KERNFORSCHUNGSZENTRUM

KARLSRUHE

September 1971 KFK 1448

Institut für Angewandte Reaktorphysik

The Challenge of Natural Gas in the Federal Republic of Germany

Z. J. Holy, G. Woite

GESELLSCHAFT FUR KERNFORSCHUNG M. B. H.

KARLSRUHE

GESELLSCHAFT FÜR KERNFORSCHUNG M.B.H.
KARLSRUHE

KERNFORSCHUNGSZENTRUM KARLSRUHE

September 1971

KFK 1448

Institut für Angewandte Reaktorphysik

The Challenge of Natural Gas in the Federal Republic of Germany

Z. J. Holy, G. Woite

Gesellschaft für Kernforschung m.b.H., Karlsruhe

Abstract

An answer is sought to the question of whether the discovery of natural gas reserves in the Federal Republic of Germany and its neighbours represents an important new energy source. Making a reasonable estimate of the future yearly natural gas consumption, the life of the reserves is forecast. The indications are that sufficient supplies within the FRG and its neighbours for about 1o % of the primary energy demand of the FRG will be available for at least three to four decades.

Es wird eine Antwort gesucht auf die Frage, ob mit der Entdeckung neuer Erdgasvorkommen in der BRD und ihren Nachbarstaaten bedeutende Energiequellen verfügbar werden.
Zu diesem Zweck wird die Lebensdauer der Reserven anhand von Prognosen über den zu erwartenden Erdgasverbrauch abgeschätzt.
Die Ergebnisse weisen darauf hin, daß die BRD und ihre Nachbarstaaten über genügend große Vorkommen verfügen, um etwa 1o % des Primärenergiebedarfs für mindestens drei bis vier Dekaden zu decken.

zum Druck eingereicht im September 1971

C o n t e n t s

1. Introduction

In the last few years the pattern of energy usage in the Federal Republic of Germany has undergone considerable changes. There has been a marked decrease in the consumption of coal, and a consequent increase in the consumption of oil. In addition both natural gas and nuclear power have recently appeared as new energy sources. This pattern must continue to change as discoveries of natural gas in great quantities make it more and more competitive.

In the year 1969 only about 5 % of primary energy consumption in the Federal Republic of Germany was derived from natural gas, while in the USA the figure was 3o % and in the USSR approximately 45 %, from which it is obvious, if a similar pattern is followed and sufficient reserves are available, that natural gas consumption in the FRG is only in its infancy.

The main objective of this report is to answer two questions. We know that there are natural gas reserves available within the borders of and accessible to West Germany. The question is whether these reserves represent a new energy source sufficient to cover at least part of the primary consumption for a reasonable period, say 3o to 4o years. If so, the second question to be answered is, how competitive is this natural gas in electricity production compared with the other fast growing energy source, i.e. nuclear power? In order to obtain an answer to the first question we must make an assumption concerning the growth of the consumption of natural gas in various energy fields, and estimate what part will be covered from the German sources and what part from imports, and from the cumulative figures judge the life of the reserves. The fact that these estimates of the consumption cannot and will not be accurate will not substantially alter the general character of the answer. In making a comparison between the economics of current and future types of nuclear power stations and natural gas fired stations we are on firmer ground, as in most cases reliable figures for both capital and fuel costs are available.

The second question thus resolves itself into one of estimating the price of natural gas which makes a plant of a particular size competitive with a nuclear power plant of the same output.

Forecasts, especially in the energy field, must be treated very carefully. They should be interpreted only as an indication of a possible trend and should form a rational basis for the initiation of action. They are of little importance without knowledge of the methods, and their implications, by which they have been produced. Forecasts should not be regarded as rigid and final, but should be revised at frequent intervals to incorporate the effects of changed economic conditions. Adherence to rigid forecasts, without their updating, can lead to wrong planning and severe problems [1].

2. Natural Gas Reserves

The natural gas reserves of a few countries of interest are shown in table 1 [2, 3, 4, 15]. The energy potential of the safe and probable natural gas resources of the world is nearly half that of the oil resources [11]. Corresponding to this, the percentage of the primary energy consumption met by natural gas is nearly half that of oil: gas 19 %, oil 42 % [11]. The safe and probable resources of both oil and gas would be sufficient to supply these portions roughly until 199o.

Because of the policy of the oil companies not to prospect more oil or gas than there will be needed in the next two decades or so it can be expected that important resources will be discovered in the next decades. Estimations of the world's possible natural gas resources vary from 14o x lo^{12} m^3 [15] to 28o x lo^{12} m^3 [21]. That means that natural gas would be able to supply its present 19 % of the world's primary energy consumption roughly until 2o1o [15] or 2o3o [21].

Since natural gas is not so easily to be transported as oil, the extent of its use varies very much from one country to another. In order to evaluate the future role of natural gas in the FRG we have to regard the local reserves. The reserves of primary interest in this study are mainly those in West Germany and the Netherlands. The Russian reserves as well as those of Africa and Near East are regarded here as being of secondary importance because of the greater distance and resulting transportation costs as well as a lower security of supply. It is considered advisable that imports from the USSR and the Arabian states should not exceed (say) 10 - 20% of the total natural gas consumption at any time, because of the difficulties which could arise if the current favourable political climate should change and restrictions be imposed. In Germany the certain and probable reserves are 343×10^9 Nm^3 while possible reserves (inferred) are 625×10^9 Nm^3. For the Netherlands the figures are 2350×10^9 Nm^3 and 4000×10^9 Nm^3 respectively. Fig. 1 shows a map with the distribution of the known reserves and as seen, the Dutch fields are located close to the areas of high industrial concentration in Germany.

In estimating the lifetime of the reserves, certain and probable reserves which can be assumed to be available for exploitation already, as well as possible reserves, were taken into account. Figure 2 illustrates the rate of discovery of additional reserves over the last decade in the FRG. Assuming that the rate of discovery remains constant as in the last few years, it is evident that within the foreseeable future the magnitude of the exploitable reserves will reach the value of the estimated possible reserves. It is the practice of the oil companies, which form the bulk of the natural gas suppliers, not to prospect for new oil or gas fields unless these can be commercially exploited within five years of discovery. Hence the impending exhaustion of available reserves provides an impetus for new exploration, resulting in new discoveries. Thus it is justifiable in these estimates to include both the probable and possible reserves.

3. Forecast of Natural Gas Consumption in the FRG

We will now estimate the natural gas consumption in the FRG and the life of the German and Dutch reserves. A number of these estimates have been published covering various time spans, and after taking all these into consideration, the overall natural gas consumption up to the year 2000 has been estimated as shown in Fig. 3. In principle this estimate ist based on [3] and [5]. In addition Fig. 3 shows estimates of the total primary energy consumption, and Fig. 5 the portions taken by nuclear power, oil and others such as coal, water etc. The units used in Fig. 3 are in 10^6 t coal equivalent, and for each energy source the percentage of the total consumption is also indicated, thus providing

an overall picture of the changing importance of the various sources. The figures for natural gas (average calorific value 83oo Kcal/Nm^3) are given in table 2.

It will be noted that, while the consumption of natural gas in our estimates continues to increase up to the year 2ooo, its percentage portion of the total primary energy consumption is nearly unchanged after the year 198o, in contrast to nuclear power which will cover an ever increasing portion of the total consumption. The reason is that total natural gas consumption is restricted by the availability of the local reserves after the year 199o, when it appears that most of the consumption will be covered by imports, thus creating transport and cost problems.

Fig. 4 again shows the estimated overall yearly consumption of natural gas, split into two portions, the part which is supplied from German sources and the part which is supplied by the imports, i.e. Dutch and Russian deliveries. As seen, the contracted Russian supplies represent only a very small portion of the overall yearly consumption and will not play any important role if they remain at their present level. On the other hand imports, **initially** of Dutch gas, will form a larger and larger part of the consumption as the German reserves are gradually exhausted. It is expected that the local exploitation rate after 198o will remain fairly static at approximately 2o - 25 x $1o^9$ Nm^3/a [3], and all the increase in the overall consumption will be covered by imports. The reasons for this are the policy of the oil companies to maintain gas prices at a profitable level by avoiding overproduction, the advisability of keeping a certain portion of the local reserves intact for emergency use at a later date, and the technical problems associated with high rate distribution and exploitation from individual fields.

Cumulating the gas consumption covered from the German sources, an estimate is then obtained of the life of the local reserves, and this is also shown in Fig. 4. Two lines of cumulative consumptions are shown, one being German sources only and the second taking also into consideration the Russian deliveries. The points of intersection of these lines with the lines of the total local reserves indicate the years of estimated exhaustion. Thus, taking Russian imports into account, and considering only certain and probable reserves now known to exist in Germany, these would be exhausted before 199o. Taking the possible reserves as a measure,the exhaustion point would be reached at the year 2ooo. If the consumption from local sources is tapered off,as indicated by the broken lines, the exhaustion point is postponed as shown in the graph. This policy might be well worth pursuing, as it would ensure that the last portion of the local reserves (say up to lo %) would be exhausted much slower, and would in fact act as a kind of emergency supply in case of need.

Thus the inescapable conclusion is that between the years 1995 and 2ooo practically all the German natural gas consumption must be covered by imports.

The question arises whether the Dutch reserves are sufficiently high to cover the expected exports as well as the home consumption. Assuming that the current rate of growth of primary energy in the Netherlands is maintained, then the total primary energy consumption in 198o should reach about 12o - 13o x lo^6 t/a coal equ. The economical long range exploitation rate of the reserves is estimated at approximately 8o x lo^9 Nm^3/a and should also be reached at about 198o /_6_7. From the 4o - 45 x lo^9 Nm^3 available for export, about 2o x lo^9 Nm^3 is already covered or is going to be covered by long range delivery contracts to countries other than Germany /_2, 7_7 leaving at most about 25 x lo^9 Nm^3 in 198o and subsequent years for export to the FRG. To this figure the contracted Russian deliveries of 3 x lo^9 Nm^3 of average calorific value of 94oo Kcal/Nm^3 must be added.

Taking the expected Dutch exploitation rate in 198o as the average yearly value, and their possible reserves of 4ooo x lo^9 Nm^3 as certain, the exhaustion of the fields would come at about the year 2o2o. Thus it is obvious that, although sufficient local and Dutch gas reserves exist to ensure continuous supply, the expected exploitation rates are such that after 198o imports from other countries must supplement the deliveries to the FRG from the Netherlands. This deficiency could be covered by increased Russian deliveries together with supplies of liquified gas from North Africa and other sources, and perhaps gas from the North Sea.

Obviously, if the Dutch exploitation rate can be increased above the assumed rate of 8o x $1o^9$ Nm^3/a the deficiency in the deliveries after 198o could be eliminated. Although this would lead to earlier exhaustion of the Dutch reserves it could be a safer policy, in that reliance is not placed on a substantial increase in Russian deliveries. On the other hand, when their reserves reach a certain point, the Netherlands may restrict exports in order to conserve supplies for their own use.

4. Natural Gas for Electricity Generation

The next question to be answered is what portion of the annual natural gas consumption will be used for the generation of electricity, i.e. to estimate the curve of the installed capacity of natural gas power plants. In order to do this we will first consider the current aspects, then the long-term prospects of competitiveness between gas-fired and nuclear power stations.

4.1 Current Economics of Natural Gas and Nuclear Power Stations

A measure of the economy of any type of power station is its total electricity generating cost. This cost depends on a number of cost items, the most essential ones being capital investment, load factor, interest rate, depreciation period, and fuel cost. All these items vary, making it hard to find a fixed basis for economic comparisons. Looking for a convenient method of avoiding this difficulty, the presentation of fig. 9 was chosen. Taking capital investment as shown in fig. 8 as a basis, the other main cost items are varied. Plant size is plotted horizontally and natural gas price vertically, so that one can compare the economics of gas-fired and nuclear power stations at any plant size and gas price. Below the curves plotted in fig. 9 natural gas gives lower electricity generating cost, while above them nuclear energy is more economic.

At load factor of o.7 a gas-fired power plant with an output less than 3oo MWe is more advantageous than a nuclear one, accourding to fig. 9. At a load factor of o.45 the break-even point is at 6oo MWe. If the 197o price at the Dutch border is considered, natural gas plants become competitive at a load factor of o.7 and a size of 6oo MWe, or at a load factor of o.45 and a size of 1oo MWe.

The capital cost data given in fig. 8 refer to early 197o. The capital cost variation indicated for the natural gas station is conservative and could be lower. It would correspond more to the cost degression of an oil-fired station, and this has been done deliberately, in order to enable the inclusion of oil prices in the economic consideration.

LWR capital cost has rised considerably since early 197o, shifting the curves plotted in fig. 9 to the right in favour of the gas-fired plants. In spite of this fact, the calculations were not reiterated because current economics are not decisive for the prospects of electricity generation from gas-fired plants. Because of the long lifetime of power plants the importance quantity is the average cost per kWh. For this reason we will now consider future prospects for natural gas, oil and uranium prices.

4.2 Prospects of Natural Gas, Oil and Uranium Prices and Supply Safety

Estimating of future prices is hard. There have been many surprises in the field of fuel prices in the past, and the only certain prospect is that this trend will continue.

The natural gas market situation is not very clear in the FRG; various prices and conditions have been contracted. Most of the natural gas is supplied by the major oil companies, who are in a position to regulate the prices of both oil and gas to suit themselves. In most price agreements the gas price is coupled to the oil price. The recent sharp rise of oil price was followed by an immediate (mostly less sharp) rise of gas prices. At the moment it seems unlikely that this marked rise will continue; but there will be a permanent danger of surprising oil and gas price boosts because of the small number of countries possessing important resources and the small number of big independent suppliers.

In contrast uranium has been found in many countries, and many independent suppliers are in competition. Yellow cake price has been slightly decreasing for a couple of years. This will end with the demand boom to come; but the most important fact for the utilities is that contracts are offered for 2o years of uranium supply at a definite price margin.

In the field of uranium enrichment, on the other hand, there is very little competition. But there are some intentions for new enrichment plants so that there may be more competitors in the future. Alternatively it is much cheaper to hold a stock of enriched uranium in order to avoid too strong dependence of the supplier than to hold a stock of an equivalent amount of oil or gas.

Beyond that the fast breeder type of nuclear plant does not need any stock of fissile material in order to achieve safe and independent supply, except the inventory for startup and first reload, because it breeds its own fissile material. Only an insignificant amount of very cheep depleted uranium, which can be stored easily, is required.

4.3 Forecast of Natural Gas Consumption for Electricity Generation

In 1967, Gas-fired plants covered 2.6 % of the total installed electricity generating capacity. According to the economic (sec. 4.1) and other advantages (e.g. short construction time and easy commissioning procedure) many decisions have been made in the past years in favour of gas-fired plants. It can be expected that in 1975 gas-fired plants will cover 1o % of the total electricity generating capacity. The question is whether this boom will continue after 1975 or if the portion of gas-fired plants will stagnate or if it will fall back. In order to judge this let us consider what a constant portion of 1o % would mean in terms of gas amount needed for electricity generation.

Reliable estimates of the total electricity generating capacity for Germany are available. Fig. 5 shows the total estimated installed capacity in GWe, split into conventional and nuclear power. For the estimate of the nuclear portion the curve given by Recker /_17_7 is used.

From the yearly variation of the installed capacity of the natural gas stations, an estimate of the net generated electricity in a particular year can be obtained in TWh/a, taking a load factor of 4ooo h/a for the natural gas stations in the next two decades when they will be run as intermediate as well as peak load stations, and 3ooo h/a after 199o. Finally, assuming 4o % thermal efficiency of a gas power plant, the gas required in a particular year for generating the above amounts of electricity can be estimated. With these assumptions the capacity of the gas-fired plants would reach 18 to 2o GWe in 199o and 28 to 4o GWe by the year 2ooo. The amount of gas for electricity generation would reach 18 to 2o x $1o^9$ m^3/a in 199o and 21 to 3o x $1o^9$ m^3/a in 2ooo. This is about one third of the gas amount which could be available for the FRG on a lang-term basis, see section 3.

Having this in mind as well as the economics and reserves situation, supply safety and safety from price increases we estimate that gas-fired power plants will not permanently exceed 1o % of the total electricity generating capacity.

On the basis of the present reserves and market situation we estimate that after the foreseeable sharp rise in natural gas use for electricity generation until 1975 the portion of gas-fired plants (in % of the total installed electricity generating capacity) will diminish.

We developped two alternative forecasts, an optimistic (forecast 1) and a more conservative one (forecast 2) which are given in Fig. 6 and 7. We expect the capacity of gas-fired power plants and natural gas consumption to grow within these alternative curves. In the following we will discuss some possibilities of future trends which would lead more to the optimistic or more to the conservative forecast

5. Discussion

Having answered our two basic questions, the conclusions are that natural gas represents a new energy source of considerable importance although of restricted duration. The known locally available reserves, and those of neighbouring countries which would be readily accessible, are such that they can guarantee the supply of increased quantities of gas for at least the next three decades. In comparison with oil reserves in the FRG, which are negligible, the reserves of natural gas are quite substantial, and natural gas imports are supplied from neighbouring countries with stable governments, which guarantees continuity. Another reason is that oil-fired stations can be changed over to gas-firing with very little time and difficulty and vice versa, thus enabling adjustment of the fuel usage according to needs and prices. In this context it must be realised that 72 % /‾3_7 of natural gas in the Federal Republic of Germany is supplied by the oil companies which also supply the bulk of the oil used. Hence it cannot be expected that natural gas will replace oil to such a degree that the oil companies will incur losses on their oil operations. Before this happens the price of natural gas will be increased to levels which will maintain the oil companies' profitability. Naturally this price monopoly could be broken by an outside supplier such as the USSR. The problem at present is not lack of supplies from Russia but the insufficiency in the distribution network on the German side. It is expected that by 198o or perhaps sooner this difficulty will be overcome, and it will be possible to count on increased Russian deliveries. In this context it should again be emphasised that any marked increase above the currently contracted Russian deliveries ($3 \times 1o^9$ Nm^3/a for 2o years from 1973) should be avoided, as increased dependence on this source could lead to problems if restrictions are imposed, whatever the reason may be. A figure of about 1o % of total gas consumption at any time would appear as a safe limit. A further point of interest is that the combustion products from gas-fired stations are relatively free, compared with oil-fired stations, from harmful ingredients which contribute to environmental pollution.

Considering the current price of delivered local gas, and making an economic comparison with existing light water reactor plants, it has been shown that at a load factor of o.7 a gas-fired station with an output less than 3oo MWe is more advantageous. At a load factor of o.45 the break-even point is at 6oo MWe. If the current price at the Dutch border is considered, natural gas plants become competitive at a load factor of o.7 and a size of 6oo MWe, or at a load factor of o.45 and a size of 1ooo MWe. Similar results apply in the case of a proposed sodium cooled fast breeder reactor.

These results are very important and can be interpreted, bearing in mind the relationship of oil and gas prices, to mean that as peak load stations (load factor o.45), gas-fired plants up to the size of 1ooo MWe are more economical than any other type of power plant. As base load stations (load factor o,8), nuclear power plants are supreme in middle and large sized power blocks (say > 5oo MWe). This leads to the justifiable question as to what will happen to the reserves, both local and foreign, if the whole increase in the German conventional electricity generating capacity after 1975 is covered by gas-fired power plants. The salient feature of this scheme would be that by 198o the total German gas consumption would reach 52 x 1o^9 Nm^3/a, in 199o-95 x 1o^9 Nm^3/a and in 2ooo about 135 x 1o^9 Nm^3/a. Because of the reasons discussed previously it would be difficult if not impossible to increase the German exploitation rate above 3o x 1o^9 Nm^3/a. At this rate the exhaustion dates of the local reserves will not change substantially from the dates given previously in Fig. 4 i.e. certain reserves 1986, probable reserves 1996. The imports required, after taking the contracted Russian deliveries into account, would be 198o - 2o x 1o^9 Nm^3/a, 199o - 6o x 1o^9 Nm^3/a and 2ooo about 1oo x 1o^9 Nm^3/a. Let us assume that all these imports will be covered from Dutch sources. In this case the Dutch exploitation rate required to cover their home consumption and exports to other countries as well, would be 8o x 1o^9 Nm^3/a in 198o, 135 x 1o^9 Nm^3/a in 199o and 18o x 1o^9 Nm^3/a over the period in question, the possible Dutch reserves would then be exhausted in 36 years, i.e. about 2oo5. Although the Dutch reserves are sufficient to cover such a scheme for a reasonable time, and although the scheme appears at least feasible up to the year 198o, the subsequent exploitation rates are completely unrealistic.

We have made two alternative forecasts on the sectors of energy demand discussed here, a more optimistic (forecast 1) and a more conservative one (forecast 2), see fig. 3, 6 and 7. We expect that the capacity of gas-fired power plants, the amount of gas used for electricity generation, and the overall natural gas consumption will nearly reach the optimistic forecast if additional significant natural gas resources would become available for the German market at competitive prices. In the following we consider two examples for such additional supply sources:

1. There is some possibility that further considerable resources of natural gas could be detected in or near Central Europe, e.g. in the North Sea. One should bear in mind, however, that the extraction and transportation of offshore gas costs about three times as much as on the mainland and has to bear additional risks [18].

2. There is also some chance that an international market of liquified gas will develop, as U.S. and Japanese contracts show. If transportation costs will decrease in the years to come, North African gas could compete on the German energy market.

If on the other hand the German market would not have access to this additional supply, the expected Russian and Dutch deliveries together with own sources would support a market which would tend to approach the more conservative forecast given (forecast 2).

6. Conclusion

Let us summarise the facts and possibilities which will tend to favour or to limit natural gas consumption in the FRG. Favouring facts are:

- substantial natural gas resources in and near Central Europe
- additional resources in Russia, Africa, Near East etc.
- low extraction cost
- competitive price under normal conditions (compared with other fossil fuels)
- very low price, if natural gas is delivered on the basis of an interruptable treaty
- low content of harmful ingredients which contribute to environmental pollution
- natural gas is very useful and easily to be handled for many industrial and domestic purposes.

Additional facts favouring the use of natural gas for power generation:

- low capital costs of gas-fired plants
- easy commissioning
- short construction period.

Limiting facts:

- the natural gas resources of Central Europe are quite substantial, but do not allow excessive growth of natural gas consumption
- the security of supply from Russia, Africa or Near East is regarded to be less than from the FRG itself or neighbouring countries

- high capital investment for transportation and distribution
- danger of unexpected price boosts

Additional limitations concerning natural gas consumption for power generation:

- lacking bids for long-term supply at definite price margin.

Taking into account the above favouring and limitating facts forecast 2 was evaluated. In this more conservative forecast we expect natural gas to cover:

- 9 to 1o % of the primary energy consumption (between 198o and 2ooo) and
- 7,7 % (198o) to 3 % (2ooo) of the electricity generation.

Furthermore the possibility of additional supply which could become available for the German market was considered such as:

- the discovery of additional resources in or near Central Europe
- prospects of an international liquified natural gas market.

If such additional resources would become available we believe that natural gas consumption could evaluate near the more optimistic forecast 1. That means that natural gas would cover:

12 to 14 % of the primary energy consumption and
1o % (198o) to 5 % (2ooo) of the electricity generation.

Acknowledgement

Acknowledgement is due to Dr. Murchland for his valuable suggestions and helpful discussions.

References

/_1_7 R. Eglin. The Cold Facts about Britain's Fuel Crisis. The Observer, 8th November 197o, p. 17

/_2_7 T. Geissler. Erdgas - ein neuer Brennstoff im Kraftwerksbetrieb. Teil I. Energie, Jahrg. 2o, Nr. 11, November 1968

/_3_7 N. Sandner. Die Bedeutung des Erdgases für die Energiewirtschaft der BRD. Glückauf 1o5 (1969) Nr. 23 (13. November 1969)

/_4_7 Information Bulletins of Various Oil Companies 1969-7o

/_5_7 Gas Wärme International, Bd. 18 (1969) Nr. 2, Seite 1o3 (Estimate for year 2ooo attributed to Esso AG)

/_6_7 H. Schelberger. Die Entwicklung der europäischen Erdgasversorgung. Gasverwendung. Bd. 2o (1969), Nr. 11, Seite 418

/_7_7 H. Schelberger. Die Situation des Erdgases in der Bundesrepublik Deutschland. Gas Wärme International. Bd. 18 (1969) Nr. 9, Seite 324

/_8_7 J. Seetzen. Wirtschaftlichkeitsaspekte (der Kernenergie). Schule für Kerntechnik, Kernforschungszentrum Karlsruhe, Januar 1969

/_9_7 H. H. Bischoff. Energieverbrauch, Energiequellen und Energiegewinnung in der Bundesrepublik Deutschland. Brennstoff - Wärme - Kraft, Bd. 2o (1968) Nr. 8, Seite 35o

/_1o_7 W. Mackenthun and E. Edelmann. Elektrizitätswirtschaft. Brennstoff - Wärme - Kraft. Bd. 22 (197o) Nr. 4, Seite 149

/_11_7 Oeldorado 7o, Sonderbeilage zum ESSO Magazin 1/71

/‾12_7 Euratom. Die Einsatzmöglichkeiten von Kernkraftswerken in der Elektrizitätswirtschaft der Bundesrepublik Deutschland bis 1985. EUR 44o7 d. Seite 53.

/‾13_7 Gasbrüter Memorandum. Bericht des Arbeitskreises Wirtschaftlichkeit. Kernforschungszentren Karlsruhe und Jülich, Juli 197o

/‾14_7 R. Ernst et al. Schnelle Brutreaktoren - Wirtschaftliche und technische Aussichten sowie aktueller Stand verschiedener Auslegungen, insbesondere hinsichtlich der Kühlmittel. Atom and Strom, Heft 1, Januar 197o

/‾15_7 H. Mandel: Die Künftige Rolle der Kernenergie als Primärenergieträger
Atomwirtschaft Mai 197o

/‾16_7 Hesselmann: Umstellung auf Erdgas und die Gestaltung von Erdgasbezugsverträgen
BWK 1/71

/‾17_7 KFK 466: Kernbrennstoffbedarf und Kosten verschiedener Reaktortypen in Deutschland

/‾18_7 K. Liesen: Langfristige Planung und Versorgungssicherheit in der deutschen Erdgaswirtschaft
Energiewirtschaftliche Tagesfragen 2/71

/‾19_7 Gils: Die Marktentwicklung in der Gaswirtschaft
Gas- und Wasserfach 5/71

/‾2o_7 ESSO: So heizt der Deutsche
Studie 5 der Volkswirtschaftlichen Abt. der ESSO AG, Hamburg

/‾21_7 M. K. Hubbert: Energy Resources for Power Production.
IAEA-SM-146/1, 197o

/‾22_7 G. C. Gambs, A. A. Rauth: The Energy Crisis
Chemical Engineering, Vol. 78, No. 12, May 1971

/‾23_7 H. Frewer: Energieverbund zwischen nuklearen und konventionellen Kraftwerken
Vortrag auf der Reaktortagung des Deutschen Atomforums und der KTG, Bonn 1971

Table 1 Natural Gas Reserves

Certain and probable Natural Gas Reserves
(possible reserves in parantheses)

	$1o^9 Nm^3$	$1o^{15}$ Kcal	$1o^3$ TWh thermal	$1o^3$ TWh	$1o^6$ t coal equiv.
Netherlands	235o (4ooo)	19.5	22.6	9.o	279o
Great Britain	991	8.2	9.6	3.8	1175
Federal Republic of Germany	343 (625)	2.85	3.32	1.33	4o7
France	3oo	2.5	2.9	1.16	355
Italy	178	1.49	1.71	o.68	21o
Σ EWG	4162	35	4o.13	15.97	5ooo
Austria	3o	o.25	o.29	o.12	36
Rumania	22o	1.83	2.13	o.85	261
USA	85oo	7o.5	82.o	83.o	1oooo
USSR	121oo	1oo.o	117.o	47.o	1435o
Near East	66oo	54.7	63.6	25.o	782o
Africa	488o	39.8	46.5	18.4	571o
World	$4o \times 1o^3$ ($14o-28o \times 1o^3$)	332 (116o-232o)	386	153	$47.5 \times 1o^3$
World, oil resources		78o (32oo)			

The following conversions between the units indicated in the table were used: Average calorific value of natural gas - 83ooo Kcal/Nm^3; 1 ton coal equivalent= $7 \times 1o^6$ Kcal.; 1 KWh = 86o Kcal; 1 TWh thermal = $1o^9$ KWh. When converting into TWhe thermal efficiency of 4o % was used.

Table 2 Energy forecasts for the FRG

Year	197o	198o		199o		2ooo	
Forecast No.		1	2	1	2	1	2
Primary energy consumption $1o^6$ t/a coal equ.	343	53o	47o	78o	64o	11oo	88o
Natural gas consumption "	2o	71	44	1o9	65	133	8o
Natural gas consumption $1o^9\ m^3/a$	17	6o	37	92	55	112	67
Natural gas for electricity gen. $1o^9\ m^3/a$	2,3	13	9	21	13	23	11
Power generated from nat.gas TWh_{el}/a	9	48	36	8o	5o	9o	4o
Load factor of gas-fired plants	o,5	o,45	o,45	o,45	o,4	o,35	o,3
Capacity " GWe	2	12	9	2o	15	3o	15
Total electricity generating capacity GWe	51	1o2	98	2o4	18o	4o8	28o
Electricity demand TWh_{el}/a	245	49o	47o	98o	86o	196o	135o

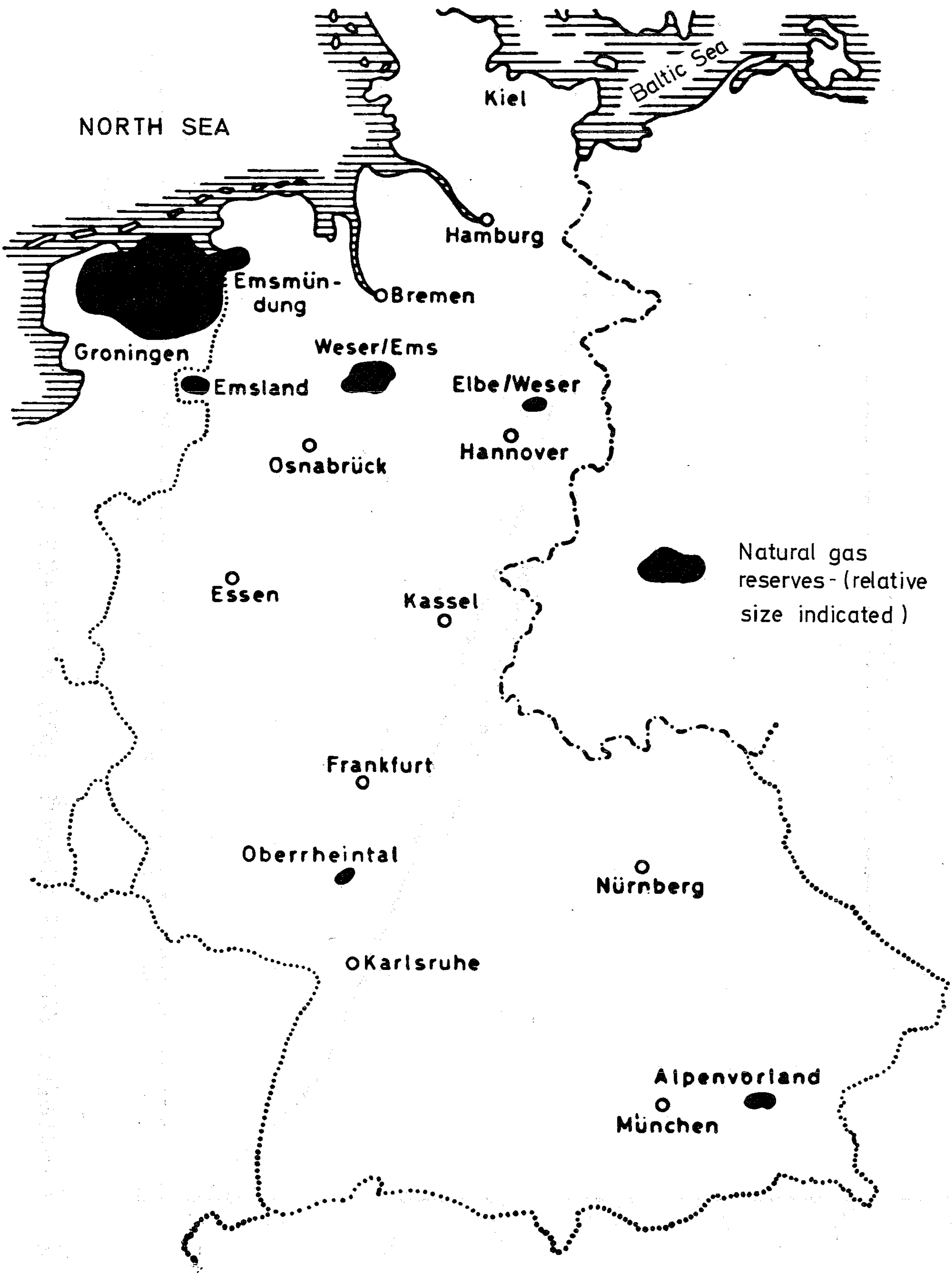

Fig. 1 Location of natural gas reserves in the FRG

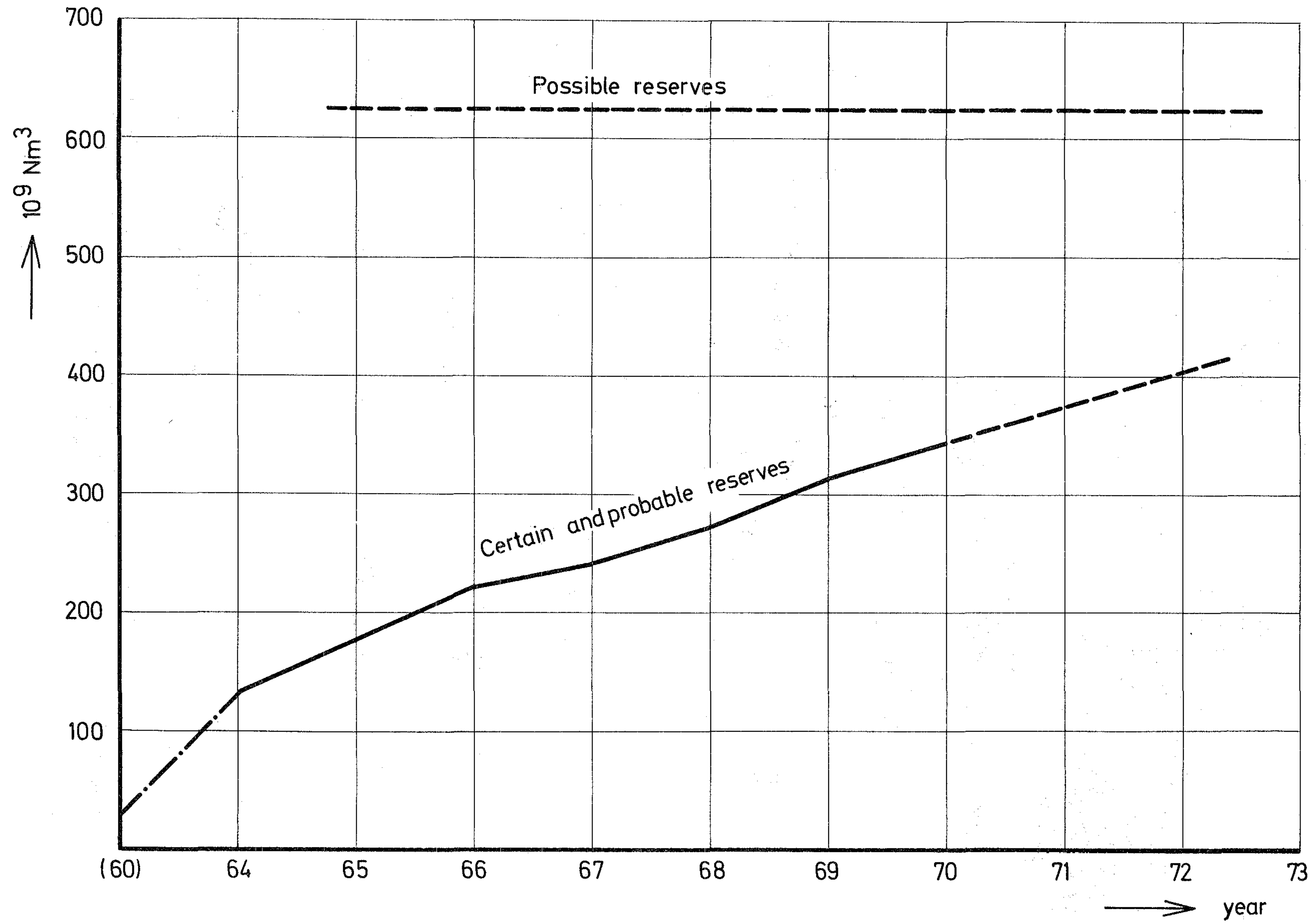

Fig.2 Discovery rate of natural gas reserves in the FRG

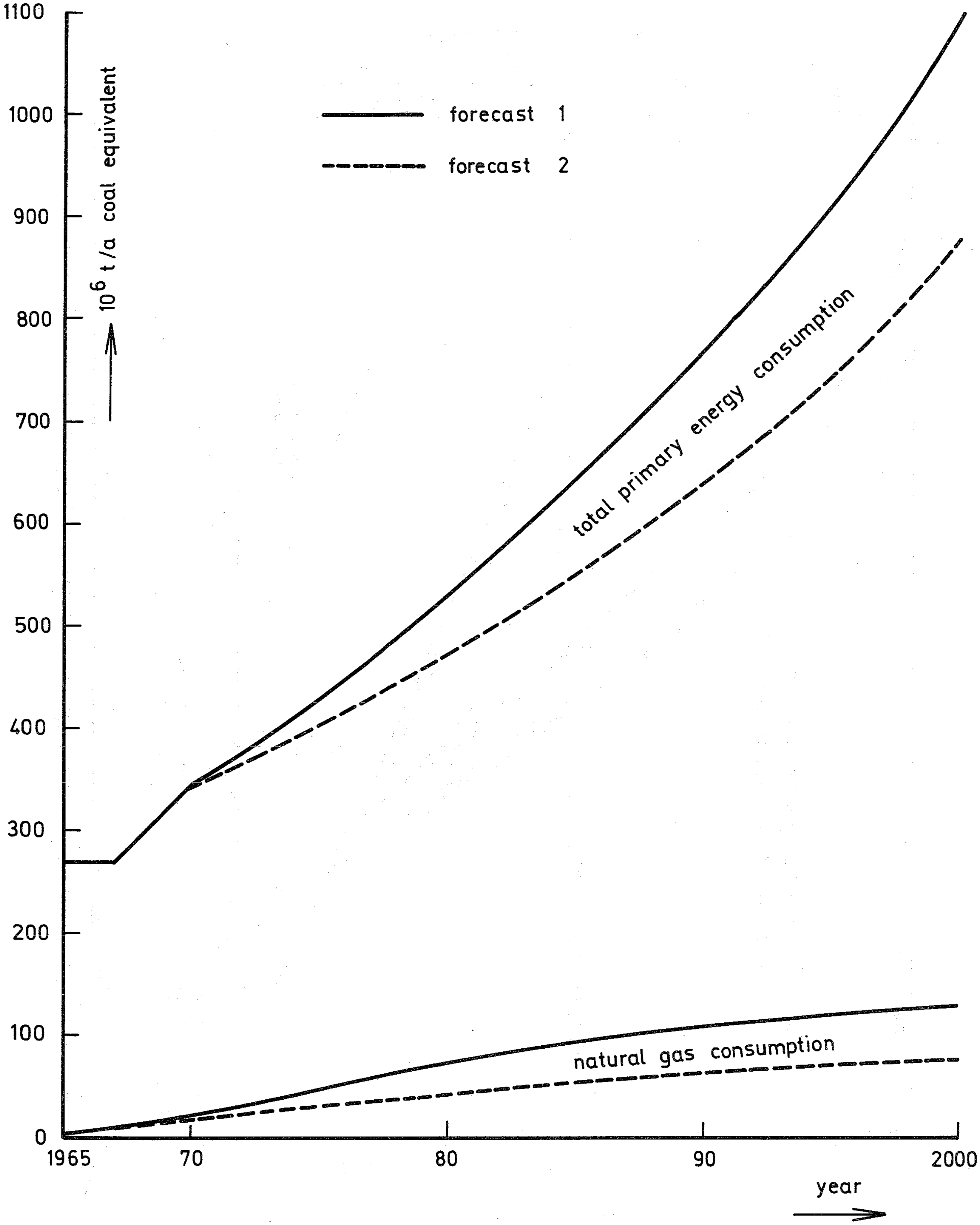

Fig. 3 Primary energy consumption in the FRG

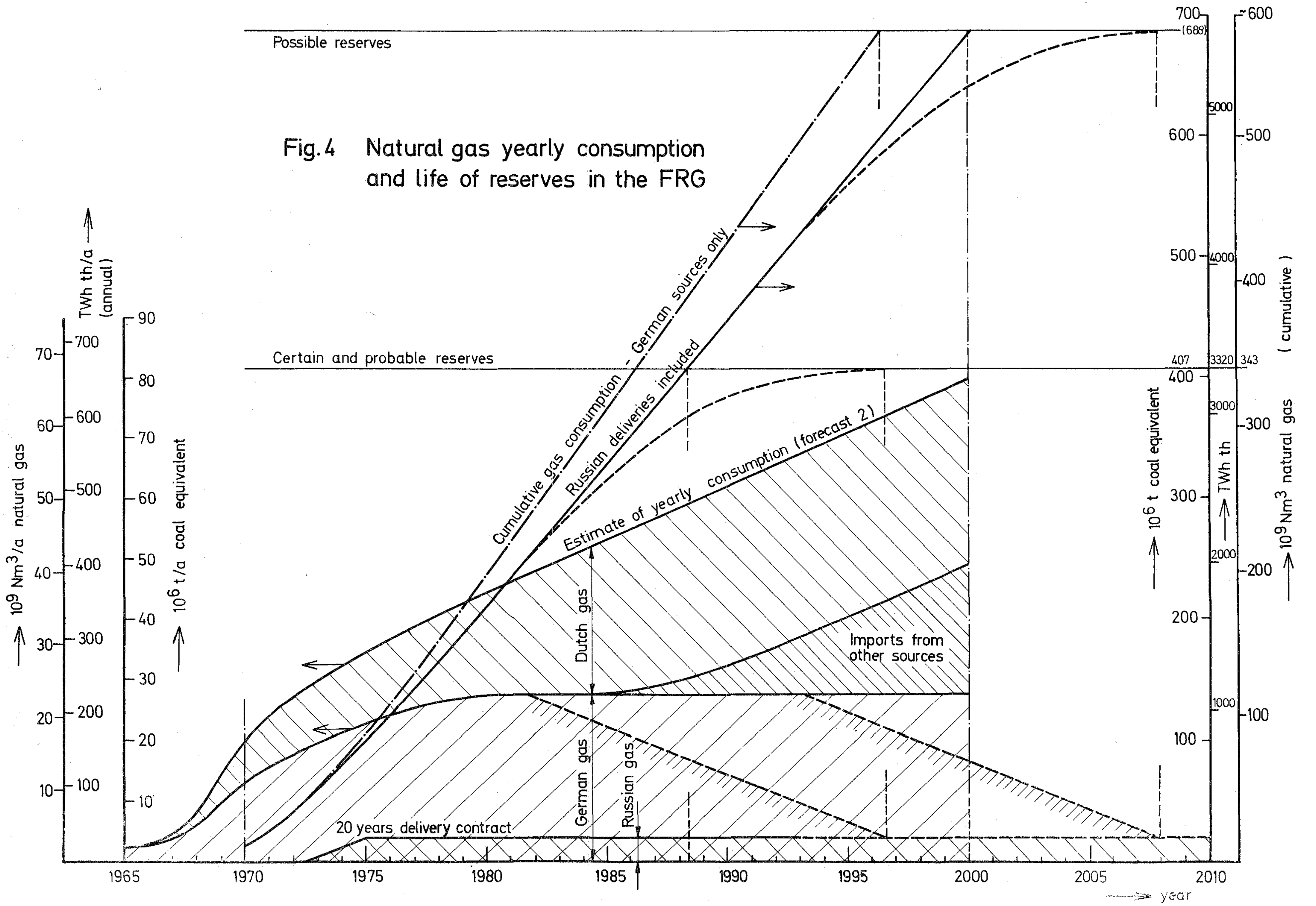

Fig. 4 Natural gas yearly consumption and life of reserves in the FRG

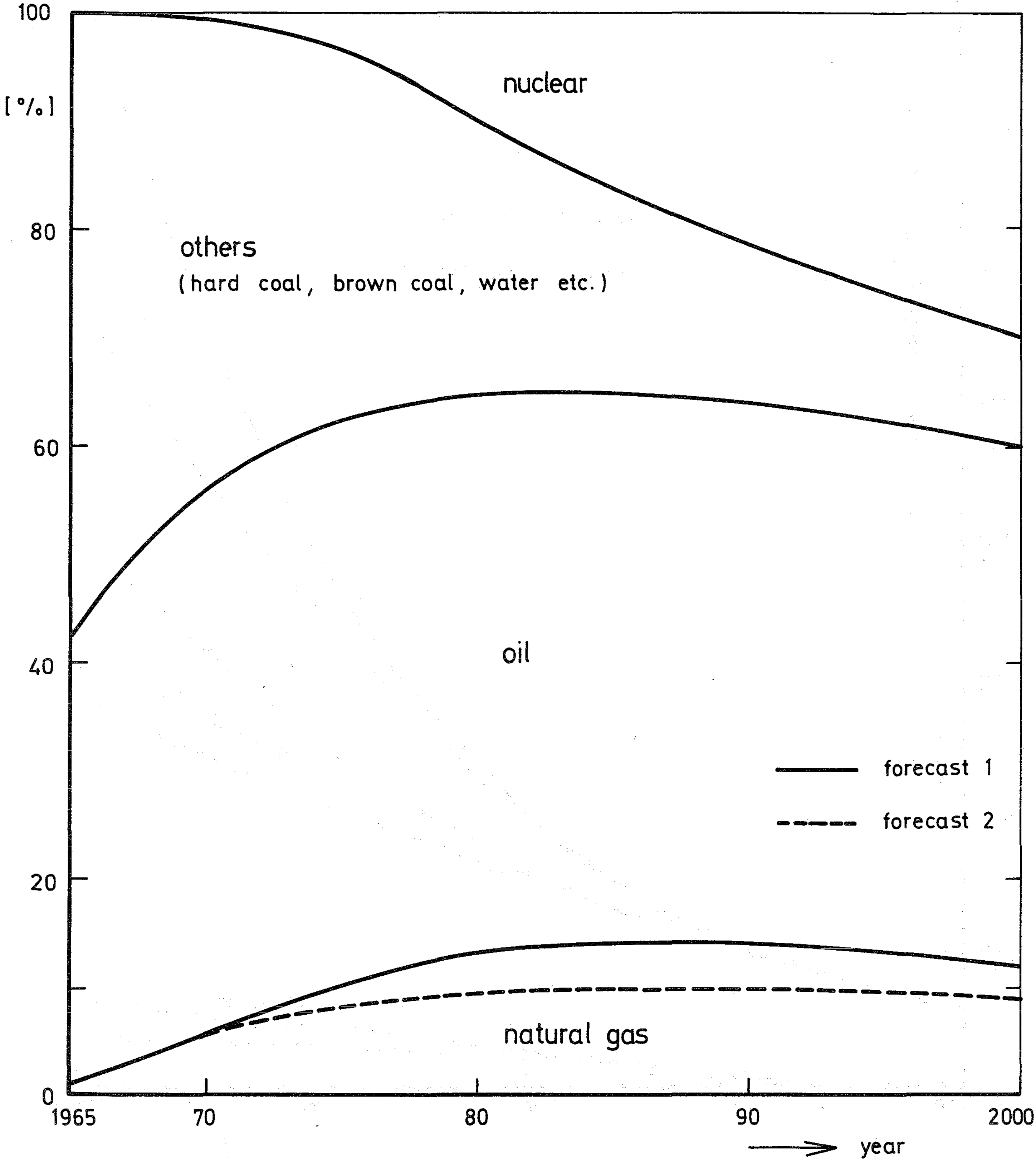

Fig. 5 Portions of the primary energy consumption in the FRG for different energy sources

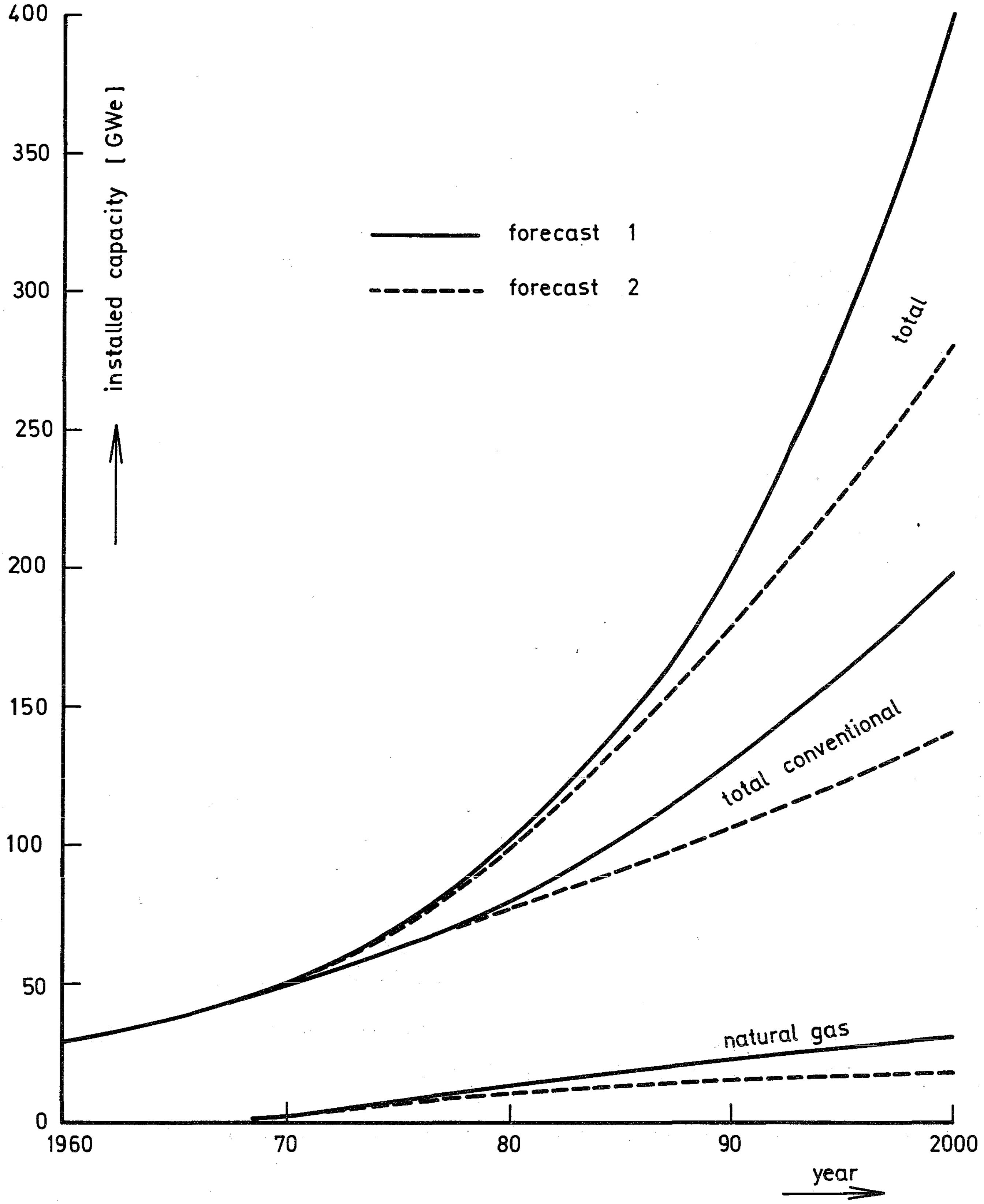

Fig. 6 Nuclear and conventional electricity generating capacities

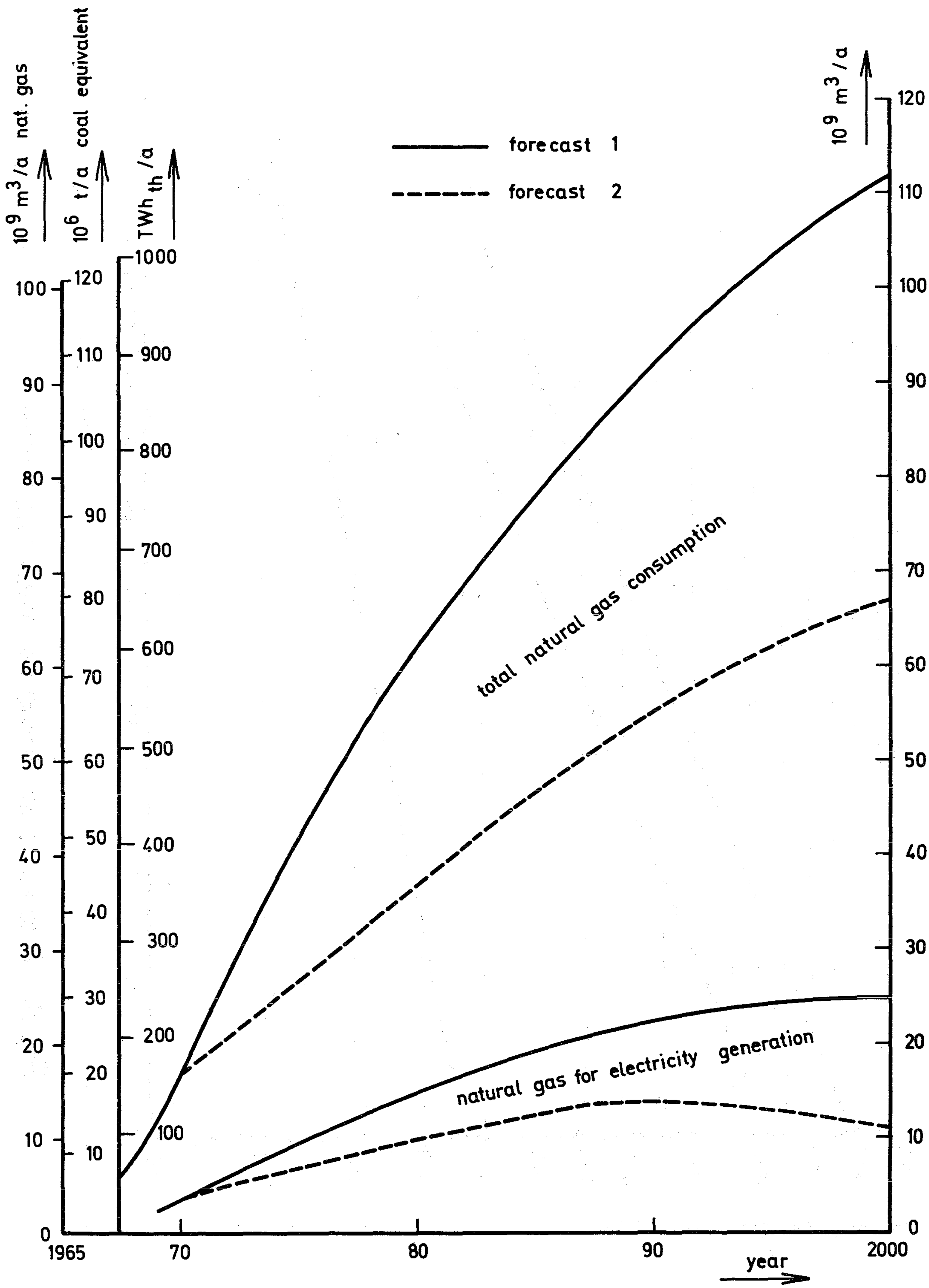

Fig. 7 Natural gas consumption in the FRG

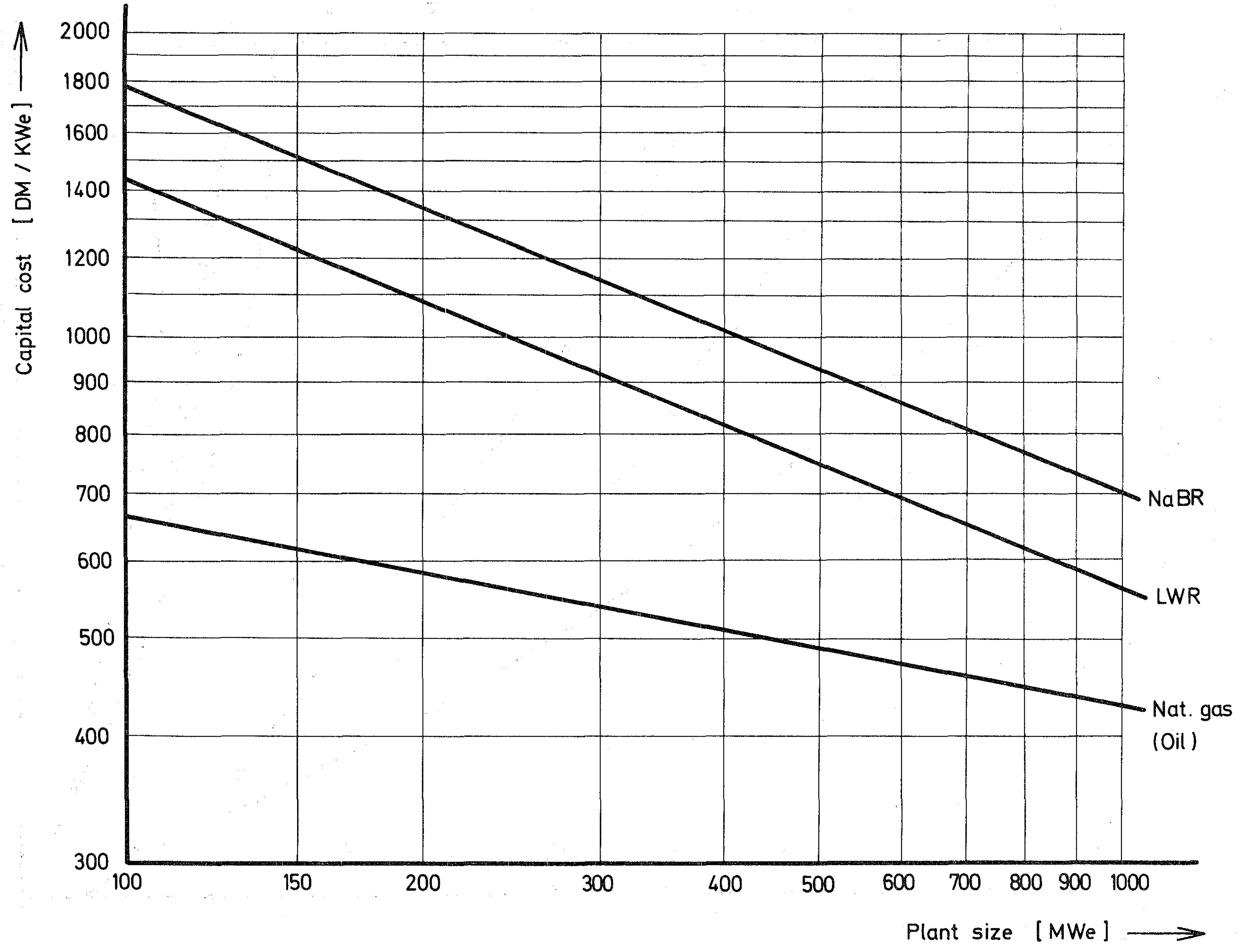

Fig. 8 Capital cost variation with plant size

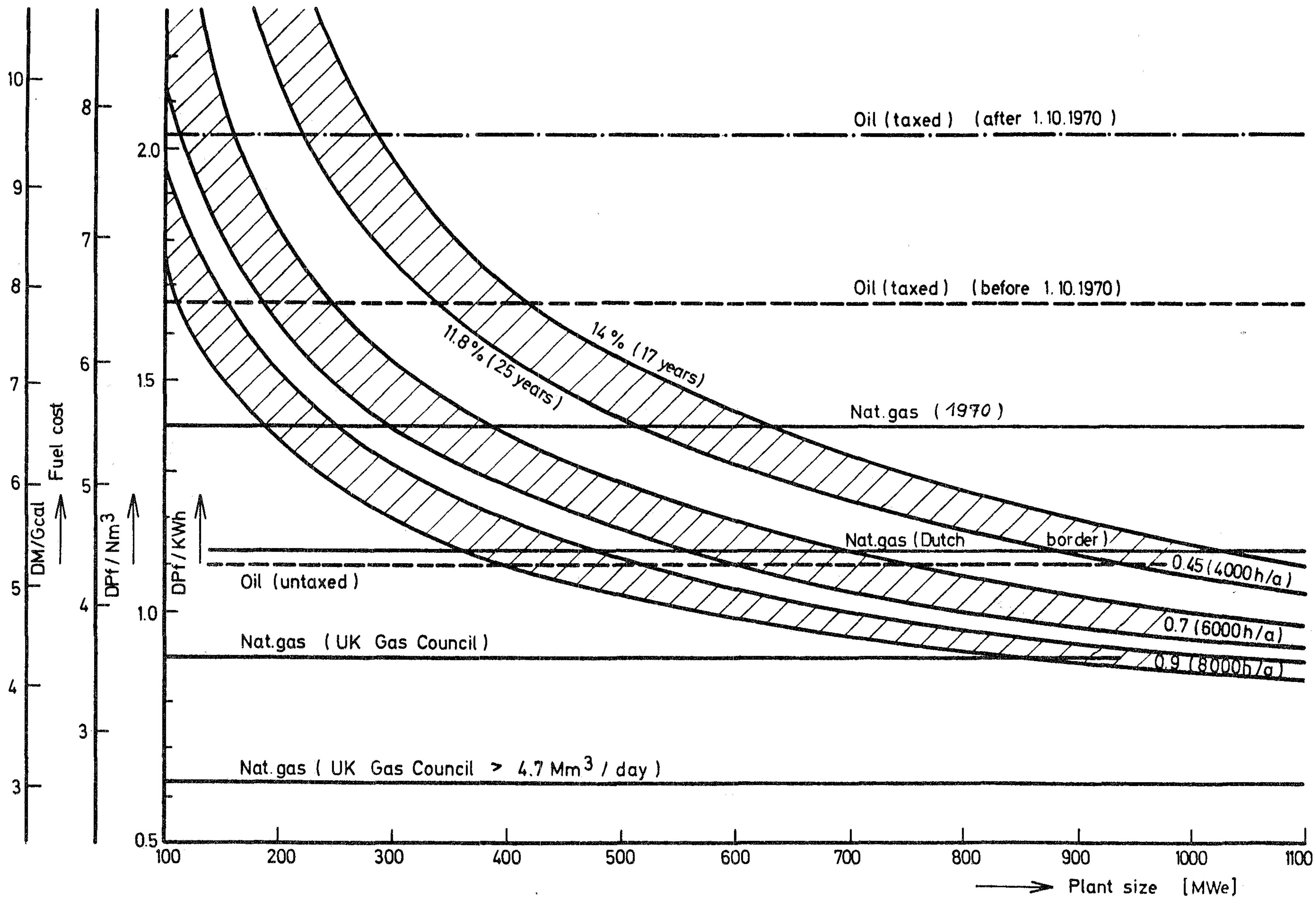

Fig. 9 Natural gas cost variation with plant size in comparison with LWR