

Along with the traditional direction of our exports, we are actively developing the southern direction, too. The biggest project there is the Blue Stream major project which provides for the construction of a gas pipeline across the Black Sea to Turkey. Apart from that, a contract has been initialled with India's Ministry of Oil and Natural Gas for the prospecting for, development and operation of a major gas field on the Bay of Bengal shelf. The Far Eastern region-China, Korea and Japan- should become a new promising gas market for us.

# Annex: Gas Pipelines Currently Entering the UK.

Gas

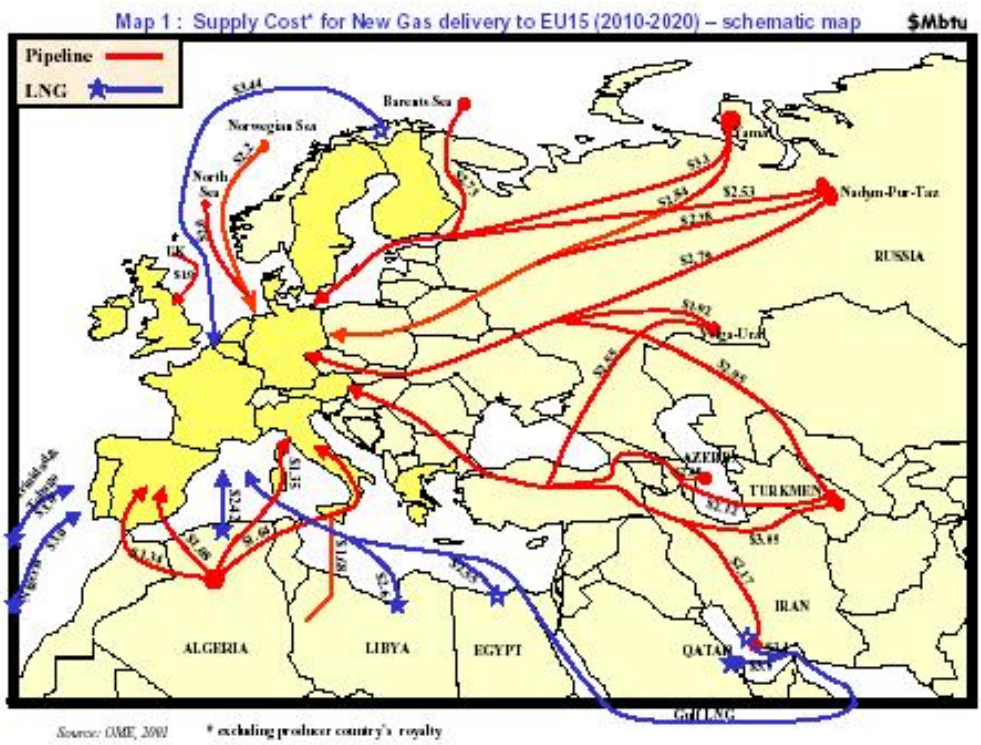


# Annex: The EU Gas Pipeline Networks.

Figure 2: The EU gas pipeline network for imports and exports of natural gas


Source: www.eurogas.org/natgas/gasgrid.htm.

## Annex: Pipelines from Russia into the EU.



# Annex: Scenario Used in this Report and the Other Scenarios considered by DTI.

**Table G.1 ESI Capacity, GW**

| LL | 1999 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|
| Coal | 20 | 19 | 6 | 0 | 0 | 0 |
| Coal FGD | 6 | 6 | 9 | 9 | 9 | 7 |
| Oil | 3 | 2 | 2 | 0 | 0 | 0 |
| Mixed | 7 | 7 | 6 | 4 | 2 | 0 |
| GT | 2 | 2 | 2 | 2 | 3 | 6 |
| CCGT | 16 | 18 | 27 | 37 | 41 | 46 |
| Nuclear | 13 | 13 | 12 | 10 | 7 | 4 |
| Renewables | 2 | 2 | 4 | 8 | 7 | 8 |
| Other | 5 | 5 | 5 | 5 | 5 | 5 |
| Total | 73 | 74 | 73 | 74 | 75 | 75 |

| LH | 1999 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|
| Coal | 20 | 19 | 6 | 1 | 1 | 0 |
| Coal FGD | 6 | 6 | 11 | 11 | 11 | 8 |
| Oil | 3 | 3 | 2 | 0 | 0 | 0 |
| Mixed | 7 | 7 | 6 | 5 | 3 | 0 |
| GT | 2 | 2 | 2 | 2 | 1 | 4 |
| CCGT | 16 | 18 | 23 | 31 | 35 | 45 |
| Nuclear | 13 | 13 | 12 | 10 | 7 | 4 |
| Renewables | 2 | 2 | 4 | 7 | 7 | 7 |
| Other | 5 | 5 | 5 | 5 | 5 | 5 |
| Total | 73 | 74 | 71 | 71 | 71 | 72 |

| CL | 1999 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|
| Coal | 20 | 19 | 6 | 0 | 0 | 0 |
| Coal FGD | 6 | 6 | 9 | 9 | 9 | 7 |
| Oil | 3 | 2 | 2 | 0 | 0 | 0 |
| Mixed | 7 | 7 | 6 | 4 | 2 | 0 |
| GT | 2 | 2 | 2 | 2 | 3 | 6 |
| CCGT | 16 | 18 | 28 | 38 | 42 | 48 |
| Nuclear | 13 | 13 | 12 | 10 | 7 | 4 |
| Renewables | 2 | 2 | 4 | 8 | 7 | 8 |
| Other | 5 | 5 | 5 | 5 | 5 | 5 |
| Total | 73 | 74 | 74 | 75 | 76 | 78 |

# UK Electricity Scenarios, Continued.

| CH | 1999 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|
| Coal | 20 | 19 | 6 | 1 | 1 | 0 |
| Coal FGD | 6 | 6 | 11 | 11 | 11 | 8 |
| Oil | 3 | 3 | 2 | 0 | 0 | 0 |
| Mixed | 7 | 7 | 6 | 5 | 3 | 0 |
| GT | 2 | 2 | 2 | 2 | 2 | 4 |
| CCGT | 16 | 18 | 24 | 32 | 36 | 47 |
| Nuclear | 13 | 13 | 12 | 10 | 7 | 4 |
| Renewables | 2 | 2 | 4 | 7 | 7 | 7 |
| Other | 5 | 5 | 5 | 5 | 5 | 5 |
| Total | 73 | 74 | 72 | 73 | 73 | 74 |

| HL | 1999 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|
| Coal | 20 | 19 | 6 | 0 | 0 | 0 |
| Coal FGD | 6 | 6 | 9 | 9 | 9 | 7 |
| Oil | 3 | 2 | 2 | 0 | 0 | 0 |
| Mixed | 7 | 7 | 6 | 4 | 2 | 0 |
| GT | 2 | 2 | 2 | 2 | 3 | 6 |
| CCGT | 16 | 18 | 29 | 39 | 44 | 51 |
| Nuclear | 13 | 13 | 12 | 10 | 7 | 4 |
| Renewables | 2 | 2 | 4 | 8 | 8 | 8 |
| Other | 5 | 5 | 5 | 5 | 5 | 5 |
| Total | 73 | 74 | 74 | 76 | 78 | 80 |

| HH | 1999 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|
| Coal | 20 | 19 | 6 | 1 | 1 | 0 |
| Coal FGD | 6 | 6 | 11 | 11 | 11 | 8 |
| Oil | 3 | 3 | 2 | 0 | 0 | 0 |
| Mixed | 7 | 7 | 6 | 5 | 3 | 0 |
| GT | 2 | 2 | 2 | 2 | 2 | 4 |
| CCGT | 16 | 18 | 24 | 33 | 38 | 49 |
| Nuclear | 13 | 13 | 12 | 10 | 7 | 4 |
| Renewables | 2 | 2 | 4 | 7 | 7 | 7 |
| Other | 5 | 5 | 5 | 5 | 5 | 5 |
| Total | 73 | 74 | 73 | 74 | 75 | 77 |

***The Scenario used in this present Report is labelled "CH".***

The single most noticeable thing about the above DTI Scenarios is that they all forecast virtually total reliance on imported gas as the source of UK electricity by 2020.