European Communities

EUROPEAN PARLIAMENT

Working Documents

1974-1975

11 November 1974

DOCUMENT 325/74

Report

drawn up on behalf of the Committee on Energy, Research and Technology

on the need for and possible features of a Community policy to promote the production of gas from coal

Rapporteur : Mr F. BURGBACHER

PE 37.577/fin.

English Edition

By letter of 26 November 1973, the Committee on Energy, Research and Technology requested authorization to draw up a report on the need for and possible features of a Community policy to promote the production of gas from coal.

By letter of 6 December 1973, the President of the European Parliament authorized the committee to report on this subject.

The Committee on Energy, Research and Technology appointed Mr Burgbacher rapporteur on 17 December 1973.

The committee considered this draft report at its meetings of 8 and 28 October 1974, and unanimously adopted the motion for a resolution and the explanatory statement on 28 October 1974.

The following were present: Mr Springorum, chairman; Mr Bousch and Mr Leonardi, vice-chairmen; Mr Burgbacher, rapporteur; Lord Bessborough, Mr Flämig, Mr Giraud, Mr Glesener, Mr Hougardy, Mr Jakobsen, Mr Kater, Mr Noè, Mr Normanton, Mr Petersen, Mr Vetrone (deputizing for Mr Andreotti).

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A

The Committee on Energy, Research and Technology hereby submits to the European Parliament the following motion for a resolution, together with explanatory statement :

MOTION FOR A RESOLUTION

on the need for and possible features of a Community policy to promote the production of gas from coal

The European Parliament,

- having regard to the report of the Committee on Energy, Research and Technology (Doc. 325/74),

- recalling its resolutions

  - on means of securing adequate energy supplies to satisfy the Community's requirements and guarantee, promote and further improve the Community's competitivity on the world market as a prerequisite for economic growth, full employment and a forward-looking social policy[1]

  - on appropriate medium- and long-term measures for the further alleviation of the energy supply crisis in the European Community[2],

1. Is of the opinion that :

   (a) the Community's - and the western world's - dependence on imported energy can be reduced by making greater use of indigenous energy sources, particularly coal;

   (b) the demandfor developed, high-quality forms of energy increases with a rising standard of living;

   (c) the application of new technologies in the use of coal and lignite will therefore acquire increasing importance in the future;

   (d) production of gas from coal offers many advantages, because gas can be burned without the emission of sulphur or dust, the formation of nitric oxides in combustion chambers can be largely controlled, gas can be stored and converted with relatively high efficiency into energy;

[1] OJ C 112, 27 October 1972, p. 32

[2] OJ C 40, 8 April 1974, p. 55

(e) apart from further development of the gasification methods used hitherto, particularly the two principal methods - that using oxygen as the gasification agent and that in which lump coal is gasified under pressure - the new methods should be promoted, viz. the one not involving the use of oxygen and the process of producing substitute natural gas (SNG), although it is realized that because of technical difficulties it will not be possible to assess whether these processes are suitable for use on an industrial scale until after 1980;

(f) the main emphasis in future research will be on gasification using nuclear reactors;

2. Requests the Commission of the European Communities

(a) to draw up a coal gasification programme in accordance with the requirements set out in this report;

(b) to provide the necessary funds for research and for financing pilot plants;

(c) to encourage cooperation between state bodies and the gasification plant and reactor engineering industries, to ensure optimum results;

(d) to submit a report to Parliament within 2 years on the measures taken and proposed in the field of coal gasification.

3. Instructs its President to forward this resolution and the report of its committee to the Council and Commission of the European Communities.

B

EXPLANATORY STATEMENT

Introduction:

Future possibilities for the use of coal and lignite[25]

1. With growing industrialization, the rise in the standard of living and the attendant increase in energy consumption, there is at the same time a fall in the direct use of primary energy sources in favour of high-quality, developed forms of energy. This is clearly shown by the example of electricity, whose annual growth rate is in some cases more than 7% and therefore greatly exceeds those of the primary energy sources. Future possibilities for the use of coal will therefore depend not only on the demand for primary energy, but also on the processes available for converting coal into high-quality products to suit the market. Efforts are therefore being directed towards the development of improved versions of existing technologies or new ones of greater profitability, which also meet the growing requirements of environmental protection.

2. The traditional methods of coverting coal into other products fall into four groups :

1. Mechanical - cleaning, briquetting
2. Thermal - coking, carbonization
3. Chemical - gasification, hydrogenation, oxidation, by-product extraction and
4. Electricity generation.

3. The processes used hitherto within these areas cannot really be replaced by anything fundamentally different, but permanent changes can sometimes be made to bring them into line with the latest technological developments.

The above remarks on future possibilities for the use of coal are also fully applicable to lignite.

(1) Position of coal gasification in the energy industry and its political aspects

4. Basically it can be assumed that energy in the form of coal, oil and gas is transportable, so that the supply and demand of energy at world-wide level must first be considered. The following reserves exist to cover future energy demands :

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[25] All footnotes refer to the documents listed in Annex III on which these notes are based.

Coal	6,700,000 million tons coal equivalent
Oil	500,000 million tons coal equivalent
Gas	310,000 million tons coal equivalent

Altogether therefore, coal reserves are more than eight times oil and gas reserves. The latter two fuels can be extracted more easily and are easier to handle from the point of view of process engineering, so that preference has been given to them in past decades and they will be extracted to an increasing extent in the future. According to many forecasts, this may mean that by the year 2000 oil and natural gas will be almost exhausted, while coal reserves will only have been reduced by 2%.

5. After this review of the situation in the world as a whole, however, it is the geographical position of the reserves which is of vital importance. The industrialized nations have to import oil and gas in large quantities to cover their energy requirements. The recent past has provided sufficient proof that this has an effect on the prices of oil and gas. The rise in prices is due, on the one hand, to competition between the industrialized nations in the purchase of energy on the world market, which has increased as a result of the general shortage of oil and gas, and, on the other, to transport costs, e.g. pipelines extending over several thousand kilometres, or in the case of liquefied gas, considerable increases in costs.

6. With continuing energy imports at higher prices, the industrialized nations are now facing with concern an increased requirement for foreign exchange. The latest increases in the crude oil listed prices have produced an extra financial burden of 35 thousand million dollars per annum for the western industrialized countries of the OECD group. The present import requirement of 133 million tons of oil involves a charge of 40,000 million DM on the foreign trade balance of the Federal Republic of Germany, for example. This high foreign exchange requirement can only be covered by corresponding export surpluses, otherwise a foreign trade deficit will arise or increase.

7. The accumulation of these dollar surpluses in the Arab states presents a danger to the whole world currency system, since the currency structure can be manipulated by means of these huge amounts. By appropriate holdings in industry, direct influence can also be exercised on the industry of the consumer countries. Another aspect of dependence on imports concerns the availability and safeguarding of fossil energy sources. Considerable political pressure can be exercised by embargo measures.

Conscious of these disadvantages, and of the dependence of energy supplies on oil and gas, all industrialized nations are thinking again about the use of their own coal reserves.

(2) The situation in Western Europe

8. In the reserves of fossil fuels in Western Europe, and in particular in the Federal Republic of Germany, the predominance of coal is more marked than it is throughout the world as a whole, as shown by the following figures for certain and probably reserves :

	1,000 million tons coal equivalent	
	Western Europe	FRG
Coal	256	230
Lignite	27	18.6
Oil	1.7	0.1
Gas	5.5	0.4

9. Of the above coal reserves in the Federal Republic, about 44,000 million tons coal equivalent can be extracted with existing mining technology, and of the lignite reserves 3,000 million tons coal equivalent are open-cast. Of the coal reserves, about 35% are high-volatile coals, at present used mainly in power stations, 54% are fat coals, used for the production of coke, and 11% are low-volatile coals which so far have been used as domestic fuel. The energy supply from fossil fuels will therefore have to be based in the next few decades on the mining and processing of coal.

10. As a result of the oil shortage this trend has already become apparent in the last few months. In the steel industry, for example, the specific coke consumption in blast furnaces has been increased from 488 to 523 kg per ton of crude iron by economizing on oil[1]. Coal-fired power stations are being used to an increasing extent for electricity generation. For various reasons, the direct use of coal will not be recommended to cover the future energy needs of the oil consumer, for example domestically, or, in particular, for the replacement in the long term of light fuel oil and natural gas. It is particularly advantageous to convert coal into gas. This fits in with the increased demand for a fuel which is easy and convenient. Another important aspect is that gas can be burned without emission of sulphur or dust and the problem of formation of nitric oxides in combustion chambers can be largely overcome. Compared with electricity generation, gasification of coal has the advantages that gas can be stored and can be transported at a much lower cost with less harm to the environment. Moreover, coal can be converted into gas with a much higher efficiency.

11. Apart from indigenous coals it is also possible to use imported coal for gasification. There are limits to this alternative, however, so that only coal mined within the Community will provide a secure supply.

12. Let us consider an example; coal output in the Federal Republic, amounting to about 100 million tons per year, can be divided into four areas:

The Ruhr region	about 80% of output
The Saar region	about 10% of output
The Aachen region	about 6% of output
The Lower Saxony region	about 4% of output

13. To continue with this example: the breakdown of this output into various forms of coal shows that the major proportion (about 66%) is provided by fat coals, 22% consist of gas coal and open-burning coal and only a small proportion consists of forge coal, lean coal and anthracite coal (12%). There has scarcely been any change in this percentage breakdown in the last few years. The proportion of fat coal rose from 60 to 66% between 1960 and 1972, and the output of gas coal and open-burning coal decreased by the same amount, whereas the percentage of forge coal, lean coal and anthracite coal remained constant.[5]

It is primarily the high-volatile coals and lean coals and anthracite which would be used for gas production. Fat coal can be used to the extent that it is not needed for coking.

(3) Use of and demand for gas

14. Gaseous fuels are needed for the production of heat in industry, commerce and domestically and as primary or intermediate products in the chemical industry.

The combustion characteristics, such as calorific value, combustion velocity, and derived quantities, for example, the Wobbe number are the most important for its use as fuel. In the public gas supply system standard values are laid down for these properties. Two main forms of gas are supplied :

(a) natural gases, with sub-groups L and H
(b) gases whose combustion properties correspond to those of coking gas.

15. Natural gases consist essentially of methane and contain differing but always relatively small proportions of higher hydro-carbons such as ethane and propane. Because of an additional, limited nitrogen and/or carbon dioxide (CO_2) content, the L-type natural gases have a lower calorific value than the natural gases of sub-group H.

16. The gases in group (b) arise as by-products in the production of coke. They are or were produced from solid or liquid fuels such as coal, liquid gas, naphtha and other mineral oil products, as well as from natural gas, by chemical conversion. In heavy industry, residual gases of very varied composition and combustion properties from production processes are also used

internally as fuel gases. These include blast-furnace gases, residual gases from large scale chemical processes and residual refinery gases.

17. The gases need in chemistry as primary or intermediate products for chemical synthesis - ammonia synthesis, methanol synthesis, oxo synthesis, hygrogenation - have different,but exactly defined compositions depending on the purpose. They consist of hydrogen and nitrogen, carbon monoxide and hydrogen, and simply hydrogen of technical purity. These gases are also produced from other fuels such as coal, mineral oil products and natural gas, by chemical conversion.

18. It is interesting and important, in order to understand the arguments expressed later, to compare consumption figures for the different forms of gas :

The total consumption of <u>all</u> gaseous fuels in the Federal Republic is given below as an example. It includes both the standardized gases in the public supply system and the wide range of gases used for internal supplies in industry. The figures are :

1972 : 55,100 million cubic metres (gross calorific value 8400 kcal/m^3), corresponding to some 61.5 million tons coal equivalent

1973 : 64,000 million cubic metres, corresponding to 71.5 million tons coal equivalent,

where 1 kg coal equivalent is approximately equal to 7000 kcal.

The figure for 1972 included the following :

Public supply gas (natural gas + coking gas + town gas) : 35,020 million cubic metres (gross calorific value 8400 kcal/m^3), corresponding to 37.9 million tons coal equivalent, of which the natural gas component was 28,140 million m^3, corresponding to 30.4 million tons coal equivalent.

In 1973, natural gas consumption rose to about 35,000 million m^3, corresponding to about 37.9 million tons coal equivalent.

On the other hand the consumption of synthesis gases in 1973 was approximately 5,000 million m^3, corresponding to about 1.9 million coal equivalent because of their low calorific value.

19. This comparison shows that, within the present economic and industrial structure, it is demand from the public gas supply system which is the determining factor in changing over to gas produced by coal gasification. Only if, in the future, petrochemical products and fuels needed for transport also have to be produced from coal as the raw material, will the production of synthesis gases take up a considerable proportion of coal output.

20. Gasification of coal will however become of increasing importance, which should not be underestimated, in the widespread use of coal as fuel by large scale consumers, for example in boiler houses and power stations. Desulphurization of coal before it is used as a power station fuel can be carried out advantageously by gasification and purification of the gas before combustion, since in this case a gas turbine can be connected in series with the boiler. In the Federal Republic a 170 MW power station of this type with preliminary gasification of the boiler coal is already on trial[6] (the 'Kellermann' power station of the Steag Company at Lünen; Lurgi pressure gasification plant). Work is in progress on projects for an 800 MW power station and even larger units. The preliminary gasification of power station coal has also been declared a priority aim in the USA as part of state-assisted research and development projects.

(4) What is 'gasification'?

21. In previous paragraphs the term gasification' has already been mentioned several times. With regard to coal it can be defined as follows: conversion of the organic coal substance by gasification agents (air + steam, oxygen + steam, steam + heat) at 800 to 1200°C and above in a combustible gas mixture with minimum heat losses, i.e. at maximum efficiency. The only solid residue is the ash contained in the coal.

The composition of the primary gas arising from the process depends on the gasification agent used (air, air + steam, oxygen + steam) and the operating conditions of the chosen process. These conditions and possible methods of coal gasification are shown in a very simplified form in the following diagram.

	Gasification	Type of gas	Constituents	Use
Coal →	using air and steam →	fuel gas (producer gas) →	carbon monoxide, hygrogen, little methane, nitrogen →	fuel gas in industry
Coal →	using air and steam at pressure →	fuel gas →	see above but more methane →	gas for power stations with topping turbine
	using oxygen and steam →	synthesis gas	carbon monoxide, hydrogen →	ammonia synthesis; methanol synethesis; oxo synethesis; hydrogen
Coal →	using oxygen and steam at pressure →	town gas; SNG (substitute natural gas)	hydrogen, methane (nitrogen, carbon dioxide) →	public supply (coking gas or town gas quality)
	using steam and heat from HT nuclear reactors →	synthesis gas; town gas; SNG (substitute natural gas)	methane (nitrogen, carbon dioxide) →	public supply SNG H or L

22. The composition of the gas produced can be varied within wide limits at relatively small expense by means of secondary processes (eliminating carbon dioxide and impurities by scrubbing, converting the carbon monoxide, transforming carbon monoxide and hydrogen into methane or cracking methane into carbon monoxide and hydrogen) and adapted to the consumer's requirements. The nitrogen content in the final gas is predetermined by the choice of gasification conditions (air or oxygen).

(5) History of gasification[7]

23. The gasification of solid fuels became of technical importance towards the middle of the 19th century for the production of industrial fuel gases (producer gas) and public supply gases (carburetted water gas). With the development of ammonia and methanol synthesis at the beginning of the 20th century the demand for synthesis gas in the chemical industry became the most effective stimulus for further technical development of coal gasification. A particular advance was the introduction of oxygen as gasification agent (around 1920) and the development of gasification of lump coal under pressure.

24. Development varied considerably in individual countries: whereas the international state of development at the beginning of the 20's was at a uniform level, in the 30's

- the United States of America had already gone over to the use of natural gas and mineral oil products for public supply and synthesis gases,
- in England and France there had been no major further developments,
- in the German Reich a number of fundamentally new processes had been developed for the production of synthesis gases and public supply gases by gasification of coal with oxygen and steam. This progress was largely due to the demand for hydrogen and synthesis gas for the production of synthetic fuels (coal hydrogenation, Fischer-Tropsch synthesis).

From about the end of the 50's interest in coal gasification diminished throughout the world, as natural gas became available for the general gas supply system, and natural gas and mineral oil products became available as raw materials for synthesis gas production in increasing quantities and at falling prices. By the time this transition occurred, all the new, technologically mature gasification processes had been developed in Germany.

At the rebirth of coal gasification which has occurred throughout the world in the last few years, these processes form the present state of the art which will provide the basis for future projects. New developments will have no effect until the 80's.

(6) State of progress in gasification, available methods[7 8 9]

25. In the central European area, particularly in the former German Reich, the coal and lignite deposits formed the nuclei for the development of large industrial complexes and to some extent also determined the branches of industry which developed locally. At the beginning, the supplies of coal, with its thermal by-product coke, were not only sufficient for the iron and steel industry but also for the chemical industry with its growing demand for synthesis gas. As a result of the growth of the heavy chemical industry, particularly in the development of the synthesis of fuel from coal, lignite became increasingly important.

26. Technically this trend brought important advantages shown by the following comparison :

Lignite is
- much more reactive than coal and therefore more easily gasified,

- non-caking, i.e. when heated it does not coagulate into lumps of coke which are difficult to crush,

- cheaper than coal because it is easier to obtain in open-cast mining.

The caking of most forms of coal involved so many difficulties that, when using coal for the production of gas, it was the well-proven and largely problem-free process of coke gasification which was used for a long time and all efforts were directed towards the gasification of lignite.

(7) Processes

7.1. Winkler Process[7 8 9 10 11]

27. The first major success achieved in new technical developments was the BASF Winkler process. The Badische Anilin und Sodafabrik urgently needed a process to produce synthesis and fuel gas for its Leuna works in central Germany using the lignite available there. After a relatively short period of development the new process was technically fully viable by 1926 for the production of fuel gas and by 1930 for the production of synthesis gas and was used on a large scale.

28. Principle of the process: Fine coal, between 0.1 and 8 mm grain size, is gasified in a 'fluidized' bed using oxygen and steam for the production of synthesis gas and air and steam in the case of fuel gas. The gasification residue, ash and some ungasified carbon are removed by a grating which acts as the inlet grating for the gasification agent.

Gasification takes place at normal pressure and, therefore new coal can be fed in and ash removed continuously without difficulty and without complicated equipment.

29. The gas produced contains mainly carbon monoxide and hydrogen, very little methane and considerable quantities of carbon dioxide. The synthesis gas produced with oxygen and steam contains very little N_2, whereas the fuel gas produced by air and steam contains 52% to 56% nitrogen.

30. The output of these Winkler generators, with an inside diameter of 5.5 metres and height of 15 metres, was up to 60,000 m^3 of crude synthesis gas per hour.

By 1945, a total of 26 units has been built, including five in Czechoslovakia and six in Japan. From 1953, a further ten units were commissioned, including two in the Federal Republic, and the rest in Spain, Yugoslavia, Turkey and India.

In the German Democratic Republic, development work was continued and an unknown number of new generators were set up at the state-owned 'Walter Ulbricht' plant (formerly the Leuna Works) and the 'Schwarze Pumpe' combine.[7]

31. The following figures and notes may be quoted for consideration later :

7.1.1. The 'gasification efficiency' - the quotient of kcal fuel value in the gas divided by the fuel value of the gasified coal - is 74%; or, in other words: during gasification, 26% of the calorific value of the coal becomes waste heat for other purposes (to produce steam in the waste heat utilization system), or is lost. (Energy required for oxygen production has not been included in the calculation.)

7.1.2. The oxygen consumption is about 0.33 m^3 per m^3 ($CO + H_2$) and about 105 to 110 m^3 per Gcal (1 million kcal).

7.1.3. The process is very suitable for gasification of lignite, but reactive, non-caking coal can also be gasified.

7.2. <u>Lurgi pressure gasification process</u> [7 8 9]

32. The basic objective in the development of this method was to produce so much methane by a high gasification pressure of 20 bars and above during the actual gasification process that, after eliminating the carbon dioxide by scrubbing, the purified gas could be used directly as town gas. This has been achieved with reactive lignites.

33. The coal is gasified in a slowly-falling bed (grain size not below 2 mm and not above 50 mm, lignite lumps or briquettes) using oxygen and steam in countercurrent flow at 20 to 25 bars. The new material is fed into the top of the generator and the ash is removed from the bottom by means of locks which can be pressurized and depressurized. At first, it seemed that it would be difficult to develop such locks for solid, granular materials, but in a surprisingly short time a technical solution was found, the principle of which is still in use today.

34. During gasification, tar, fuel oil, light oil, phenols and ammonia were produced as valuable by-products. Because of its calorific value, the gas produced could be used directly as town gas. By 1945, three plants had been built, one of them in Czechoslovakia, with a total of fifteen generators.

After 1945, the process began to spread throughout the world. In countries with lignite deposits, new plants were built and existing ones enlarged, for example, in the German Democratic Republic, Czechoslovakia and Australia.

35. After Lurgi and the Ruhrgas company had further developed together the process for the gasification of non-caking coals (1949-1952), coal-based plants were constructed in the Federal Republic of Germany, Great Britain and South Africa. Including some smaller plants in South Korea and Pakistan, by 1970, a total of 14 plants with (approximately) 170 generators had been built in nine countries. Because of the methane content in the gas produced, the process was used mainly for the production of public supply gas. The advantage that the gas was available at an initial pressure of 25 bars, however, resulted in the largest plant, the Sasol Plant in South Africa, being constructed to produce synthesis gas. It was accepted that, because of the methane content, secondary processes would be needed in the further processing of the gas.

36. Here are some figures :

7.2.1. The gasification efficiency, based solely on the gas produced, is between 75% and 85%. Including the saleable products in the heat balance, the resultant efficiency is between 84% and 90%. These values, and the specific oxygen consumption, depend, within wide limits, on the varying composition and reactivity of the coal.

7.2.2. The specific oxygen consumption depends on the reactivity of the coal[12] and, in the case of lignite, is 0.12 m^3 O_2 per cubic metre (hydrogen, carbon monoxide and methane; after purification and elimination of carbon dioxide); for coal, it is 0.187 to 0.2 m^3 and for anthracite and coke, up to 0.3 m^3 O_2.

About 62 m^3 O_2 are used per Gcal gas and about 58 m^3 O_2 per Gcal (products + gas).[13]

7.2.3. Gasification of high-caking coals has so far only been possible experimentally; the coal also has to have the minimum possible fine grain content (below 2 mm in diameter). This means a considerable limitation on the possible application of the process.

The largest generators so far have an inside diameter of 3.65 metres with a crude gas output of about 43,700 m^3/hour, or 1.1 million m^3/day.

37. A completely new application for Lurgi gasification has been developed in the last few years by the Steag company and Lurgi, viz. preliminary gasification of power station coal with air and steam at a pressure of about 20 bars, removal of sulphur from the gas (and thus extensive reduction of sulphur dioxide emission by the power station), combustion of the gas in a boiler with a high-pressure combustion chamber and subsequent expansion of the boiler gases in a power turbine. The process is at present under trial at the 'Kellermann' power station of the Steag company at Lünen in a 170 MW power station with five Lurgi generators (inside diameter of shaft about 2.4 m) but as yet without purification of the gas.[6 14]

7.3. <u>Koppers-Totzek Process</u> [7 8 9]

38. In this chronological list, there now follows another very successful process for the gasification of pulverized fuels with oxygen and steam in a flame, which forms in the reactor in front of the mouth of the inlet nozzles. Development of the Koppers-Totzek process began at the end of the 1930s. The first large experimental plant was commissioned after the war in the United States by the US Bureau of Mines.

The process is suitable for <u>all</u> kinds of coal, from lignite to the high-caking fat or coking coals; gasification takes place at normal pressure.

39. The process has the following advantages :

General : <u>all</u> types of coal can be gasified, irrespective of their caking properties.

Particular : the very low methane content of the gas is a considerable advantage for its use as synthesis gas.

There are, on the other hand, the following disadvantages :

General : the gas is gasified at normal pressure. The gasification efficiency is lower and the specific oxygen consumption somewhat higher than in the previous processes.

Particular : for the production of gas for the public supply system, the low methane content in the crude gas is a disadvantage from the point of view of energy, as all methane has, therefore, to be produced by the conversion of carbon monoxide with hydrogen, which involves high heat losses.

40. For these reasons, the Koppers-Totzek process has, so far, only been used to produce synthesis gas, even though use of the process to produce public supply system gas and for the preliminary gasification of steam coal offers promise for the future.

So far, a total of fifteen plants have been built with 53 generators in fourteen states. One plant in Zambia (an extension) has been ordered and the construction of the first plant in the United States - at a foundry belonging to General Motors - is under consideration.[15]

41. The following parameters may be noted :[7 16]

7.3.1. Gasification efficiency of 72% to 77% depending on the type of coal.

7.3.2. Specific oxygen consumption of 0.28 to 0.33 m^3 per m^3 (carbon monoxide + hydrogen) or 92 to 110 m^3 per Gcal latent heat in the crude gas.

7.4. Preliminary degasification of steam coals at the power station

42. Because of the increased demand for gas at the beginning of the 1950s, work was started on the development of processes for preliminary degasification of steam coals in conjunction with a power station. The aim was to separate out the volatile constituents of coal which were valuable at the time (gas, tar, light oil, aromatics) before the coal was fired in the boiler house. Of the experiments carried out, only the work begun jointly by Lurgi and Ruhrgas on the development of the so-called LR process[17] resulted in the construction of a full-sized demonstration plant. It had a throughput of about 230-250 tons of open-burning coal per day and operated in conjunction with a power station. The hot coke arising in the process went into the boiler furnace at 900-950°C without any heat loss. The gas arising was of the same composition and quality as coking gas. At relatively low temperatures (600°C coke temperature), using this process up to 16%-18% of the clean coal weight can be obtained in the form of tar.

7.5. Other processes [7]

43. Within this limited survey, it is not possible to describe all the processes in as much detail as those above. For the sake of completeness, however, reference may be made to certain developments which have led to arrangements which are attractive from the point of view of process technology and have been used industrially :

(a) Koppers Circulating Gas Process for the gasification of lignite briquettes. (Used at a very large plant in central Germany to producer Fischer-Tropsch synthesis gas.)

(b) Pintsch-Hillebrand Process, again for the gasification of lignite briquettes (Union Kraftstoff Wesseling).

(c) Leuna slagging producer for gasification of coke and

(d) a similar type: Thyssen-Galoschi slagging producer for the gasification of coal coke.

In the United States, two interesting processes have been developed for the gasification of pulverized coal :

(e) Babcock-Wilcox process for the gasification of pulverized coal at normal pressure.

(f) Texaco Pulverized Coal Pressure Gasification.

44. While processes (a)-(d) are still economically unattractive compared with the others, Texaco is now about to resume the development of pulverized coal pressure gasification which was discontinued in the middle of the 1950s. The Babcock-Wilcox process also seems worth remembering for the future.

(8) Recent developments : Possible future trends[9 18]

45. Despite becoming almost of no importance in the meantime, work on the further development of coal gasification was continued in several places, particularly in the United States, in the 1950s and 1960s. It is not surprising that, during this quiet period, new ideas were able to develop. The design concepts of the advanced American projects provide for,

(a) Gasification processes not involving the use of oxygen, to save the relatively high capital costs of oxygen installations,

(b) Formation of the maximum possible proportion of methane by direct hydrogenation of coal in the production of a substitute natural gas (SNG), i.e. public supply gas from coal, which, because of its combustion properties, is completely interchangeable with natural gas.

46. Whereas the problem at (a) was difficult and did not seem to lead to the economies which were hoped for, much more success was achieved in the application on the principle of methane formation by hydrogenation.

47. These American developments are based on logical principles and offer the prospect of increased thermal utilization of coal, since the heat losses in methane formation by hydrogenation are much lower than in the case of

methane formation by conversion of $CO + H_2$. In the case of the Lurgi pressure gasification system, this leads to a much lower oxygen consumption per Gigacal latent heat in the gas.

48. This relation can be roughly illustrated with the aid of figures from the literature. The figure for the HY-gas process is based only on provisional measured results which have been extrapolated to large-scale plant conditions.

Process	m^3 O_2/Gcal in SNG
Gasification of pulverized coal	125
Lurgi, gas only	58
Lurgi, gas + products	47.5
HY-gas	about 30

49. The aim of the American work was to develop this advantage of a lower O_2 consumption and to avoid certain disadvantages of the Lurgi process (risk of caking of the coal in a fixed bed) by using pulverized or very fine-grained coals. In practice, however, it was found that the new processes involve certain complications with equipment, for example, difficulties in feeding pulverized coal into a pressurized reactor vessel (70 bars) and making use of the thermal advantages of methane formation by hydrogenation where the coal is flowing counter-current to the gas.

50. To summarize, it can be said that the new processes which are being developed or have been proposed in the United States are attractive in principle, but, because of their technical difficulties, it will not be possible to assess the possibility of using them in full sized plant until after 1980.

51. In this connection, reference may be made in particular to the following processes :

- HY-gas process of the Institute of Gas Technology;[19]
  State of development : Industrial pilot plant with a throughput of 75 tons of coal per day. Engineers : Procon.

- Synthane process of the US Bureau of Mines;[20]
  Pilot plant of 70 tons per day completed. Engineers : Lummus.

- BI-GAS process of Bituminous Coal Research Inc.;[21]
  Pilot plant for 120 tons per day under construction. Engineers : Stearns and Roger.

- Special case : CO_2 acceptor process of Consolidated Coal Co.[22]
  (for lignite only) : plant of 40 tons per day started up. Engineers : Stearns and Roger.

52. As is known, a shortage has developed in the United States in natural gas supplies and this is to be filled by increasing output in the country itself, but also to a considerable extent by the production of synthetic natural gas (SNG) and by importing liquefied natural gas (LNG) from overseas. It was initially hoped to increase SNG production from liquid fuels (natural gas condensate, naphtha) for which there are a number of industrially proven processes (British Gas Corporation, licences to engineering firms; Lurgi/BASF; Japanese Gasoline; Universal Oil Products). There were also plans for the construction of about forty such plants with a capacity of the order of 60,000 million to 64,000 million m^3 SNG per year. These plans also included five 'energy refineries' which were to process crude oil exclusively into light heating and heavy fuel oil, with a sulphur content of less than 0.3%, and SNG, by a combination of known and industrially proven processes. Only a fraction of these projects can be carried out, however, because of the bottleneck which has arisen not only in the supply of naphtha but also in that of crude oil. All projects based on coal gasification are now, therefore, so much more important.

53. In examining the technical possibilities of coal gasification for plants to be built within the 1970s, the new processes developed in America were not taken into account for the reasons mentioned above, and, so far, five large companies or groups of companies in the gas industry have decided rather to build Lurgi pressure gasification plants. Plans for the construction of a further four plants have recently been announced in the press.

54. The plants are designed for a unit capacity of 250 million standard cubic feet per day = approximately 6.72 million m^3 SNG per day. The capital investment needed in America for a plant of thirty generators with an approximate inside diameter of 3.8 metres is $330 million to $400 million, depending on site conditions.

55. The Koppers-Totzek process is attracting increasing interest as it can also be used for high-caking coals, such as occur predominantly in the east of the United States.

56. The costs of the gas produced will be much higher than the present cost of gas to the consumer, but only part of this increase in price will take effect initially, as the companies aim at charging the customer a mixed price based on old cheaper contracts and the new dear gases. It has to be taken into account that the period of cheap natural gas is coming to an end everywhere, and considerable price increases are to be expected in the near future.

57. Finally, it is interesting to note that in the United States the capital investment for importing 10,000 million m^3 per annum of natural gas from Algeria and that for the production of 10,000 million m^3 of SNG per annum from coal are approximately the same. It is to be expected that this equality of costs and the fact that, in SNG production from coal, the capital investments largely remain within the country itself will have a greater influence on American energy policy decisions in the future. From the practical point of view of the availability of raw material and water - each of these plants uses about 30,000 tons of coal per day, including energy coal for steam and oxygen, as well as 30,000 to 40,000 m^3 of fresh water - it is possible to construct 170 to 175 plants of this type. It is, therefore, not surprising that studies in America for the year 2000 anticipate a coal consumption of 300 million tons per annum and more for gas production alone.

58. In addition to this quantity of coal, there is also that needed in future for power stations. For power station operation, it is again expected that, for reasons of environmental protection, only those with preliminary gasification of the coal and subsequent purification of the fuel gases will be constructed. The first plans are again based on the existing German processes (Lurgi, Koppers) but extensive work has also been started on the development of processes by American companies and organizations.

(9) Outlook

Federal Republic of Germany and Europe

59. What is the position in the Federal Republic, the example we have quoted? The basic economic conditions in the Federal Republic are not as favourable as in America. The coal price is an important component of the gas production cost and at approximately 100 DM/t = $46/t, it is three to five times as high as the price of American coal. On the other hand, the Federal Republic does not have any noteworthy oil reserves and has to import more than 90% of its oil requirements, so that the increased oil prices have penetrated to such an extent that the cost of heat from oil and oil products is at present higher than the cost of coal. Itcan therefore be assumed that, in economic development over the next few years, coal gasification will also have to be used to some extent in the Community to cover the energy demand.

60. Because of the price and the advantages in process technology, lignite comes to mind first of course, but the reserves and annual output are limited. As lignite has so far mainly been burned in power stations, its availability for the production of public supply gas is greatly dependent on how rapidly the plans for the construction of further nuclear power stations can be implemented, or to what extent the economy will still be dependent on electricity produced from lignite in the next two decades.

61. Seen in the long-term, however, coal will form the main basis for future production of SNG from the point of view of quantity. The government of the Federal Republic has, therefore, adopted a financing programme to promote coal gasification. As part of this programme, it is also intended to revive work in the field of preliminary degasification in conjunction with a power station boiler, both by Ruhrgas (LR process) and by others (the Steinmüller process to be used by VEW).

Technical aspects of future development

62. In the development of new processes, the main consideration - here and in the USA - is to produce a substitute for natural gas, i.e. a gas with the highest possible methane content, by gasification of lignite and coal. In the first stage, new coal will be gasified by hydrogenation in order to produce as much methane as possible. Lignite is primarily suitable for this, as, in contrast to coal, it does not cake under the operating conditions of gasification by hydrogenation. This stage of the process is, at present, being investigated on a semi-industrial scale at Rhein-Braun AG.[23] This development follows the trend in the United States.

63. The work which is beginning in the field of gasification of coal is based primarily on older developments and essentially represents a necessary and logical continutation of work which had been discontinued. One of the main features of the latest work is the further development of the Lurgi pressure gasification system, proposed by Ruhrgas, Rührkohle and Steag, the aim of which is the construction and operation of an experimental generator with a 5-metre diameter and an output of 75,000 cubic metres of crude gas per hour or 1,800,000 cubic metres per day per unit. By means of appropriate engineering developments, the generator is also intended to accept without difficulty the German coals which cake more readily, and a broader range of grain size. So far, only about 25% of German output has been suitable for gasification in the Lurgi pressure generator.

The Koppers firm in Essen has combined with Shell to undertake further development of the proven Koppers-Totzek process for high pressure pulverized coal gasification, making use of the experience of both parties; the main disadvantage of the process has been eliminated as a result.

Renewed consideration is also being given to preliminary degasification of pulverized boiler coal before it is fired and the separate production of gas and liquid hydrocarbons. (See 7.4.)

64. The crucial question in this further development of almost fully-developed processes is how long it takes to complete potential projects. If the Community mining industry and the firms concerned were to undertake the development of new processes, American experience shows that more than a

decade could be spent in the first stages from the laboratory experiments and system studies up to the construction of the first industrial pilot plant with a throughput of 50 to 80 tons per day; that is to say, new types of processes could not be expected until the 1980s. Under these circumstances, it seems more reasonable to wait for developments in the USA and, where applicable, build plants under licence.

In this way, intellectual and material resources would become available to undertake a really new and major step, viz. the gasification of coal using heat from high-temperature reactors.

(10) <u>Coal gasification using heat from nuclear reactors</u>[23 24 25]

65. In the conventional processes described above, coal acts as raw material both for the produced gas and as the source of the heat required in the process. It is used both for the production of the process steam, the other energy required and electricity, as well as to cover the heat requirements of the endothermic gasification reaction. The task of converting expensive coal into gas cannot, therefore, be carried out with optimum efficiency using the existing autothermal processes, e.g. the Lurgi pressure gasification system or the Koppers-Totzek gasification system. The development of high-temperature nuclear reactors gives rise to the idea of using the high-temperature process heat in the gasification process, saving coal as the heat supplier and thus converting it as completely as possible into useful gas. Relevant investigations have been under way for some years with financial support from the German Federal Ministry of Research and Technology, as part of a larger research programme in which the Bergbau-Forschung GmbH, Essen, the Kernforschungsanlage Jülich GmbH and the Rheinische Braunkohlenwerke AG, Cologne are involved.

66. The advantages of using heat from nuclear reactors can be shown by the following comparison of production of synthetic natural gas by way of steam gasification and catalytic methanation, the steam gasification being carried out in one case by the conventional process, and, in the other case, using HTR heat.

Comparison of SNG production from coal using steam gasification and methanation, by conventional means and using heat from nuclear reactors

Input requirements for 1,000 m^3_n SNG (gross calorific value 8400)

	Conventional	Using heat from nuclear reactors
Coal*	1.8 t	1.1 t
Feedwater	3.2 t	2.9 t
Pure oxygen	0.9 t	-
Nuclear heat	-	5.2 Gcal
Gas yields in m^3_n Gas/t coal*		
CH_4	550	880
CO_2	1,030	700
CO_2 emission m^3/Gcal fuel gas		
at site of gasification	218	93
at site on combustion	117	117
Total	335	210

* open-burning coal (7.8 Gcal/t waf)

Using an open-burning coal with 36% volatile constitutents, the input requirements for the production of 1,000 m^3_n synethetic natural gas are as shown in the table. It can be seen that, by using nuclear reactor heat, it is possible to save 0.7 tons of coal (29%) and 0.3 tons of steam (10%) and, in addition, no oxygen is required. 5.2 Gcal of nuclear reactor heat are needed at temperatures between 900 and 1,000°C. Where the nuclear reactor heat is obtained at favourable cost, there is, of course, a considerable reduction in the cost of production of gas because of the savings in coal, steam and oxygen.

67. The use of nuclear reactor heat for gasification processes is also important from the point of view of protection of the environment. Because it is necessary to remove dust and sulphur from the product gas for its subsequent application, use of gas in energy generation is in both cases a process which is not harmful to the environment, but gasification with nuclear reactor heat has the additional advantage that, in the whole process of gas production and combustion, less CO_2 is produced, as shown by a comparison of the gas yields. To appreciate the importance of this fact for the introduction of CO_2 into the environment, it is necessary to calculate the CO_2 emission per Gcal of the produced gas. CO_2 emission occurs both in the production of the gas and in its combustion. When using nuclear reactor heat, CO_2 emission is reduced by a factor of 0.43. During combustion, of course, the same CO_2 emission takes place because the composition of the gases is the same. Nevertheless, the total of CO_2 emission from gas production and combustion still shows a considerable reduction, by a factor of 0.625.

68. The husbanding of coal reserves and the reduced production of CO_2, which is a burden on the environment in the long-term, are important advantages in the use of nuclear reactor heat for conversion of coal into gas. In countries with high coal costs, for example, the Federal Republic, nuclear reactor heat will probably be available at a lower price than heat from coal, so that the costs of production of the gas can also be reduced.

69. Considerable development work still has to be done, both on the high-temperature nuclear reactor and the corresponding gasification processes, if this method is to be brought to fruition. The aim of this development programme is a demonstration of the process at the beginning of the 1980s. Commercial plants could be constructed and operated in the second half of the next decade.

70. For the production of 1,000 m^3 of methane, 1.8 tons of coal are needed in the case of conventional autothermal processes. Using nuclear reactor heat, this reduces to 1.1 tons. In addition, expensive oxygen is not required. This produces a perceptible reduction in costs for the materials used; at a heat price of, for example, DM 7 per Gcal for nuclear reactor heat, there is a saving of 32% in methanation.

Technical implementation[25]

71. Preliminary studies in Germany and various other countries have shown the problems which still remain to be solved in order to produce high-temperature process heat plants. Today it is considered that these problems can be solved. Nevertheless, extensive and to some extent long-term development work is necessary. Fundamental work is already being carried out in all important areas.

72. It is questionable, however, whether the cost of nuclear heat will be the DM 7 per Gcal expected by its advocates and confirmed in reports. In the opinion of the undersigned, experience so far in the field of nuclear energy shows that such estimates are subject to considerable uncertainty. The possibility should, therefore, not be excluded that nuclear heat will cost DM 12 per Gcal and above. This means it will cost the same as heat produced from coal.

Coal gasification plants in operation

Site	Number of Generators	Output	Type of Gas	Coal used
I. Winkler-process				
1. GORAZDE, Yugoslavia Fabrika Azotnih Jendinjena	1	5,000 m^3/h	Synthesis gas	
2. KUTAHYA, Turkey Azot Sanyyii Tas	2	18,000 m^3/h each	Synthesis gas	
3. MADRAS, India Neyveli Lignite Corp.	3	41,600 m^3/h each	Synthesis gas	
II. Lurgi pressure gasification				
1. WESTFIELD, Scotland	4	1.2 Mio m^3/d	Town gas	Coal
To be shut down 1974/75. A pilot plant with a small pressure slagging producer is to be operated as an experimental generator with the assistance of Lurgi and firms from the American gas industry.				
2. Czechoslovakia				
(a) ZÁLUŽÍ works	16	2.2 Mio m^3/d	Town gas	Pitch coal or lignite
(b) ÚŽÍN works	14	1.75 Mio m^3/d	Town gas	Lignite
(c) VŘESOVÁ works	26	max.3 Mio m^3/d	Town gas	Lignite
3. Republic of South Africa				
SASOLBURG	13	245,000 m^3/h and 30,000 m^3/h	Synthesis gas Town gas	
The plant is to be enlarged.				
4. GDR				
(a) BÖHLEN	10(or 11)	295 Mio m^3/a	Town gas	Lignite
(b) SCHWARZE PUMPE	24	2,200 Mio m^3/a	Town gas	Lignite
5. Yugoslavia				
KUSOVO	6	480 Mio m^3/a	Synthesis gas	Lignite
6. Pakistan	2		Synthesis gas	Coal
7. South Korea	4		Synthesis gas	Coal

III. Koppers-Totzek process

1. Greece				
(a) PTOLEMAIS nitrogen plant	4	629,000 m^3/d	Ammonia synthesis gas	Powdered Lignite
(b) PTOLEMAIS nitrogen plant	1	165,000 m^3/d	Ammonia Synthesis gas	Powdered Lignite
(c) PTOLEMAIS nitrogen plant	1	242,000 m^3/d	Ammonia Synthesis gas	Powdered Lignite
2. Thailand				
Artificial fertilizer works MAE MOH, LAMPANG	1	217,000 m^3/d	Ammonia Synthesis gas	Powdered Lignite
3. Turkey				
Azot Sanayii T.A.S. KÜTAHYA works	4	775,000 m^3/d	Ammonia Synthesis gas	Powdered Lignite
4. Zambia				
Industrial Dev. Corp. KAFUE, Lusaka	1	214,320 m^3/d	Ammonia Synthesis gas	Powdered coal
5. South Africa				
AE & CI Ltd. MODDERFONTEIN Plant Commissioning on 15.8.1974	6	2,150,000 m^3/d	Ammonia Synthesis gas	Pulverized coal

6. 4 more plants with a total of 13 generators are under construction or at the design stage.

Other plants planned

I. On order

(1) Lean gas for power stations
Owner: Commonwealth Edison

3 generators with an inside diameter of 3.8 m. Gasification using air and steam. Output per generator: about 18 tons per hour. As at STEAG AG's 'Kellermann' power station, the lean gas produced is used as a clean fuel, for the generation of electricity in a gas turbine and steam power station.

(2) SNG
Owner: American Gas Association

1 pilot generator with an inside diameter of 3.8 m.
Gasification of coal with oxygen and steam.
The pilot generator is being operated with the aim of optimizing gasification under the specific conditions under which coal will be used in future large plants, and of training the personnel required for the operation of these plants.
(operation to begin in 1976/77.)

II. Projects for which the planning and design work has been completed and orders are now expected to be placed

(1) Lean gas for power stations
No definite projects

(2) SNG
5 plants each with 27 to 30 generators with an inside diameter of 3.8 m. Output per plant: 2,200 to 2,500 million cubic metres of SNG per annum, gross calorific value 9100 to 9250 kcal/m^3. Coal consumption: 7 to 7.3 million tons per annum per plant. In addition, about 1.5 million tons of power station coal per annum per plant.

Details of the plants:

(a) Wesco plant, Farmington, New York
Owner: Texas Eastern Transmission and Pacific Lighting Co.
Type of coal: non-caking coal of recent formation
Gross calorific value (water and ash-free): 7507 kcal/kg
Feedstock coal: 12.4% water
25.6% ash

Coal consumption: 7.35 millions tons per annum
SNG output (gross calorific value 9125): 2,400 million cubic metres per annum

By-products:	Tar and oil	0.474	million	tons	per	annum
	Light ends	0.089	"	"	"	"
	Crude phenol	0.03	"	"	"	"

About 30 generators

(b) El Paso Natural Gas, Burnham, New Mexico

Type of coal: non-caking coal of recent formation
Gross calorific value (water and ash-free): 7345 kcal/kg
Feedstock coal: 16.2% water
19.3% ash
Coal consumption: 7.17 million tons per annum
SNG output (gross calorific value 9097): 2,500 million cubic metres per annum

By-products:	Tar and oil	0.408	million	tons	per	annum
	Light ends	0.71	"	"	"	"
	Crude phenol	0.036	"	"	"	"

(c) Panhandle, Converse County, Wyoming

Type of coal: hard lignite
Gross calorific value (water and ash-free) 7065 kcal/kg
Feedstock coal: 28.0% water
5.5% ash
Coal consumption: 7.01 million tons per annum
SNG output (gross calorific value 9123): 2,400 million cubic metres per annum

(d) Beulah-Hazon, North Dakota

Type of coal: hard lignite
Gross calorific value (water and ash-free): 6700 kcal/kg
Feedstock coal: 25.0% water
8.7% ash
Coal consumption: 7.25 million tons per annum
SNG output (gross calorific value 9123): 2,400 million cubic metres per annum

(e) Northern Natural Gas, Gelette, Wyoming

Type of coal: hard lignite

Gross calorific value (water and ash-free): 7176 kcal/kg

Feedstock coal: 28.0% water

6.7% ash

Coal consumption: 6.86 million tons per annum

SNG output (gross calorific value 9264): 2,200 million cubic metres per annum

The abovementioned five plants will consume a total of 35.6 million tons of coal and lignite per annum and about 7 to 8 million tons of coal and lignite per annum for the generation of steam and electricity (for plants' own consumption).
Total gas output of all five plants: about 11,900 million cubic metres per annum.

Together the five plants will also produce:

1.96 million tons of tar and oil per annum

0.338 million tons of light ends per annum

0.513 million tons of crude phenol per annum

0.27 million tons of ammonia per annum

III. Other planned projects on which preliminary work has begun

The information on these projects is very unreliable. Understandably, Lurgi will not name its customers until they have published unambiguous press releases. According to - in some cases contradictory - reports in American information bulletins and industrial journals the following are being discussed:

(a) 3 plants using hard lignite in the North Dakota/Wyoming area;

(b) at least 2 plants using coal of recent formation in the New Mexico area;

(c) 1 normal-sized plant for the Transcanada Pipeline;

(d) increase in gas production at the Sasol plant.

In addition Lurgi has stated that it is looking into a far larger number of tentative enquiries.

When evaluating the trend in America it must be remembered that the average price of the coal used there is DM 2.50 to 4.00/Gcal, whereas the coal available in the Ruhr region costs about DM 18.00/Gcal. A paper given by Lurgi's managing director, Dr.Hiller, at the annual conference of Deutsche Gesellschaft für Mineralölwissenschaft und Kohlechemie on 1 October 1974 revealed that the gas produced from American coal in Lurgi plants costs an average of $ 1.845 per million BTU, which, at DM 2.63 to the $, is equivalent to DM 19.25/Gcal net calorific value. Produced under the same conditions from Ruhr coal, the gas would cost about DM 44.60/Gcal and about DM 26.00/Gcal if produced from Rhenish lignite.

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