A TARGET

FOR

EURATOM

REPORT

submitted by

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at the request of the governments

of Belgium, France, German Federal Republic, Italy,

Luxembourg and the Netherlands

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LETTER OF SUBMITTAL

of Messrs. Armand, Etzel and Giordani to the Ministers of Foreign Affairs of the six Euratom countries

May 4th, 1957

Your Excellency,

In accordance with the terms of reference laid down for us by yourself and your colleagues, we have the honour to attach our Report on the amounts of nuclear energy which can be produced in the near future in the six Euratom countries, and the means to be employed for this purpose.

In order to draw up our Report, we first of all consulted the government and industrial circles responsible for nuclear energy in our countries. We held a series of discussions in Paris, Brussels and Bonn with the authorities and with leading figures from the French, Italian, Belgian, Netherlands and German industries. In view of the shortness of the time at our disposal, the Italian representatives were good enough to come specially to Paris, and the Netherlands representatives to Brussels. In Brussels we had the further advantage of being able to discuss our problems with Mr. Spaak and his colleagues of the Intergovernmental Conference on the Common Market and Euratom.

We were enabled in this way to obtain a general picture of the outlook with regard to energy requirements and resources, and of the nuclear programmes envisaged in each of the six countries. At the invitation of the American, British and Canadian Governments, we then visited their countries in order to study on the spot, with the assistance of qualified experts, the results of their work in the nuclear field and the conclusions to be drawn from it. These tours were exceedingly valuable from the fact-finding point of view.

In the United States, we were received by President Eisenhower. We had talks with the Secretary of State, Mr. John Foster Dulles, with the President of the Atomic Energy Commission, Mr. Lewis Strauss, and with his colleagues and assistants. We inspected an atomic power station now in process of completion at Shippingport, and also visited the National Laboratory at Oak Ridge, one of the main American nuclear research centres. In New York, at a meeting arranged by the Atomic Industrial Forum, we met the heads of the principal industrial firms working on the peaceful uses of nuclear energy.

In Canada, we talked with the Minister of Economic Affairs, Mr. Howe, and with the president of Atomic Energy of Canada Ltd., Mr. Bennett. We were also taken on a particularly instructive tour of the Canadian Atomic Research Centre at Chalk River.

In Britain, we met Lord Salisbury, Lord President of the Council, Lord Mills, Minister of Power, Sir Edwin Plowden, Chairman of the Atomic Energy Authority, and his colleagues and staff, and Lord Citrine, Chairman of the Central Electricity Authority, and his colleagues. We were given valuable information when we were shown round Calder Hall. We also had various profitable discussions with representatives of the industrial groups which have been set up in Britain to build atomic power stations.

We take this opportunity to thank the American, British and Canadian Governments and all those who helped us to derive such benefit from our inquiries.

The American Atomic Energy Commission and the British Atomic Energy Authority in addition most kindly put at our disposal experts whom we were able to consult after we returned, in order to line up our technical information on the American and British reactors in our Report and its annexes.

Our special thanks are due on the American side to Mr. Richard Cook, Deputy General Manager of the Atomic Energy Commission, Mr. Paul Fine, Director of the Operations Analysis Division, Mr. Louis Roddis, Deputy Director of the Reactor Development Division, and Mr. Andrew Van der Weyden, Deputy Director of the Division of International Affairs; and on the British side to Dr. Hill, Deputy Director of Technical Policy at the Atomic Energy Authority, Dr. Brown, Deputy Chief Engineer of Civil Reactors, and Mr. Johnson, Overseas Manager in the Technical Policy Branch. We are particularly grateful to them for their invaluable assistance.

We are, of course, entirely at your disposal as regards answering any questions you may desire to ask us after reading the Report and annexes. We would conclude by thanking your Excellency for the honour which you and your colleagues did us in entrusting us with a mission which was of such vital importance for the future of our countries in view of their very serious energy position and the potentialities opened up by nuclear energy.

We have the honour to remain, Your Excellency's most obedient servants,

ARMAND ETZEL GIORDANI

REPORT

A Target for Euratom

PREFACE

On November 16, 1956, the Ministers of Foreign Affairs of Belgium, France, the German Federal Republic, Italy, Luxembourg and the Netherlands instructed us to report 'on the amount of atomic energy which can be produced in the near future in the six countries, and the means to be employed for this purpose'.

On March 25, 1957, the Treaty instituting the European Atomic Energy Community (Euratom) was signed by the same Ministers in Rome and is now being submitted to the parliaments of our six countries. In the hope that this Community can begin to function in the very near future, we have entitled our report: A Target for Euratom.

While endeavouring to define this objective, we have been aware of the unique chance which the advent of nuclear energy offers our countries. Only ten years ago, Europe seemed to be condemned to have less abundant and more expensive energy than the United States; nobody would have imagined that this opportunity would emerge. Today, it can be said that if our countries, guided and stimulated by Euratom, make the necessary effort they will in future command—as the New World does now—abundant and cheap energy supplies, enabling them to enter boldly into the atomic era.

ESTABLISHMENT OF A TARGET

Europe's Energy Problem.

In the 19th century coal, produced cheaply and abundantly, multiplying a hundredfold the effectiveness of human effort, turned Europe into the 'workshop of the world'. In the last five years of postwar expansion, Europe has suddenly discovered that this favourable situation has entirely changed and that a new fact conditions all its prospects: the shortage of energy threatens to become a major brake on economic growth. This is the context in which the new prospects opened up by nuclear power must be assessed. It has become a practical possibility at a turning point in Europe's economic history (1).

In 1870, total world energy production amounted to 218 million tons of coal. Of this, the United Kingdom and our six countries together produced three-quarters. The story of the industrial development of the nineteenth century is bound up in these figures. Britain and the Continent not only powered their own unprecedented industrial progress; they were the great exporters of energy and its products to the world.

Unfortunately, if Europe's internal resources of energy were abundant by the standards of 1870, it is becoming clear that by the far higher ones of 1957 and still more of 1970, they are, and will be, increasingly inadequate. Though today our six

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(1) Annex I gives a detailed picture of the energy problems of the six countries together and individually.

countries alone mine more coal than the world did in 1870, they provide only 15% of world energy production. The rapid growth of their imports since the war shows that Europe's own supplies of all kinds of energy are falling far behind demand.

On the eve of the second world war, our six countries' energy imports were only five per cent of total requirements. During the postwar recovery they began to rise steeply. This was generally assumed to be temporary, while European coal production got back on its feet. And, indeed, in 1950 something like the pre-war equilibrium seemed to be within reach. But now, after the growth of the last seven years, it is clear that the demand in industry and transport, in the home and in agriculture is rapidly outrunning internal supply. Europe has lost its independence in energy.

The greatest possible effort to increase the output of energy from conventional sources must be undertaken in our six countries. But, however great this effort, it cannot keep pace with our needs. The conditions in which coal is mined, much less favourable to mechanization than in the United States, slow up the possible rate of growth. As more coal is sought, the veins to be exploited become deeper and more difficult to work, setting a limit to the further expansion of output. The same applies to hydro-electric power, the resources of which have been already largely developed. As for oil and natural gas, the prospects in our countries are good, but not by any means on a scale to bridge the gap between needs and supplies.

Europe's energy imports would rise to intolerable heights without nuclear power. Today already the six countries import nearly a quarter of their energy supplies, the equivalent of 100 million tons of coal, most of which is oil from the Middle East. The Suez Crisis has shown how precarious these supplies are.

For the future, we have assumed the greatest possible development of conventional power sources, and have based our estimate of energy requirements on a moderate but steady rate of economic expansion which is considerably slower than that since the war. Every effort has to be made to increase domestic production, but it must be realized that even on this assumption fuel imports into our countries would double in ten years and treble in twenty. They would reach 200 million tons (33% of total requirements) in 1967 and might reach 300 million tons (40%) ten years later. (See Fig. A p. 21.)

These enormous figures in fact call in question the whole future of Europe's economic growth, and even of its political security in the world. First, they imply an annual bill for energy imports rising (in round figures, at constant prices) from $ 2 billion now to $ 4 billion by 1967 and $ 6 billion by about 1975. Even taking into account the part of this bill met in national currencies, especially through the contribution of our merchant marine, the need for foreign exchange would put a most severe strain upon the balance of payments of our countries. The need to earn this additional foreign currency would also involve very important investments in export industries. And the increased pressure to sell on the world market would tend to push the terms of trade against Europe, a point of vital importance to the world's greatest trading area.

A second, still graver threat is the evidence, provided by recent political events and the ensuing oil shortage, that even the availability of imported energy is uncertain. Oil already provides over a fifth of our countries' energy supplies. It is cheaper per calorie than imported coal, and it is more convenient to handle and use. It is therefore likely that most of the increase in the demand which must be met by imports will take the form of oil.

We cannot expect to obtain this oil from the Western Hemisphere because demand there is rising faster than production. The only region of the world capable of supplying these quantities is the Middle East, where a very high proportion of world oil reserves is located. The oil discoveries in the Sahara are promising, but it can hardly be expected to provide more than a fifth of our energy imports by the mid-sixties. Thus without nuclear power, Europe's dependence on the Middle East is bound to increase. The Suez Crisis has given us a warning of what this could mean. As the quantity of oil imported from the Middle East increases, there will be a corresponding increase in the political temptation to interfere with the flow of oil from that region. A future stoppage could be an economic calamity for Europe. Excessive dependence of our highly industrialized countries on an unstable region might even lead to serious political trouble throughout the world. It is essential that oil should be a commodity and not a political weapon.

The European economy must be protected against an interruption of oil supplies, by finding alternative sources of energy to limit the further rise in oil imports. Only nuclear power, providing Europe with a new source of energy, can achieve this.

Scope for Nuclear Power.

Though it may be used to propel ships and to heat urban areas, the real contribution of nuclear energy in the next twenty years will be to produce base-load electricity in big power stations (1).

Electricity consumption is growing rapidly, doubling every ten or twelve years. To cover this new demand, the domestic

(1) Base-load electricity is power produced round the clock, as distinct from 'peak-load' power produced for only a few hours each day.

sources of energy specially adapted for power production (water, lignite, low-grade coal and natural gas) must be developed to the utmost. Even so, they cannot together meet more than one-third of the increase of electricity needs in the next twenty years. Two-thirds of the additional output must come from power stations fired with imported oil or coal, unless nuclear stations are built in their stead. The increase in production of saleable coal will be absorbed by other uses, especially for coke-ovens. The capacity of such power stations is estimated to rise by 22.5 million kW, from 38 million kW at the end of 1960 to 60.5 million kW by the end of 1967, apart from replacements amounting to more than 5 million kW in this period (see Fig. E Annex III p. 83). This is the field into which nuclear power can be fitted.

Every year that is lost in constructing nuclear power stations means that conventional stations, requiring increased oil or coal imports—and which continue to consume oil or coal throughout their lifetime of twenty or thirty years—will be built instead. In view of this situation, Europe must within the limits set by the pattern of electricity production, construct nuclear stations as rapidly as possible.

Nuclear plants take up to four years to build. Although some already under construction (such as the French power plant, E.D.F. 1), or shortly to be ordered, should come into operation in 1961 and 1962, nuclear power cannot be expected to provide a big contribution before 1963, since orders cannot be placed for substantial construction of plants before the end of 1958. Further, industry will need time to build up capacity before it can provide all the nuclear plant that could be used. Industrial firms will have to adapt their staffs and their production facilities to a new technology on a big scale. This means that we must expect a progressive build up in the rate of construction of nuclear power stations. This delay will enable us to reach decisions on the basis of two or more years experience from the big nuclear power stations now under construction in the United States and the United Kingdom.

In view of these considerations, we estimate at some 15 million kW the nuclear power capacity that can be accommodated in the electricity system of the six countries during the next ten years. If this can be done, it will stabilize imports at the level they would otherwise reach in 1963 of around 165 million tons of coal equivalent a year (1).

This is an ambitious target. It will call for a great, continuous effort, since our industries, with the exception of the French, have had practically no experience in the nuclear field. Moreover, far from conflicting with an all-out effort to increase the output of conventional forms of energy, it is only by close collaboration between all methods of producing electricity that this target can be attained and the level of imports stabilized.

Great Britain has already faced a similar issue, and has come to a similar conclusion. She has in fact reacted very quickly to an energy problem that is less threatening than our own. Britain to-day imports only 12% of her total energy requirements, while we import 23%; in ten years' time these imports, if not checked by nuclear power, would rise to 22% in Great Britain, against 33% in our countries. Her programme of 6 million kilowatts by 1965 is expected to stabilize fuel imports from 1960 onward. The 15 million kilowatts which we are taking as our 1967 target can achieve the same result for us in 1963.

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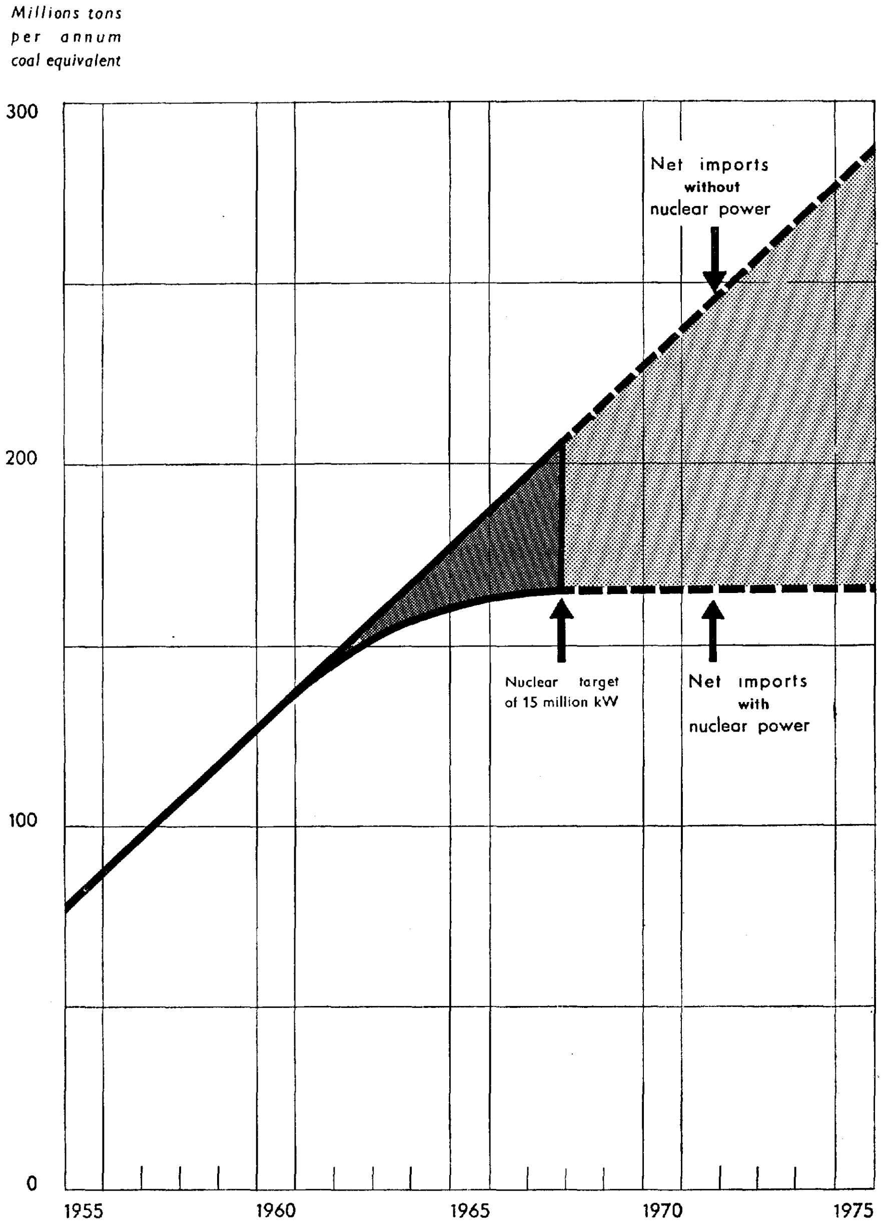
(1) Since oil has a higher calorific value than coal, it is necessary to convert oil tonnages into their 'coal equivalent' to obtain comparable or total figures for energy imports.

FIGURE A

Energy imports of six countries



This target is two and a half times the British programme, which seems reasonable when we consider that the ratio of population is 3 to 1, and that of electricity output 2.8 to 1, and that, as mentioned above, the six countries are starting out from a far less favourable position than Great Britain in the matter of energy imports.

It is not for us to translate this target into a programme. Without doubt our target is far larger than the sum of the existing plans prepared separately by our six countries, plans which would involve the installation of about 6 million kilowatts capacity between now and 1967. Incidentally, it has been possible to see since our investigations began—perhaps it should be regarded as one of their first results—a very marked tendency for each country to expand its programme.

We also had to compare our target and the programme it entails with the industrial resources available in our six countries for the building of reactors. The British experience is the only one to which one may refer in order to have an idea of how industry can be adapted to an important atomic programme. In Great Britain, it is considered that, by 1965 (the execution of the British programme was started in 1955), industry will be in a position to install 5 to 6 m. kW of nuclear energy and, moreover, be able to export the same amount (1), totalling 10 to 12 m. kW of nuclear power capacity. The engineering industries of the six Euratom countries have an overall capacity which is approximately 1.6 times that of the same industries in Great Britain (2). On this basis, one can therefore consider that—given an effort comparable to that undertaken by Great Britain—our countries

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(1) This export capacity is of course dependent on timely arrangements to enable British industry to supply difficult items such as graphite and steel plate for pressure vessels.

(2) See O.E.E.C. report 'Les industries mécaniques et électriques en Europe' (1956).

should be able to build over 15 m. kW of nuclear energy in the course of ten years.

This is, of course, an appreciation of our nuclear possibilities. As in any big industrial development, bottlenecks are bound to appear. The part which the United States, Great Britain and Canada play in the way of cooperation with regard to processing, fuel, reactor components etc., will therefore consist not only of facilitating our effort from a general point of view, but also of helping us to overcome the temporary difficulties which may arise at the start in various fields. Although our 15 m. target is ambitious, it is compatible with the industrial potential of our countries, taking into account the help we can expect from Great Britain and the United States.

Euratom will create new opportunities. It will pool the scientific as well as the industrial resources of our six countries and their varied skills. A common market for nuclear equipment to be set up within a year will promote industrial specialization. Further, Euratom will represent our nations as a single unit vis-à-vis other states, and will be far better placed to obtain full cooperation from then than our countries separately.

Our enquiry abroad has already shown the expanded opportunities for outside help opened up by Euratom. The contribution in nuclear fuels, reactor technology and components can make the difference between a rapid and a slow European departure in nuclear power production. To take one concrete example: the scarcity of trained technicians could seriously hamper the rapid execution of a big programme. During our visit to America, Britain and Canada, training facilities were offered to Euratom on a scale never contemplated for our individual nations.

A critical moment has been reached: atomic power is coming of age. Nuclear power has moved out of the scientist's laboratory onto the engineer's drawing board; it will now come quickly into commercial phase. This provides a great opportunity for our countries if we seize it and a grave danger if we do not. Scientific and technical knowledge can be borrowed; but industrial capacity one must create oneself. If our industries do not go ahead on a big scale now, at a time when others are poised to do so, they will soon be unable to face competition from the full-grown industries which have seen and seized their chances in time. Later development would only be possible behind protective walls with all the drawbacks they involve. In view of the growing importance of atomic techniques for industry, Europe, as the world's greatest exporter of engineering goods, cannot afford to miss the chance to move off to a rapid start.

So long as we act with drive and determination, the possibilities created by Euratom give us every hope of meeting the challenge of the atomic era, and, in so doing, of resolving our energy problem.

CONDITIONS OF ACHIEVEMENT

The scientists of our countries made fundamental contributions to the discoveries on which nuclear power prospects are based. But, as a result of the war and their divisions, they have taken little part during the last fifteen years in the massive and costly build-up of the foundations of nuclear industry. France has already begun to apply nuclear power on an industrial scale, and Germany, Italy, Belgium and the Netherlands are actively engaged in power projects and reactor development. But these efforts fall far short of what Britain, not to speak of the United States, has done to lay the basis for the commercial application of nuclear power. If our industries had, today, to start entirely on their own, an unduly slow and costly growth would be unavoidable. The American interest in the world-wide extension of atomic energy for peaceful purposes to which President Eisenhower's 'atoms for peace' programme testifies, has relieved our countries of some of the penalties of their handicap.

Cooperation with the United States, the United Kingdom and Canada.

The United States government showed a keen interest in the prospects of a big Euratom programme for the production of nuclear energy. Their well-known support for European unity and their interest in Europe's economic strength and stability explain this welcoming attitude. Europe can help America in the future as America is prepared to help us now. The average cost of electricity in America is about two-thirds of what it is in Europe, so atomic power will compete in Europe long before it can do so in the United States. An impressive amount of research and development done both through the Atomic Energy Commission and by private industry have provided America with the most complete nuclear foundation in the world. But the large-scale application of this immense potential appears to be at least five to ten years off. Europe, on the contrary, needs atomic energy right now. No amount of research can be a substitute for the practical knowledge to be gained by the large-scale industrial application of atomic power. Europe could make this experience available to the United States. Our talks in Washington convinced us that, on the healthy basis of a two-way traffic, a close partnership as equals can be built up between the United States and Euratom and their respective industries.

For peaceful purposes, our visit provided indications of how the partnership would work. The United States would make available the necessary fissile materials and the technical knowledge to set our industries going. Once Euratom is established, a task force composed of some of America's most able men would be at out disposal to continue studying with European experts the many technical problems posed by our programme. America would provide training facilities for our scientists and technicians. Joint projects, for instance to improve and adapt reactors, can be envisaged between American and European industries, as well as between the American and European Atomic Energy Commissions.

Britain has concentrated on a reactor type which is now fully in the commercial phase. The British authorities have declared their readiness to facilitate contacts between British firms and those in Europe interested in building this type of reactor. They are also willing to assist Euratom in the vital matter of training scientists and engineers, and in putting their experts at our disposal to study the technical aspects of our programme.

Canada is equally prepared to cooperate. It can do so in two important ways. To begin with, it is one of the world's major sources of natural uranium. It would be ready to provide natural uranium to supplement European resources, provided it receives notices several years in advance, and that any agreement with Euratom guarantees the use of the uranium exclusively for peaceful purposes.

Further, Canada has done important original work on a type of reactor which promises to be particularly well adapted to European requirements, combining as it does many of the advantages of the natural and slightly enriched uranium approaches followed so far by Britain and the United States respectively. This reactor is well into the development stage. We have every reason to believe that Euratom would find the Canadian authorities willing to cooperate on the construction of prototypes.

In consequence of the far-sighted view the United States, Britain and Canada have taken of their interests in cooperating with our nations in nuclear development, we have the assurance that a large nuclear programme would obtain not only the benefit of years of development in these countries, but also the material supplies and technical assistance indispensable to a quick start. This broad cooperation is being offered because Euratom gives prospects of joint action on a scale our countries individually cannot propose and has been made possible by the Euratom provisions for an effective system of control of fissile materials.

Agreements of association should therefore be concluded between these countries and Euratom immediately after its establishment. At the same time, close cooperation should be developed with neighbouring countries, particularly Switzerland, Austria and the Scandinavian States, through O.E.E.C. or in other ways.

Strong cooperative ties with other countries—by which we obtain, now and later, the help of those who have explored nuclear possibilities more fully than we have, and in return offer our help in future to them and to other interested nations—must be the foundation of Europe's atomic progress. Far from undermining our independence, it is the only way we can gain our place as equals in the field. The road to dependence would be the opposite one, to confirm our backwardness by resorting to the illusion of self-sufficiency. Cooperation with others will not limit our opportunities, but create new ones, so that our industries can eventually acquire their own, distinct nuclear personality.

Reactor Construction.

Our inquiry has convinced us that, though there are at least a dozen prototype reactors in an advanced stage of design or under construction, only two types are ready for commercial use. One has been developed in the United States and the other in Britain and France (1).

The first is fueled with slightly enriched uranium (2), and is cooled by water under pressure, or by boiling water. This system was originally developed for submarines, and one unit has been functioning without interruption in the Nautilus for nearly two years. The experience gained on this project gives great confidence in the reliability of this type of reactor. Full scale commercial prototypes of both versions of these reactors are under construction, in several cases entirely by private firms.

The second type, developed furthest in Britain, is the gas-cooled reactor fueled with natural uranium. Its prototype at Calder Hall has been working successfully for the last six months.

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(1) Annex II describes reactors in greater detail.

(2) Uranium in which the content of the fissile isotope U-235 has been increased above the level of 0.71% found in nature.

Confidence in the performance of this reactor enabled Great Britain first to set up a nuclear programme in the beginning of 1955, and then, at the beginning of this year, to treble it. Several large stations are now under construction for the British electricity authorities. The first French reactors now functioning or being built are of the same type.

Attention should be given by European firms interested in building power reactors and by Euratom itself to the development of two other types, not yet in the commercial phase, but which appear specially appropriate for Europe: a version of the British gas-cooled reactor, operating on slightly enriched uranium, and the heavy-water reactor developed mostly in Canada. Joint projects might be launched by industry or Euratom to solve the design and development problems to be overcome before these reactors can become commercial.

To begin quickly we must either buy some reactors from the United States and the United Kingdom or build them under license. This will not involve accepting permanent industrial dependence. On the contrary, it will speed up our industries' nuclear education, and provide a basis of well tested experience to root and nourish their own original contribution. Even if the reactor itself has to be imported, a large proportion of each of the first nuclear power plants will be built by our own engineering industries, and the proportion of components that must be imported will quickly fall.

The industrial re-orientation required will undoubtedly raise difficult problems, but they may prove less intractable than is often thought. Intensive re-training of engineers and scientists will be needed, but both the United States and the United Kingdom are ready to help. Euratom must carry out training programmes with the facilities they offer, on top of those already existing in Europe, and those that it will itself create. Further, the number of trained men required to design and build proven reactors is smaller that that needed to develop entirely new ones. A high proportion of the construction work in nuclear power plant differs little from the tasks which engineering firms are performing today. The industrial groups which have designed and are now constructing power reactors in the United Kingdom started with limited nuclear experience 18 months before their tenders were submitted to the U.K. Electricity Authorities.

Euratom and its objectives will be the stimulus, guiding and enabling better use to be made of our industries. The standardization of reactor components and procurement contracts should be encouraged. Also, a certain amount of general coordination will be essential because a programme involving millions of kilowatts under construction at any one time, and requiring a wide range of new materials and components, might easily be thrown out of gear by serious shortages and costly delays. Industry, for example, should be informed of the need for big high-pressure shells for reactors at least four years ahead of delivery in view of the likelihood that its capacity for their manufacture would have to be expanded.

Fuel Requirements.

Fuel requirements will depend very much on the types of reactor chosen by the electricity suppliers. However, it is now already clear that the fuel required to reach the target envisaged for Euratom will be obtained without difficulty, since its requirements are a small part of world production of nuclear fuels during the period under review (1). The uranium production in our countries, although small at present, is expected to rise as prospecting extends the field of known reserves. Further we have

(1) Fuel needs are estimated in Annex III.

assurance that, in Canada, natural uranium output can increase considerably if the demand is firm.

We also attach particular importance to the statement made by the U.S. authorities that they do not consider that nuclear fuels will be a limiting factor. This opinion has been inserted in the Communiqué (1) which the Secretary of State and the Chairman of the Atomic Energy Commission issued jointly with us at the end of our discussions in Washington. As this statement comes from the country which is the world's biggest producer of enriched uranium, and one of the biggest of natural uranium, we can be sure that the availability of nuclear fuel will not limit the realization of our target.

Euratom's action on fuel supplies could be of decisive importance for our industries. The total expenditure on nuclear fuels in the ten-year period required to reach the target of 15 million kW would amount to about $ 2000 million (2). According to the Euratom Treaty, special fissile materials will be owned by the Community. Therefore Euratom will retain title of the enriched uranium it will put at the disposal of the users and may well finance both enriched and natural uranium centrally as is done domestically in the United States and the United Kingdom.

Fuel problems do not end with the supply of fissile material. Both natural and enriched uranium have to be fabricated into fuel elements (3) before use. And after use they must generally be processed in chemical plants to recover the valuable fissile products still left in the spent fuel.

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(1) See Annex V.

(2) See Annex III, para. 8.

(3) For the present types of reactor, the nuclear fuel must be formed into cylindrical or plate-type elements enclosed in suitable materials (magnesium, zirconium, stainless steel, beryllium, etc.).

Undoubtedly, for the needs of the first nuclear power plants, fuel elements can be imported from abroad, and the spent fuel returned to be processed. Both America and Britain are willing to do this, and have indicated the prices they will charge. But it would be inconsistent with our need to reduce our dependence on costly energy imports to continue to rely on other countries for these services. Both operations require plants serving many reactors to be economic. If each of our countries were to act as separate unit, it would take many years before it would be possible to build these plants on an economic basis. The establishment of the European Atomic Energy Community will allow us to build both fuel fabrication and chemical processing plants as soon as a large number of reactors are being built.

Euratom could also construct a plant to produce the enriched uranium needed (1). Till recently, this seemed the only way to obtain it. But there is now no doubt that our countries can obtain enriched uranium from the United States in the necessary quantities, and at the low published prices. These low prices are a consequence of the vast size of American plants, the extremely low power costs in the areas where they are located, low finance costs, and a very highly developed design and technology. Enriched uranium produced in Europe would, therefore, probably cost two to three times as much.

The building of a Euratom diffusion plant has been advocated to avoid basing nuclear energy production on a material that must otherwise be obtained from another country. If important quantities of enriched uranium had to be permanently imported, this argument would carry weight. But several years would elapse before Euratom's diffusion plant could operate. And the future of enriched uranium requirements is very uncertain.

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(1) Known as 'gaseous diffusion' or 'isotope separation' plants.

Even apart from the prospect of breeder reactors (1), plutonium will be produced in the fuel of Europe's first reactors. It is very probable that we will find an economic way to use this plutonium, and so reduce our needs of enriched uranium. Other improvements in reactors may have the same effect. In the end, these developments might even enable power reactors of all types to be based exclusively on natural uranium with fuel recycling.

Therefore, while it is essential for our countries to study with the greatest care the economic and technical aspects of uranium enrichment, it should be noted that the decision to build a diffusion plant on a commercial scale, which means a heavy investment of capital and would consume large quantities of energy, does not have to be taken before a programme for the production of nuclear electricity is launched.

Costs of Nuclear Electricity.

At what cost will electricity be produced by the nuclear reactors commissioned before the end of 1967? And how will this cost compare with the cost of energy obtained from the new coal- and oil-fired stations which would have to be built if nuclear plants are not erected instead? Certain general points must be mentioned.

In the first place: only very limited experience is available in regard to full-scale power reactors; nuclear electricity costs are therefore always estimates, never proven facts. After extensive checking and discussion, inter alia, with the experts whom the American Atomic Energy Commission and the U.K. Atomic Energy Authority so kindly put at our disposal, we consider those which follow to be reliable.

In the second place: the cost of electricity produced by a given reactor will not remain continuously on one level, but will

(1) Reactors producing more fissile material than they consume.

follow a descending curve as the operating technique improves in the course of time. Cost estimates must, therefore, be based on the *average* estimated cost of the electricity produced by a nuclear reactor in the course of its life. Operating costs will be high at the outset of the operation, but will decline in the following years—to a lower level as operating conditions are stabilized. Even in the case of the first reactors, power costs will continue to fall gradually as the techniques of using fuel improve. Nuclear fuel costs are low—less than half the fuel costs in conventional plants—and the saving will apply only to about one quarter of total nuclear costs, though they could be significant. Unlike nuclear stations, the fuel costs of conventional plants must be expected to rise slowly but steadily, relative to the general level of prices.

In the third place: comparison with the electricity costs of conventional plant must be based on new conventional plant burning imported fuel, because we have seen that nuclear power plants will only replace those which would have to consume imported fuel. It is impossible to evaluate in terms of costs the increasing risk of a stoppage in the flow of oil from the Middle East. But electricity producers would be ill-advised not to take this risk into account.

In the fourth place: as it is unlikely that advanced reactors promising far lower power costs, will come into commercial use before the end of our ten-year period, we do not propose to discuss them. But all the best authorities (1) agree that the cost of nuclear energy, even for current reactor types, will decline in the next ten to fifteen years.

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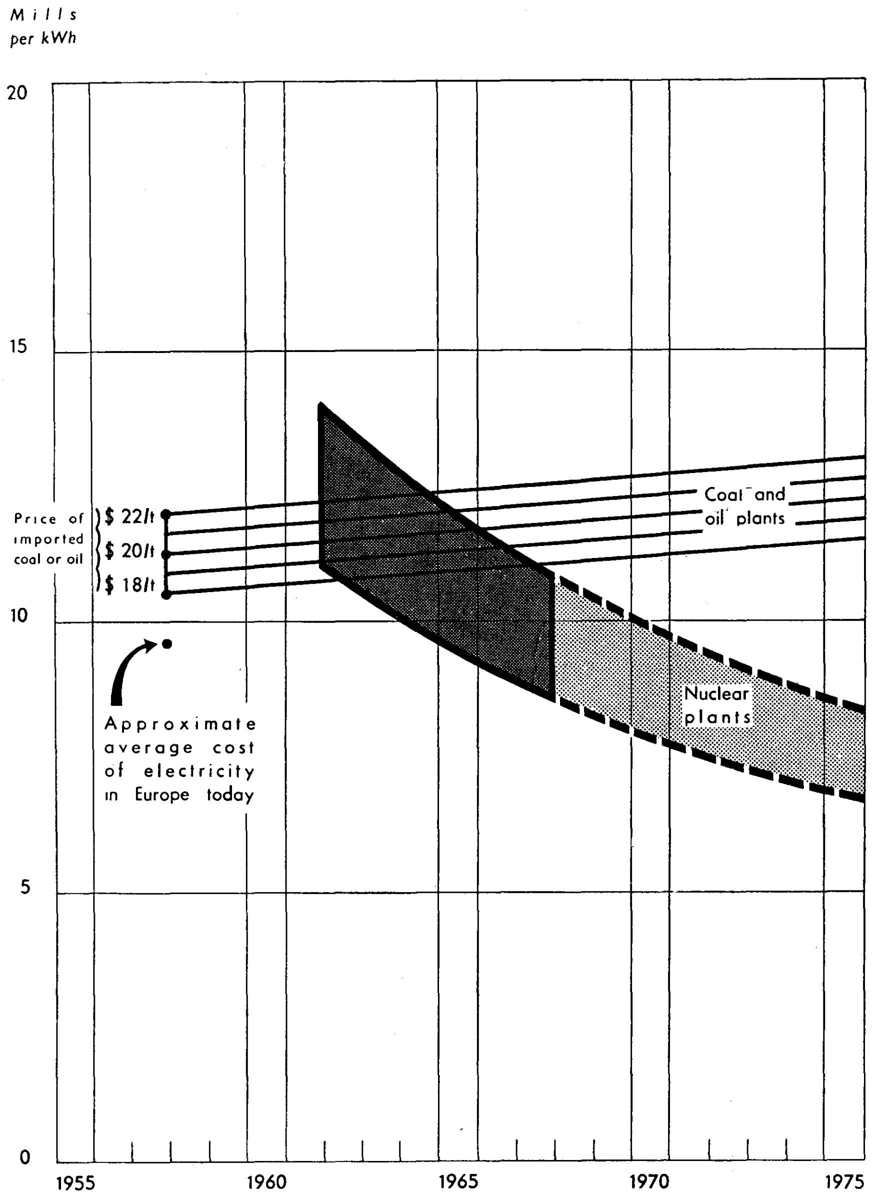
(1) Cf. two of the most important recent studies — lecture on 'The Future for Nuclear Power', delivered by Sir Christopher Hinton, member of the United Kingdom Atomic Energy Authority (March 15, 1957); and 'The Latest Prospects for Economic Nuclear Power', prepared by W. Kenneth Davis, Director, and Louis H. Roddis, Deputy Director, Division of Reactor Development, of the United States Atomic Energy Commission (March 14, 1957).

FIGURE B

Future electricity costs · Trends for new plants



Taking these general considerations into account, our conclusion is that the range of costs of electricity produced by nuclear reactors of both the American and the British type, may be estimated at 11 to 14 mills per kWh, while the cost of electricity from new conventional stations, which must use imported fuel, will be 11 to 12 mills per kWh (see Fig. B) (1). Further, while the cost range of conventional stations is moving slowly upwards, that of nuclear power is moving down. These figures do not apply to the few large reactors which will be brought into service before 1962, and which are more prototype than commercial in character.

In view of this cost comparison, it is clear that the time has come when nuclear power can provide an economic means to stabilize our energy imports. The long-term prospects of reducing production cost are not an argument for delay; on the contrary, a big commercial programme now is the best way to secure a solid basis for massive expansion later.

We must finally point out that the first orders should be placed by the end of 1958, when results of experience will be available, not only from Calder Hall, but also from Shippingport, which will influence the decisions for subsequent steps of the programme.

At this stage, it is necessary to start with big plants; but this does not imply that the six countries are in a position to commit themselves now on the plants to be constructed during the ten-year period.

Investments.

Fuel costs loom large in the cost of conventional power and play only a minor role in nuclear power. In the case of investment costs the opposite is true. The investment costs for nuclear plants,

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(1) See Annex II for detailed analysis. (One mill is a thousandth of a U.S. dollar.)

including fuel inventory, must be estimated for stations to be brought into service in the next ten years to average somewhat more than two and a half times the cost of conventional steam stations, with a gradual decline towards the end of the period. For 15 million kW the difference would approach $ 4,000 million (1), or between 1 and 2 per cent of the estimated total gross investments of our six countries together in the next ten years. This additional investment burden creates some difficult problems for our national economies.

To a certain extent, this implies a changed pattern of investment rather than a truly increased burden. The greater fuel bill for coal and oil in the absence of nuclear plants would have to be paid for by increased exports which, in their turn, would require bigger investments in our export industries. Greater coal and oil imports for conventional stations would also require new investments, notably in ships and ports for their transport.

At first, the expenditure on nuclear power stations will also pose balance of payments problems, because as much as 50% of their cost may have to be paid in foreign exchange. But over the whole of the ten-year period the total import content of expenditure on nuclear plant is unlikely to exceed $ 1,100 million. Further if *all* the fuel for 15 million kW of nuclear plant had to be imported—a pessimistic assumption in view of the uranium production available within our countries—its cost would be about $ 2,000 million for inventory and make-up (2) in the first ten years; and only about $ 200 million per year thereafter (ignoring plutonium credits), compared with an oil and coal bill to import fuel for the same plant capacity of about $ 800 million a year at present prices.

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(1) of which about $ 1,100 would be nuclear fuel inventory (see Ann. III, para. 10).

(2) Make-up is the amount of fresh fuel which must be put in the reactor periodically as spent fuel is withdrawn.

Therefore, though the balance of payments situation of our countries would not benefit immediately by the rapid introduction of nuclear power, the moderate increase in imports during the first years will be rapidly offset by big foreign currency savings subsequently. For these reasons, the expenditure of larger sums on building nuclear rather than conventional power stations is in the public interest.

However, this does not help our electricity suppliers to solve their investment problem; even now the rapid growth of electricity demand is putting a severe strain on the investment resources of our electricity industries. There is a gap between the public interest—which calls for the achievement of our target—and that of the individual electricity supplier, who faces commercial risks by investing heavily in nuclear rather than conventional stations. Yet a prompt commitment on the first plants is essential, both in order to get a quick start and to obtain the greatest experience of reactor construction in the shortest time.

As conditions differ widely in each of our countries, we are not in a position to suggest solutions. However, the Euratom Commission, jointly with the governments and industries concerned, should make a thorough study of this problem, for if it is not solved, it will make our target and the consequent stabilization of energy imports totally illusory. They should also consider incentives, such as increased depreciation allowances for nuclear stations, operative in the first and most difficult years, and other financial measures.

We also attach the greatest importance to a common legislative approach on insurance for nuclear plant, covering the third-party liability of companies engaged in constructing and operating reactors, as well as the liability of manufacturers outside our countries with respect to the performance of their products.

In the United States, the absence of adequate Federal legislation may have seriously retarded the construction of reactors by private industry. Legislation to cover this gap is now being discussed by the U.S. Congress. All experts, both in the U.S. and the U.K., agree that the chance of accidents is exceedingly small. Nevertheless, additional protection against liability in excess of the available insurance coverage is necessary. If an accident should happen on the border of one of our countries, the damage might extend across frontiers. Big nuclear power stations might be ordered jointly by electricity companies in several of our countries. The common market for nuclear products, to be set up within a year of the establishment of Euratom, will also facilitate the placing of orders across national borders. For all these reasons, a common legislative approach to these problems is necessary.

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* *

Europe's economic growth is in danger of being seriously hampered by the lack of energy to nourish it. Being short of domestic energy supplies, our countries must turn increasingly to imports to meet their needs. But imports are costly; and in their most important form of Middle East oil, the supply itself is uncertain. To rely unduly upon them would be increasingly burdensome and hazardous. The advent of nuclear power now gives us a chance to stem their rising tide by building nuclear instead of new conventional power stations using imported oil or coal.

Comparison between the price of nuclear and conventional energy has lead us to conclude that a big effort now would be justified. Industrially, we believe this would be feasible, if our six countries act together, with the help of America, Britain and Canada, who are ahead of us in the application of nuclear techniques, and ready to cooperate fully with us.

The pooling of our financial resources, industrial capacities and varied skills through Euratom will enable our countries to muster the great effort required. Euratom will be able to guide and stimulate action, in particular by providing means to bridge the gap in the initial period between the commercial risk, which firms face in building nuclear plants, and the public need for the most rapid progress.

The establishment of the European Atomic Energy Authority, on which our nations are called to decide, offers the means to achieve the target we envisage: the construction of 15 million kW of nuclear plant by the end of 1967, in order to stabilize our imports early in the 1960's.

ANNEXES

ANNEX I

THE ENERGY ECONOMY OF THE EURATOM COUNTRIES

Historical Survey of the World Output of Energy.

1. Up to the beginning of the first world war the world's economic development was based on coal. After the turn of the century, first in the U.S.A.—and much later in Europe—oil began to acquire growing importance as a source of energy. Between the two world wars natural gas and hydro-electric power have been developed as secondary sources of energy.

World Production of Commercial Energy (1)

	Hard coal	*Brown coal*	*Oil*	*Natural gas*	*Hydro-power*	*Total*
			Million metric tons hard coal equivalent (= *Mt HCE*) (2)			
1870	203	4	11	—	—	218
1900	701	22	29	9	16	777
1913	1216	39	77	22	45	1399
1955	1604	152	1086	360	190	3392
			Percentage of World Production			
1870	*93*	*2*	*5*	—	—	*100*
1900	*90*	*3*	*4*	*1*	*2*	*100*
1913	*87*	*3*	*5*	*2*	*3*	*100*
1955	*47*	*4*	*32*	*11*	*6*	*100*

(1) Primary energy in so far as it is commercially used, wood and waste fuels excluded.

(2) Conversion factors:

Hard coal:	7000 Kcal/kg
Brown coal:	2100 Kcal/kg
Oil:	10000 Kcal/kg
Natural gas:	9000 Kcal/m³
Hydro-power: 1870-1913:	7000 Kcal/kWh
1955:	2800 Kcal/kWh

Between 1870 and 1955 world production of commercial energy increased at an annual rate of about 4%. At the same time the output of oil, natural gas, and to a lesser degree also hydro-power, rose at a considerably faster rate than the extraction of hard coal. Nowadays the relative importance of hard coal in the world's energy economy is only half as great as it was in the closing decades of the last century.

The reasons for the slower progress of coal extraction since the beginning of the first world war lies partly in the technical changes that have occurred in the demand for energy, e.g. the emergence of the internal combustion engine and the diesel motor, and partly in the increasingly unfavourable natural conditions attaching to coal extraction. In Europe the exhaustion of deposits, the greater depths to which mine shafts must be driven, and the unfavourable conditions for the mechanization of coal mining play a particularly important role. They largely explain the rise in the real production costs of coal, its extremely limited adaptability to fluctuations in demand, and the fact that, for 30 to 40 years past, there has not been enough capital available for opening up deposits. The most convincing evidence of all these happenings is to be found in the British coal mining industry. In 1870 the United Kingdom produced 54% of all the world's coal, in 1913 it still produced 25% and in 1955 only 13%. On account of the territorial changes that have taken place it is not feasible to make a comparison of coal production in the ECSC countries for the same period, but there is evidence to show that the share of the ECSC countries in world coal production fell from about 21% in 1938 to 16% in 1955. Even the United States of America with rich coal deposits which can be worked cheaply, has seen its share in world coal production fall from 41% in 1913 to 28% in 1955. The United States' share of the world production of total energy is as high as it was at the beginning of the first world war.

2. A second factor which has made a significant change in the situation as regards output of primary energy is the rapid expansion of oil production in the Middle East, particularly since the end of the second world war. As the Middle East countries alone, on the basis of 1955 estimates, possess 66% of proved world reserves of oil, and in addition produce it considerably more cheaply than other countries, this trend will continue. It is anticipated that by 1975 the Middle East will be producing about 50% of world oil output. During the next decades, the oil consumption of the Western Hemisphere will grow more rapidly than their production with the result that they will become net importers.

Actual and Potential World Oil Production (Major Areas)

(Mt HCE and as % of World Production)

	World	*U.S.A.*	*Rest of America*	*Middle East*	*S.E.Asia*	*Europe*	*U.S.S.R.* (1)
			Mt HCE (2)				
I. *Actual*							
1938	385	235	63	23	12	11	41
1955	1091	477	230	230	24	28	100
II. *Potential* (3)							
1965	1740	635	420	575	70	40	—
1975	2600	635	520	1290	115	40	—
			as % of World Production				
I. *Actual*							
1938	*100.0*	*61.0*	*16.5*	*6.0*	*3.1*	*2.7*	*10.7*
1955	*100.0*	*43.7*	*21.0*	*21.3*	*2.2*	*2.6*	*9.2*
II. *Potential* (3)							
1965	*100.0*	*36.4*	*24.1*	*33.2*	*4.0*	*2.3*	—
1975	*100.0*	*24.3*	*20.0*	*49.6*	*4.4*	*1.7*	—

(1) Production of USSR in 1938 and 1955 estimated; provisions for 1965 and 1975 not available.

(2) Converted into HCE at the ratio of 10:7 to facilitate comparison with the other tables; excluding natural gas liquids.

(3) These figures do not include the output of the newly discovered Sahara oil reserves, which are estimated at about 10 Mt HCE for 1960 and about 40 Mt HCE for 1965. Realization of these reserves would considerably mitigate Europe's energy supply problem in the years immediately ahead.

Energy Supplies of the Euratom Countries during the Last Twenty Years.

3. In 1935-36 the ECSC-Community's gross domestic consumption (1) (apparent consumption) of energy amounted to 295 Mt HCE or 2.1 t HCE per head of the population. In 1955 it had risen to 400 Mt HCE or 2.45 t HCE

(1) Gross domestic consumption = apparent consumption plus variations in stocks held by producers; Net imports = gross domestic consumption minus indigenous production.

per head. Between 1950 and 1955 the energy consumed had risen by 36% while the gross national product rose 34%.

	1936 (1)	*1950*	*1955*
		(*Mt HCE*)	
Consumption	295	293	400
Indigenous production	275	261	316
Net imports	20	32	84

Within this development there has been a great change in the form of demand for energy, becoming more and more one for finished products such as electricity, gas and refined mineral oils. Thus, the consumption of electricity increased almost threefold between 1935 and 1955; and the proportion of mineral oils, which used to be not more than 6-7% of the consumption, is now about 20%.

Even more important is the fact that the six countries are becoming more and more net importers of energy. There are two reasons for this. First, the extraction of hard coal—hitherto, and still today, the ECSC countries' most important source of primary energy—is unable to keep up with the growth in demand, partly because the reserves of coal are not large enough to enable it to do so, partly because in our coal-mining areas extraction from deep shafts cannot be easily adapted to a growing demand, and lastly also because it is becoming more and more difficult to obtain manpower. The second reason for the increased dependence on imports is that in our countries sources of energy other than coal are available only to a limited extent. Some of our countries have water power resources, but those which can be economically exploited have already been largely utilized. The deposits of oil and natural gas in our countries are certainly not unimportant, but they are by no means sufficient to meet the rapidly growing demand for these products. In 1955 the imports of mineral oil amounted to about 103 Mt HCE, of which more than 80% came from the Middle East. Nearly 22 Mt HCE of liquid fuel were re-exported as finished products.

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(1) Estimated figure for 1936-37; no reliable calculation can be made because of the territorial changes which have occurred.

Future Energy Requirements.

4. The following estimates of the internal requirements, indigenous production and net imports are based on studies—still not all published—made by the High Authority of the European Coal and Steel Community for the years 1955 to 1965 (1). Further forecasts have been made for 1965 to 1975 which, however, indicate a general tendency only.

The estimates made of the general expansion of the national economies comprised in the ECSC countries are based on the following hypotheses: *a*) the active population will be fully employed throughout the whole period and those still unemployed in some countries in 1955 will, except for those seasonally or temporarily out of employment, be absorbed into industry; *b*) there will be a high rate of increase in productivity per man/year after allowing for some reduction of weekly working hours and an extension of annual holidays; *c*) only the long-term development trend is taken into account.

On these hypotheses the development of the gross national product (GNP) is estimated to be as follows:

	1955-1965	*1965-1975*
Increase in working population (as % of initial value)	6.5	3.4
Annual rate of increase of productivity (%)	3.7	2.7 (2)
Annual rate of increase in GNP (3) (%)	4.3	3.1

(1) Reference is made in detail to the following studies:

a) Report of the Mixed Committee of the High Authority of the Coal and Steel Community and the Council of Ministers (further referred to as 'Mixed Committee') on the prospects and conditions of general economic development in the Community's countries (not yet published).

b) Report of the Mixed Committee on the structure and trends of the energy economy in the Community countries (not yet published).

c) Report of the High Authority on the 'General Objectives for Coal and Steel' (further referred to as 'General Objectives'); published in the General Report of the High Authority to the Assembly, April 1957.

(2) On the assumption that the working year during this period will be reduced by 3% and productivity per hour increased by an overall 35%.

(3) The transition from a high rate of increase in the first ten-year period to a low rate in the second is actually a continuous, not a discontinuous process, as might be supposed from the figures in the table. As an example, the annual rate of increase in productivity in the years from 1965 onwards should approximate 3% or even a little less.

5. The estimate of energy requirements is computed by ascertaining the ratio between the changes in such requirements over a period of time and changes in the gross national product. The following table shows the data used and the results of the estimates compiled by the High Authority or the Mixed Committee, as the case may be.

Total Energy Requirements of the Euratom Countries

	German Federal Republic (1)	*Belgium*	*France*	*Italy*	*Luxem-bourg*	*Nether-lands*	*Six Countries*
			GNP Index Figures				
1955-1965 (1955=100)	155	139	149	163	115	138	152
1965-1975 (1965=100)	137.5	127	134	142.5	110.6	126.5	135.5
			Ratio of Changes in Energy Requirements to Changes in GNP				
1955-1965	0.70	0.70	0.90	1.00	0.95	0.90	0.79
1965-1975	0.70	0.75	0.95	1.05	0.95	1.00	0.83
			Energy Requirement Indices				
1955-1965 (1955=100)	138.5	127.3	144.1	163.0	114.2	134.2	141.3
1965-1975 (1965=100)	126.2	120.2	132.2	144.6	110.1	126.5	129.8
			Energy Requirements (2) (3) (*Estimated Apparent Consumption*) (*Mt HCE*)				
1955	182	34	107	47	4	27	400
1960	214	38	129	59	4	31	475
1965	252	43	154	76	5	36	566
1970	286	47	178	92	5	40	648
1975	318	51	202	110	5	45	731

(1) Since the 1st of January 1957, the Sarre Territory belongs to the Federal Republic. 1955 figures for the Sarre have been added to the figures of the Federal Republic.

(2) The figures in the above Table are slightly different from the data contained in the Mixed Committee's report which has not yet been published. Apart from revisions subsequently supplied by individual countries, the differences are due to the fact that in our calculation the production of hydro-electric power over the whole period has been computed on the basis of an equivalence of 400 g HCE/kWh. This corresponds to the specific fuel consumption prevalent in 1956 in modern thermal power stations.

(3) Figures for 1960 and 1970 are interpolated.

According to this estimate the six countries' energy requirements over the period 1955-1965 will rise by about 3.5% annually and over the period 1965-1975 by about 2.6%. The reasons for adopting these rates of increase as a basis for further analysis are the following:

a) The Mixed Committee estimates that between 1955 and 1965 the gross national product will rise by 52%, resulting from 6.5% increase in population and from 43% increase in productivity. Such an increase in productivity, however, can only be achieved with the help of more abundant supplies of energy, especially when it is remembered that in the next few years the efforts being made everywhere to shorten hours will prove successful.

b) The expansion of national economies will primarily be the consequence of an anticipated rise in industrial production and, as an approximation, it can be assumed that a rise of about 60% in industrial production will correspond to a 50% rise in the national product. The branches of industry which are large consumers of power, such as chemicals, will play an increasingly prominent part in this process.

c) The expansion is accompanied by a growing urbanization, which means a rise in domestic energy consumption.

d) Agriculture is entering an era of mechanization and will become a relatively bigger consumer of energy than hitherto.

In general, the energy situation in the six countries is coming to resemble that in the United States and also in the United Kingdom with its distinguishing feature of a high rate of consumption per head of population.

Growth of Domestic Energy Supply.

6. Estimates of the indigenous production of primary energy are difficult to establish, on account of the varying evaluation of reserves in the case of oil and natural gas, and of future production conditions in the case of hard coal.

For hard coal we have adopted in the first place the estimates of the 'General Objectives' Committee, which are based on an optimistic hypothesis. This hypothesis takes into consideration all the workable deposits already existing and assumes that, in spite of the tendency to reduce the working week and to lengthen annual holidays, the number of days of production per year will in future be 300; it is further estimated that output per man and underground shift can be expected to rise by 30% in 20 years. The figures thus computed give the maximum productive capacity, if some 30 new pits are opened. A conservative estimate is based on the assumption that it will not be possible to compensate the expected reduction in the working week; and that the trend of future production will be reflected in a reduction of the number of days per year actually worked from 300 to 260.

In the case of brown coal it is assumed that maximum use will be made of the existing deposits and that all the extra crude coal produced is used as fuel in power stations (more particularly, in the case of brown coal from the Rhineland).

In the case of hydro-electric resources that can still be expanded the assumption made is that of maximum exploitation.

The estimates for the future of oil and natural gas are less reliable; in this case the data obtained from the individual countries have been adopted. The future production from oil deposits in the Sahara is treated statistically as part of the imports of the six countries.

Finally, the Mixed Committee has made an estimate of the probable development of indigenous production, which comes more or less halfway between the optimistic and the conservative hypothesis. We have adopted these figures also, subject, however, to the variation that maximum use is made of available water power resources (1).

The following table gives the results of the calculations. Figures for the separate countries will be found in the tables at the end of this Annex.

Production of Primary Energy in the Euratom Countries

(Mt HCE)

	1955	*1960*	*1965*	*1970*	*1975*
	Optimistic estimate				
Hard coal	243.3	262	285	300	320
Brown coal	28.5	32	40	45	49
Oil	7.5	24	40	55	71
Natural gas	5.5				
Hydro-electricity	30.9	35	45	50	56
Total	315.7	353	410	450	496

(1) This is one of the basic factors determining the magnitude of a nuclear power programme (see Annex III).

Production of Primary Energy in the Euratom Countries

	1955	*1960*	*1965*	*1970*	*1975*
	Conservative estimate				
Hard coal	243.3	245	250	262	277
Brown coal	28.5	32	40	45	49
Oil	7.5	23	34	36	43
Natural gas	5.5				
Hydro-electricity	30.9	35	45	50	56
Total	315.7	335	369	393	425
	Estimate of Probable Indigenous Production				
Hard coal	243.3	254	265	279	293
Brown coal	28.5	32	40	45	49
Oil	7.5	13	19	24	29
Natural gas	5.5	10	15	18	22
Hydro-electricity	30.9	35	45	50	56
Total	315.7	344	384	416	449

7. As a result of deteriorating conditions in the coal seams and of the increasing use that is being made of machinery in coal mining, the extraction of hard coal with a high ash content will rise. Similarly, as a result of more intensive preparation of run-of-mine coal, the proportion of so-called middlings and slurry will increase. We define slack with a high ash content, middlings and slurry together as 'low-grade coal'.

Production of Low-grade Coal in 1955

	Actual Tonnage (*millions*)	Percentage of total coal production
Federal Republic	18.0	*12*
Belgium	8.3	*28*
France	11.6	*21*
Netherlands	1.5	*12*
	39.4	*15.7*

Because of its high percentage of ash and other unfavourable physical characteristics, low-grade coal is not suitable for long-distance transport and is therefore earmarked for use in pithead power stations (its caloric value is taken as 4,300 Kcal/kg as against 7,000 Kcal/kg for ordinary coal). Utilization in this way also fits in with the efforts being made for the electrification of coal-mining operations. The 'General Objectives' Committee has evaluated the share of low-grade coal in future production and has taken as a basis the assumption that more particularly in the West German coal mines, seams high in low-grade coal will in future be worked more intensively. If the percentage figures as estimated by this Committee are applied to the probable production estimates, the output of low-grade coal will be as follows:

	Probable Total Coal Production (*Mt*)	Probable Output of Low-grade Coal		
		% of Total Production	Actual Tonnage (*Mt*)	Converted into HCE (*Mt*)
1955	243	*15.7*	39.4	23.3
1960	254	*16.3*	41.4	24.8
1965	265	*17.4*	46.1	27.7
1970	279	*17.5*	48.5	29.1
1975	293	*17.6*	51.6	31.0

These figures cannot be related directly to the output of electricity from pithead power stations given in Annex IV (para. 4), because part of the low-grade coal is used for other purposes.

Net Imports of Euratom Countries.

8. The six countries' net imports, reckoned as the difference between domestic consumption and indigenous production, will even on the optimistic estimate of production, be in 1965 almost double and in 1975 nearly three times the 1955 figure.

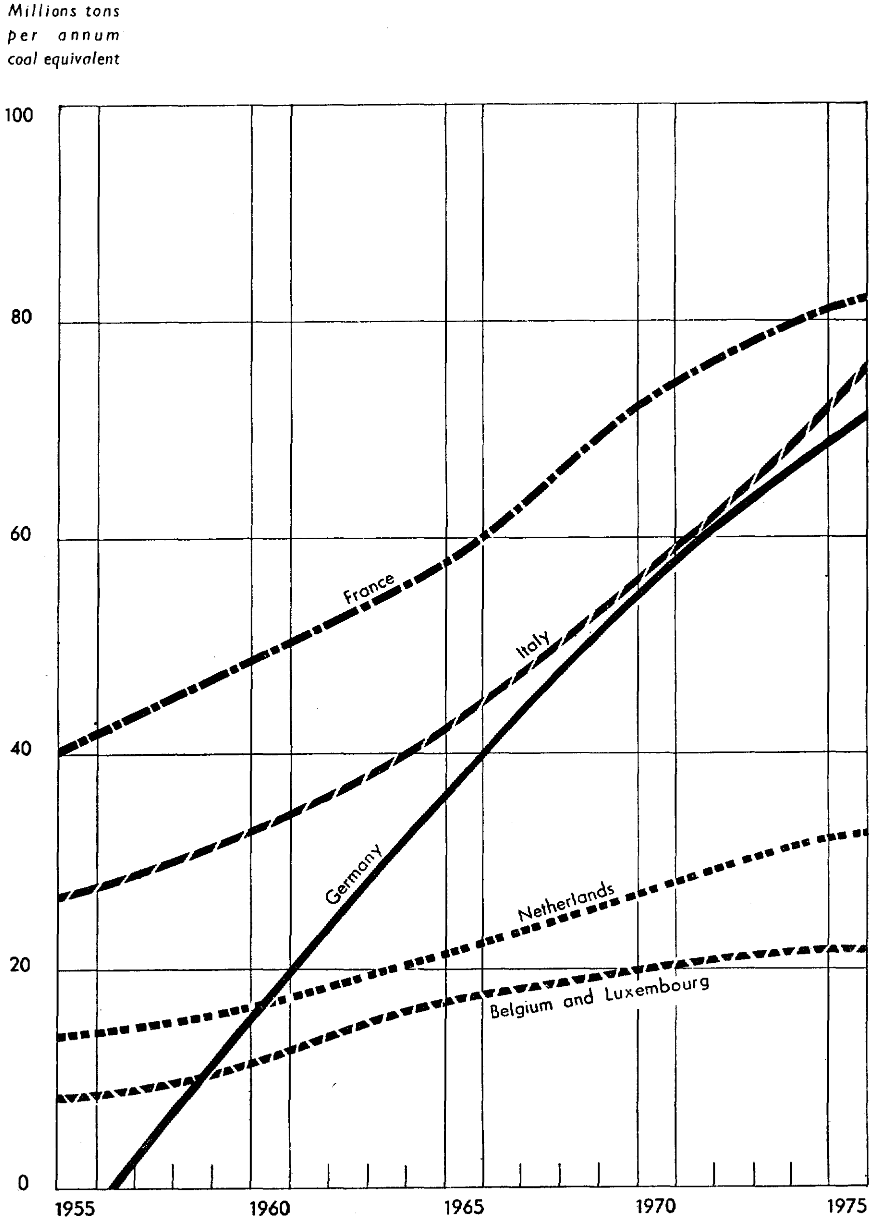
Net imports

	1955	*1960*	*1965*	*1970*	*1975*
Optimistic estimate of indigenous production.					
(*Mt HCE*)	84.3	122	156	193	235
%	*21.0*	*26.7*	*27.6*	*30.0*	*32.2*
Conservative estimate of indigenous production.					
(*Mt HCE*)	84.3	140	197	250	306
%	*21.0*	*29.5*	*34.8*	*38.9*	*41.9*

The figures so computed embody a number of fortuitous and doubtful factors which will probably be magnified as the period under consideration is extended. On the long-term view it is advisable to take as a basis the *probable* trend of production (see para. 6).

FIGURE C

Net energy imports of individual countries



Probable Trend of Net Imports

	1955	*1960*	*1965*	*1970*	*1975*
	—	—	—	—	—
Estimated consumption (*Mt HCE*)	400	475	566	648	731
Indigenous production (*Mt HCE*)	316	344	384	416	449
Net imports (*Mt HCE*)	84	131	182	232	282
Net imports (%)	*21.0*	*27.5*	*32.2*	*35.9*	*38.6*

On this basis it would seem that at present the ECSC countries' net imports of energy amount to just about 100 Mt HCE or 23% of domestic consumption; in ten years they will be roughly 200 Mt HCE or 33% of estimated consumption; and in twenty years will be around 300 Mt HCE or about 40% of estimated consumption—all this in the absence of nuclear energy (See Figs. A and D).

The share of net imports in total requirements (estimated consumption) varies from country to country, according to the level of indigenous production. In the next ten or twenty years the extent to which countries depend on imports will be altered. The most far-reaching change will be that affecting the German Federal Republic which now has an evenly balanced energy trade account. In 1965, however, she will probably need net imports of 38 Mt HCE or 15% of total requirements, and in 1975 they may reach 72 Mt HCE or nearly a quarter of her consumption. As Fig. C shows, the deterioration of her foreign trade balance in the matter of energy supplies is progressing more rapidly than in any other Euratom country. Detailed figures of the energy balance for each country are given at the end of this Annex.

Comparison with O.E.E.C. Estimates. (1)

9. Our estimates for energy requirements and production differ to a certain extent from those published in the O.E.E.C. Report on 'Europe's Energy Requirements', which are as follows:

	1955	*1960*	*1975*
	—	—	—
Maximum	100	118	178
Mean	100	115	165
Minimum	100	112	150

(1) 'Europe's Growing Needs of Energy—How Can They Be Met?' O.E.E.C., A Report Prepared by a Group of Experts, May 1956.

The O.E.E.C. estimate involves a 3% annual increase for the period 1955-1975 according to the maximum estimate, and a 2.5% annual increase according to the mean estimate. The Mixed Committee estimates the annual rates of increase for the E.C.S.C. at 3% for 1955-1975. Deviations between the estimates exist for the first period. O.E.E.C. assumes an annual rate of 3% for 1955-60, whereas the Mixed Committee assumes 3.5% for 1955-65.

The O.E.E.C. report does not give full particulars for individual countries, so its estimates can only be compared indirectly, by subtracting an independent estimate for Great Britain and our own estimate for the six countries from the O.E.E.C. maximum estimate, to see if the balance left for other O.E.E.C. countries appears to be reasonable. For energy requirements, this gives the following figures:

	1955	*1960*	*1975*
		(Mt HCE)	
O.E.E.C. estimate for all countries	730	860	1 300
Estimate for Great Britain (1)	250	275	363
Present estimate for six countries	400	475	731
Other O.E.E.C. countries (by difference)	80	110	206

For indigenous production of primary energy, the same procedure gives the following figures:

	1955	*1960*	*1975*
		(Mt HCE)	
O.E.E.C. estimate for all countries	584	645	755
Estimate for Great Britain	222	230	255 (2)
Present estimate for six countries	316	344	449
Other O.E.E.C. countries (by difference)	46	71	51

It is apparent that the O.E.E.C. maximum estimate is in line with that of the present Report for requirements, but much more cautious with respect to indigenous production.

Demand for Specific Types of Energy.

10. The demand for energy is to some extent a demand for specific kinds of energy: coking plants require coal; automobiles and aeroplanes need liquid fuel. Much of the demand for energy, however, can be met by coal or by oil. In this field, which covers heating requirements for industry and

(1) G. H. Daniel 'Britain's Energy Prospects'; the Viscount Nuffield Paper; 15 December 1955.

(2) Daniel, op. cit., gives no estimate for 1975; the figure given above is that for 1970.

households and the thermal production of electricity, the various types of energy compete with one another.

The High Authority's memorandum defining the 'General Objectives for Coal and Steel' and the Mixed Committee's studies on power economy give estimates of energy requirements by types which are reproduced in the following table. In these estimates no allowance has yet been made for nuclear energy. The demand of the final consumers for electricity is considered, in this case, as a specific energy demand.

Types of Energy required for Specific Consumer Needs

	1955		*1965*		*1975*	
	(*Mt HCE*)	%	(*Mt HCE*)	%	(*Mt HCE*)	%
Specific requirements:						
Electricity (1)	92	*23.0*	161	*28.5*	253	*34.5*
Hard coal (2)	114	*28.4*	144	*25.4*	168	*23.0*
Oil (3)	21	*5.3*	41	*7.2*	63	*8.6*
Non-specific requirements	173	*43.3*	220	*38.9*	247	*33.9*
Total requirements	400	*100.0*	566	*100.0*	731	*100.0*

The following deductions may be drawn from this table, which provides only rough indications of requirements:

a) The share of electricity in the total amount of energy consumed will rise 50% by 1975 (in terms of HCE).

b) Specific requirements in hard coal are estimated to rise by 54 Mt HCE by 1975. Its share in the total amount of energy consumed will decline, but the absolute increase exceeds that which can be anticipated in hard coal production ('probable' estimate).

c) Non-specific requirements are estimated to rise by 74 Mt HCE between 1955 and 1975.

d) The whole increase in non-specific consumption and in the non-specific requirements of power stations will have to be met by increased imports, except in so far as nuclear power takes their place. The future structure of consumption in the six countries' energy economy will therefore

(1) As a secondary form of energy, the demand for electricity is specific; but over half of it is produced by 'other thermal' power stations, the primary energy consumption of which is non-specific (for figures see table at end of Annex IV).

(2) Coking coal requirements of coking plants and gasworks plus collieries' own consumption.

(3) Petrol and diesel oil used by road and air traffic vehicles only.

be determined mainly by the relationship between the prices of imported coal and imported crude or fuel oil.

Fuel Import Prices.

11. If the six countries are going to have to depend more and more on imports for their supplies of energy, this cannot fail to affect the cost of our energy supplies. The upward price-trend thus induced will become all the more noticeable as other countries which are big consumers find themselves obliged to rely increasingly on imports of energy. Great Britain would—without its nuclear power programme—have to raise its imports of energy from 28 Mt HCE to 108 Mt HCE by 1975. Even the United States will have to cover its oil requirements to an increasing extent by imports.

The Community of the Six is a very big importer of energy, but at the same time it is also an important exporter of refined energy products and is earning quite substantial profits on the refining process. In 1955, gross imports of energy from third countries amounted already to 14.3% of the total goods imports and a fifth of the imports of raw materials and feed products. These proportions will rise rapidly; a distinguishing feature of the future development will be the shift which will occur in the composition of imports as a result of the increasing amounts of energy imported.

The Euratom Countries' Trade in Energy with third Countries in 1955

	Quantities	*Values*	
	(Mt HCE)	(mill. $)	($/t HCE)
Total imports:			
Hard coal	22.9	.	.
Crude oil	92.8	.	.
Refined oil	9.6	.	.
Total	125.3	1,946	15.8
Total exports:			
Solid fuel (coke, etc.)	18.9	.	.
Liquid fuel (refined oil)	21.7	.	.
Total	40.6	895	23.9
Balance:			
Solid fuel	4.0	.	.
Liquid fuel	80.7	.	.
Total	84.7	1,051	8.1

Computed foreign trade values for 1955 cannot be considered significant for the future because they reflect neither the increase of import demands since then nor the growth of requirements to be expected in the future. During the first six to nine months of 1956 the import prices were $ 2.5 per ton HCE higher than the corresponding figures of 1955.

The prices of imported coal and fuel oil are related; they compete directly on the Eastern Seaboard of the United States. In 1956, for instance, f.o.b. prices of coal were $ 12-13/ton, and quotations for bunker C oil were near $ 10/ton (converted into HCE); allowing for subsequent increases in oil prices, and a somewhat stabler coal market, representative f.o.b. prices appear to be $ 12/ton for coal and $ 11/ton for oil. In the future, the anticipated steep rise of U.S. oil imports may well modify this relationship.

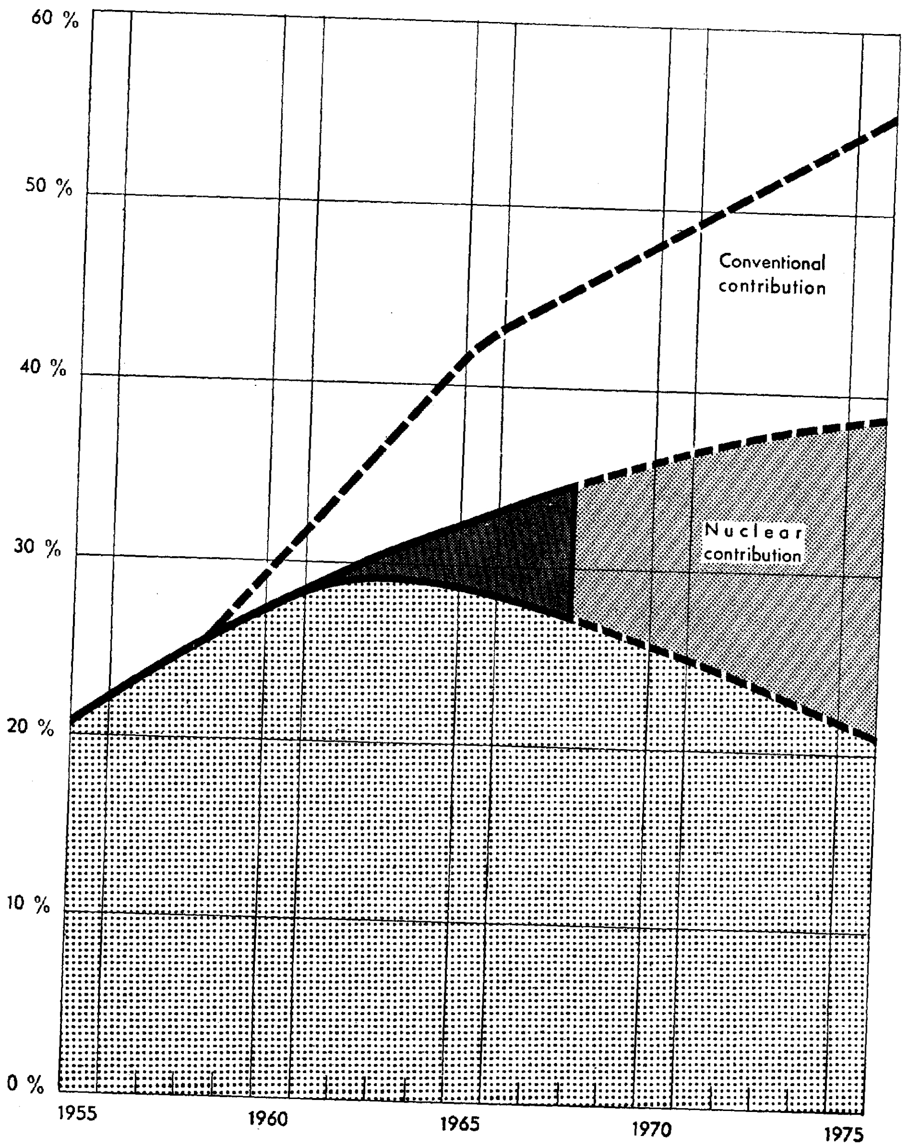
Long-term freight rates for shipment of coal from the United States to Europe may be assumed to settle down in the neighbourhood of $ 8/ton, with a corresponding figure for oil of $ 5/ton (HCE). This would give c.i.f. prices of $ 20/ton for coal and $ 16/ton for oil. To these prices must be added charges for handling and inland transport of about $ 2/ton, giving prices of $ 22/ton for coal and $ 18/ton for oil delivered to consumers near ports. In practice, this difference may tend to narrow in the future. Although fully realizing the uncertainties of such forecasts, we think it reasonable for present purposes to take a delivered price of $ 20/ton (HCE) for energy imports of the six countries.

A specific demand for American coking coal, and traditional or technical preferences for coal on the part of some groups of consumers, even in the future, may tend to increase coal imports appreciably. But it must be concluded from the comparison of prices made above that the future increase in energy imports of the six countries will tend to a very great extent to take the form of oil rather than of coal.

FIGURE D

Limitation of energy imports by nuclear power and by expansion of convential supplies

(as % of total energy requirements)



Tables showing Energy Balances of Individual Countries (1)

(Mt HCE)

	1955	*1960*	*1965*	*1970*	*1975*
	—	—	—	—	—
GERMAN FEDERAL REPUBLIC					
Estimated Consumption	181.7	214	252	286	318
Probable Production:					
Hard coal	148.8	155	163	173	184
Brown coal	27.2	30	36	40	46
Oil	4.5	5	6	6	6
Natural gas + peat	1.0	1	2	2	3
Hydro-power	4.8	5	7	7	7
Total	186.3	196	214	228	246
Net imports	— 4.5	18	38	58	72
As % of consumption	*— 2.5*	*8.4*	*15.1*	*20.2*	*22.6*
BELGIUM					
Estimated Consumption	33.6	38	43	47	51
Probable Production:					
Hard coal	29.4	30	31	32	34
Hydro-power	0.1	0.1	0.1	0.1	0.1
Total	29.5	30.1	31.1	32.1	34.1
Net imports	4.2	8.0	12	15	17
As % of consumption	*12.5*	*21.1*	*27.9*	*31.9*	*33.4*
FRANCE					
Estimated Consumption	107.0	129	154	178	202
Probable Production:					
Hard coal	52.2	55	58	60	62
Brown coal	1.2	2	2	2	2
Oil (2)	1.3	5	9	12	16
Natural gas	0.4	3	6	9	12
Hydro-power	10.2	14	20	23	28
Total	65.3	79	95	106	120
Net imports	41.7	50	59	72	82
As % of consumption	*39.0*	*38.8*	*38.3*	*40.4*	*40.6*

(1) The figures are taken mainly from national data. However, it is assumed that the fullest use is made of the available waterpower resources.

(2) The estimate of indigenous consumption does not take into account the future production of oil in the Sahara.

Tables showing Energy Balances of Individual Countries (1)

(Mt HCE)	*1955*	*1960*	*1965*	*1970*	*1975*
	ITALY				
Estimated Consumption	46.4	59	76	92	110
Probable Production:					
Hard coal	1	1	1	1	1
Brown coal	0.2	0.6	1	1	1
Oil	0.3	1.4	3	4	5
Natural gas	4.3	7	8	8	8
Hydro-power, Geothermal	13	16	19	20	21
Total	18.8	26	32	34	36
Net imports	27.6	33	44	58	74
As % of consumption	*59.5*	*56.0*	*57.9*	*63.0*	*67.3*
	LUXEMBOURG				
Estimated Consumption	4	4	5	5	5
Indigenous Production:					
Hydro-power	0	0.3	0.3	0.3	0.3
Net imports	4	3.7	4.7	4.7	4.7
As % of consumption	*100*	*92.5*	*94.0*	*94.0*	*94.0*
	NETHERLANDS				
Estimated Consumption	26.7	31	36	40	45
Probable Production:					
Hard coal	12.0	12	12	12	12
Oil	1.5	2	2	1.5	1.5
Natural gas	0.2	0.3	0.3	0.4	0.4
Total	13.7	14.3	14.3	13.9	13.9
Net imports	14	16.7	21.7	26.1	31.1
As % of consumption	*52.4*	*53.9*	*60.2*	*65.2*	*69.1*

(1) The figures are taken mainly from national data. However, it is assumed that the fullest use is made of the available waterpower resources.

ANNEX II

NUCLEAR POWER PROSPECTS

Reactor Types

1. The rapidity of nuclear development, and the publicity which has accompanied its remarkable success, have made it difficult for experts and laymen alike to judge objectively the problems and the probable cost of the first nuclear stations. Now that a dozen or more central station nuclear power plant prototypes are in course of construction or in an advanced stage of design, the possibilities of economic nuclear power can be assessed with some confidence.

The best routes have not yet been firmly established, and experts are confident that radical advances will be realized within the next ten years. But already now nuclear electricity is produced commercially. In view of the very favorable prospects ahead, any big nuclear power programme has to be very flexible, and must pursue short-term and longer-term developments in close association with commercial application. For the beginning of such programmes there are however two classes of reactor available now; and even they will be improved considerably during the next ten years.

(*a*) PWR/BWR: The American pressurized-water reactor PWR prototype at Shippingport (near Pittsburgh) is due to come into operation in about six months, and several improved units of around 140 eMW (1) capacity are in course of construction or design. The prime-mover for the nuclear submarine Nautilus is of this type, and it has on this account had the benefit of a very thorough engineering development. The civilian power version is fueled with uranium having an average concentration of U-235 from 2 to 4 times that of natural uranium.

The boiling water reactor BWR is a variant of PWR which avoids

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(1) The abbreviation eMW is used to distinguish the net electrical capacity of nuclear plants from their heat rating, which is often expressed in mega-Watts.

the latter's high vessel pressure, and permits steam to be used directly in turbines or passed through an intermediate boiler stage depending on the exact design. Its fuel element design and circuit technology are closely akin to PWR, and experience with its 5 eMW prototype at Argonne is very encouraging. A large (180 eMW) unit is now under construction.

Detailed engineering and cost considerations will determine the optimum steam content of the water leaving the core, and the ratio of heat transferred to primary and secondary steam circuits, so the PWR and BWR approaches may well tend to coalesce in the course of development.

(*b*) PIPPA: The British gas-cooled reactor prototype at Calder Hall has been working very successfully for the last six months, and several two-reactor stations of approximately 300 eMW are under construction for the electricity authorities. This type was adopted in the U.K. because it involved a high proportion of conventional engineering, while promising great scope for future improvement; it was capable of operation on natural uranium, thereby avoiding a claim on uranium enriched in U-235; and it lent itself to production of military plutonium with power as a by-product (although this no longer applies to the commercial stations).

Two further types may be ready for construction of full-scale units during the next 3 or 4 years:

(*a*) ENRICHED PIPPA: A gas-cooled graphite reactor with moderately enriched fuel is the next obvious stage for PIPPA, but it has not yet been designed in detail. Moderate enrichment offers greatly increased fuel burn-up; and unlike natural uranium it can support cladding (e.g. stainless steel) and alloying materials capable of much higher temperature duty. This would raise both rating and efficiency, and so reduce capital as well as operating costs.

(*b*) HWR: The heavy water type has attained a well-advanced basic technology largely as a result of Canadian work at Chalk River, and of its close ties with the PWR development. Its engineering is less advanced, but several prototypes are now in course of design and development in the U.S. and Canada. The heavy water moderated reactor makes possible very high utilization of natural uranium fuel without recycle; and, if the coolant can be contained in tubes instead of a high pressure shell, this offers the possibility of very large unit capacities.

2. PWR/BWR and PIPPA are the only immediately available full-scale designs, and their initial costs and uncertainties are expected to be very comparable. Each approach has potential advantages and scope for development that makes it important to gain the fullest experience now by construction of big plants of both types. But Europe's requirement for power reactors differs in important respects from that of the U.S. and the U.K. Urgent consideration must be given to the further evolution of these designs to suit Europe's needs, with respect to their methods of fueling in all its implications, as well as to the primary objectives of cost reduction and reliability. This may well entail the addition within the next few years of heavy water systems as a third main line when their development problems are solved, and preparation of a PIPPA design with optimum U-235 enrichment, since both promise favorable fuel cycles with straight-forward engineering requirements, and appreciable cost reductions. It is also very important to develop means of using plutonium as fuel in power reactors, in order to decrease the requirements for enriched uranium.

3. Other types of reactors which show less promise of favorable costs in the near future, or have a long and perhaps uncertain development period ahead of them yet, are among others the sodium-graphite, organic cooled (and moderated), fast plutonium breeder, aqueous homogeneous, liquid-metal fuel, and high-temperature gas-cooled reactors. Some of these types have especially good long range promise when their development problems are solved.

Active work is already under way in some of our countries both on the earlier reactor types and on types of long-term promise. France has completed since 1948 the reactor G1 at Marcoule and five research reactors, and is currently building three large-scale gas-cooled power reactors, two at Marcoule and one at Chinon, which will feed a total of 160 eMW into the E.D.F. grid. She is planning a large programme of future additions to this capacity. Italy, Germany, the Netherlands and Belgium are installing PWR/BWR type reactors with light or heavy water coolant. And all five have atomic energy development programmes, in various degrees, studying such advanced types as homogeneous, fast breeder, high temperature gas-cooled and others.

Nuclear Costs.

4. It is important when considering nuclear power costs that the terms be properly defined. One is dealing with a situation where a power station which is in the planning stage now, will be completed within three to five years, and may operate for twenty years or more thereafter. The cost of operation will be higher during the initial phase than once the stable operating condition is reached, but this phase can be expected to last only one or two years. From then on, the cost will continue to decrease slowly with improvements in fuel element fabrication costs and irradiation time, even in a reactor already built; until eventually maintenance costs rise to end its useful life. One is dealing with a period of perhaps thirty years from the time of initial planning, during the last twenty-five of which the cost will be varying from a high initial level to a lower limit due to fuel cycle improvements. Thus for nuclear power plants completed in 1965, to be compared with conventional plants for the same period, one should really compare an average cost of the nuclear plant over its whole life with the average cost of a conventional plant on the same basis. When costs are quoted this is usually what is actually meant; this is the procedure adopted in the following calculations. In Fig. B, the average cost over the life of the plant is plotted against the actual startup date of the plant. This is especially significant when allowance is made for the rising cost of conventional fuels and the expected fall of nuclear fuel costs over the life of both types.

Performance data and estimates for the cost of electricity generated are tabulated below for three specific power projects, which are representative of the reactor types now ready for commercial application—PWR, BWR and PIPPA. These tables are based on the best available published information. The greatest uncertainties in the next 2 or 3 years center on initial plant construction costs and fuel burn-up; the published figures used represent the objectives of the plant designers, though the first reactor or the first set of fuel elements may not reach these goals.

The estimates do *not* apply to small plants, which have higher investment costs per kW and much higher power costs.

Reactor Characteristics

	PWR (*a*) (Yankee)	BWR (*b*) (Dresden)	PIPPA (*c*) (Hunterston)
	—	—	—
Rated total thermal power (MW)	480	627	530
Gross electricity output (eMW)	143	192	168
Net electricity capacity (eMW)	134	180	150
Overall thermal efficiency (%)	27.9	28.7	28.4
Steam pressure (psia)..................	36.56	67.85/33.4	41.48/11.25
Specific power (MW heat/tonne U)	19.7	11.5	2.1
Fuel in reactor (tonnes U)	24.4	54.5	251
Total fuel inventory (tonnes U) (*e*)	51	82	310
U-235 assay of fresh fuel (kg/tonne U) .	26.0	15.0	7.1
Fuel exposure (MWD/tonne) (*f*)........	8,000	10,000	3,000
U-235 assay of spent fuel (kg/tonne U) .	19.0	5.5	4.4
Load factor (%) (*g*)	80	80	80
Fuel throughput (tonnes U/year)	17.5	18.3	51.5
Total plutonium production (kg/year) ..	85	100	93
Fuel form...........................	Stainless Tube UO_2	Zirconium Tube OU_2	Magnesium Cam U metal
Capital cost of plant ($ m.) (*h*)	39.2	45.0	52.5
Interest during construction ($ m.).....	5.9	6.8	7.9
Total capital cost ($ m.)	45.1	51.8	60.4
Specific capital cost ($/kW)	340	290	400

NOTES

(*a*) See A.S.M.E. Paper No. 56-A-166- 'The Yankee Atomic Electric Plant' (capital cost adjusted on basis of private communication).

(*b*) See A.S.M.E. Paper No. 56-A-169- 'The Dresden Nuclear Power Station'.

(*c*) See Nuclear Engineering, February 1957. (Figures are for half of a two-reactor station).

(*d*) Dual steam cycles.

(*e*) Inventory allows 18 months out-of-pile for PWR and BWR; but 14 months for PIPPA, because the latter will feed and discharge fuel continuously.

(*f*) The fuel burn-up limits shown are the designer's estimate of average burn-ups that appear achievable for the fuel considered during the steady operation of the plant. These limits are set by one or more of the problems of irradiation damage, corrosion or reactivity. From an irradiation damage standpoint the present state of knowledge is based on limited results from successful experiments wherein uranium metal samples have been exposed to over 3,000 MWD/T and uranium oxide samples to over 10,000 MWD/T, but in both cases the number of samples has been too small to establish the incidence of fuel element failure. Good statistical data will, in fact, not be established until several reactors have been in operation for an appreciable period of time. Corrosion does not appear to be limiting in any of the three designs shown. Reactivity is not limiting in any of the three designs at the burn-ups shown; it becomes limiting in the PIPPA case without enrichment around 3,500 MWD/T.

(*g*) The assumption of 80% load-factor may surprise those familiar with the utilization generally experienced with conventional plant; but careful consideration in conjunction with the experts we have consulted has satisfied us that nuclear stations will realize very high load-factors. Experience with existing reactors indicates a physical availability of well over 90%; and when allowance is made for despatching shut-downs, at times when hydro-spillage or other surplus power having very low incremental costs may absorb the whole of the load within reach, we believe that 80% is a realistic average load-factor to allow for nuclear stations.

(*h*) Plant cost excludes research and development, off-site civil works (such as approach roads), purchase of land and interest during construction (shown separately).

Estimated Cost of Electricity

(*in mills per kilowatt-hour*)

	PWR	BWR	PIPPA
Fuel costs:	—	—	—
Uranium in fresh fuel (*a*)	5.8	2.1	2.0
Fuel fabrication (*b*)	1.1	1.7	0.4
Chemical reprocessing (*c*)	0.4	0.3	0.3
Plutonium credit (*d*)	—0.9	—0.8	—1.0
Uranium credit (*e*)	—3.7	(—0.3)	(—0.3)
Net fuel cost	2.7 (*f*)	3.3 (*f*)	1.7
Other operating costs (*g*)	1.0	1.0	1.0
Fuel inventory charges (*h*)	1.3 (*f*)	0.8 (*f*)	0.7
Capital charges (*i*)	6.3	5.4	7.4
Total cost of electricity	11.3	10.5	10.8
Total plus 25% contingency (*j*)	14.1	13.1	13.6
Cost range	11.3—14.1	10.5—13.1	10.8—13.6

NOTES

(*a*) Uranium costs in fresh fuel are based on the schedule of charges for enriched material announced by the U.S. A.E.C. on the 18th November 1956, and on the price for natural uranium metal of $ 40/kg announced 8th August 1955.

(*b*) Fabrication costs for PWR stainless steel elements $ 60/kg U, and for BWR zirconium elements $ 115/kg U, including the cost of conversion of UF_6 to UO_2 and scrap recovery, and allowing all operation and overhead charges for fuel fabrication plant on a production basis. In the case of PIPPA, a charge of $ 9/kgu is allowed for fabrication from metal, being the difference between the price of $ 17,500/tonne for fuel elements quoted by the U.K. A.E.A. and the cost of the uranium at $ 40/kg. The price of $ 20,000/tonne often quoted in this connection is the U.K. A.E.A.'s estimate of a long-term maximum value, including allowance for possible increases in the cost of uranium metal and of improved canning materials and fabrication of fuel elements.

(*c*) The cost of recovery from PWR and BWR irradiated fuel of plutonium and uranium in the form of nitrate is based on the charge of $ 15,300/day announced by the U.S. A.E.C. on 18th February 1957 for a 1 ton/day plant. These charges assume a plant capacity of 300 tonnes/year and include waste disposal, but not transport (shipment to the U.S. for processing would cost about 0.2 mills/kWh). In the case of PIPPA the U.K. A.E.A. estimate of £ 2,500/tonne for a plant to process 2,000 tonnes/year of Magnox-clad elements is assumed.

(*d*) The plutonium recovered from PWR and BWR fuel elements is credited at the price of $ 12/gm metal announced by the U.S. A.E.C. on 18th November 1956, less the official charge of $ 1.50/gm for conversion of nitrate to metal. For PIPPA the U.K. A.E.A. value of £ 5,000/tonne plus £ 2,500/tonne for reprocessing is assumed; this gives $ 11.70/gm for nitrate.

(*e*) The uranium recovered is credited according to the U.S. A.E.C. schedule announced 18th November 1956 in the case of PWR. The bracketed credits for BWR and PIPPA are not allowed in the net fuel cost, because they are calculated by linear extrapolation of the published schedule below natural uranium concentration. In all cases, an estimated charge of $ 3/kg U for conversion from nitrate to UF_6 is deducted.

(*f*) This difference of fuel costs and inventory charges is a consequence of fuel element design, not of differences between the two reactor types.

(*g*) Operating costs assume $ 7/kW-year for operation, maintenance and stores in all cases, giving 1.0 mills/kWh at 80% load-factor.

(*h*) Fuel inventory is charged at 8% on the actual value of the fuel throughout its cycle, including fabrication, transport, storage, in pile, cooling, transport and processing.

(*i*) Capital charges of 13% are assumed as an average representative of conditions in the six countries, covering interest and depreciation (over 15 years) and overheads, but excluding taxes and special nuclear risk insurance. (Provisional U.S. domestic rates for special nuclear insurance would come to about 0.2 mills/kWh, subject to revision based on experience at the end of ten years).

(*j*) For contingency, see para. 5 below.

5. The many variables which must be adopted in such calculations of nuclear power costs are often lost sight of, leaving only the final figure in mind. To guard against this danger, a *contingency of 25%* has been added to the above estimates of costs, which have been calculated on the basis of what appears to be reasonably achievable as average costs during the life of plants brought into service early in the 1960's, and the costs then shown as a range. This contingency serves to emphasize the actual uncertainties inherent in cost estimates made at this time, and it may be interpreted to include all adverse elements which might combine to raise costs. For example, the 25% figure allowed would cover at the same time a rise of 50% on operation, 25% on fabrication and processing, 15% on plant investment (and insurance) *and* a reduction of irradiation by 25%, all together. These factors are unlikely all to go in the unfavorable direction, particularly in view of improvements in fuel cycle costs.

6. On the other hand, these cost estimates take no credit for sources of economy which cannot yet be expressed in definite figures. The first commercial designs are necessarily conservative. Already the next units will probably incorporate refinements and simplifications and re-optimization may increase capacity (estimated at about 40% in the case of PIPPA); so the cost per kW should be reduced significantly in the near future for these reasons.

The estimates are based on a one-reactor station (half of two-reactor station in the case of PIPPA); but nuclear stations consisting of several reactors of fully 200 MW net electric capacity each should reduce cost per kW substantially.

Plant and erection costs are about 20% lower in some of our countries than in the U.S. and U.K. The nuclear common market provided by the Euratom Treaty will promote specialization, and there will be great scope for standardization and bulk ordering in a big coordinated programme comprising a number of identical reactors of each type.

Large common plants to fabricate and process fuel elements would keep the costs of these operations at a minimum. If nuclear fuels could be supplied at the U.S. domestic use charge (4%), fuel inventory charges would be reduced by 0.2 to 0.5 mills/kW depending on the reactor type.

In countries like ours where conventional fuel costs are high, combining PWR/BWR steam generators with conventional fuel-fired superheaters offers very low incremental costs and fuel consumption reducing nuclear costs indirectly.

7. In addition to these factors, which will tend to reduce the range of power costs of nuclear plants built in Europe during the next ten years below that estimated in para. 4 above, it is generally recognized that these reactor types all offer scope for major improvements of plant design and fuel cycle economy during this period. Furthermore, the heavy water and enriched PIPPA systems may begin to play an important part in European conditions from about 1965 onwards, and by the early 1970's some of the more advanced types may be expected to come into commercial use. Taken together, these developments may realize a downward trend(1) of nuclear power costs of the sort illustrated in Fig. B.

Comparison with Conventional Power Costs.

8. The competitive status of nuclear power is defined by comparison with the costs of new hard-coal and oil stations which it would replace. Despite considerable current cost varitions, this comparison for future plants to be built in the six countries can be made on a common basis, because nuclear costs will be practically the same in all locations. Moreover, conventional costs can be calculated on the following generalized assumptions:

a) All of the fuel for new coal/oil stations will have to be imported in all six countries, so the present *delivered* price of imported fuel oil of *$ 20/ton* of equivalent coal can be adopted as a representative average (see Annex I, para. 11). The price delivered to sites near ports may in some cases be as low as $18/ton, rising to a maximum of $22/ton at sites far inland.

b) The *net* efficiency of big coal/oil stations built in Europe during the next few years is likely to be around 33% over the life of these plants (2,657 kWh/ton of equivalent coal)(2), giving a unit fuel cost of $20.00/2,675 = 7.50 mills/kWh, which must be increased to about *7.7 mills/kWh* to cover coal and ash handling charges or equivalent costs associated with sulphur and vanadium in the case of heavy oil. The corresponding minimum/

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(1) See Davis and Roddis 'The Latest Prospects for Economic Nuclear Power' NICB Conference, Philadelphia, March 14th, 1957; and Hinton 'The Future for Nuclear Power', Axel Johnson Lecture, Stockholm, March 15th, 1957.

(2) Certain plants will undoubtedly achieve higher net test efficiencies than 33% in this period, but when allowance is made for the whole range of plants built (including many small extensions), and for some fall-of of efficiency over the life of each plant as it operates at lower load-factors and gradually wears out, 33% is considered to be a realistic average value.

maximum range is 7.0 to 8.4 mills/kWh. The upward trend of imported fuel prices (relative to the general price level) must be expected to raise these costs by something like one mill per kWh by 1975 despite a further improvement in thermal efficiency. Taxes are not included.

c) The capital cost of coal/oil plant varies in the six countries from \$120/kWh to \$170/kW (on a net capacity basis, including all charges except interest during construction and taxes). However, if we take into account the fact that in some of our countries high interest rates are partly compensated by lower installation costs, it is permissible to adopt a single representative figure of *13%* annual charges for interest depreciation and overheads, and \$ 140/kW for capital cost, which must be increased by 15% to *\$ 160/kW* to include interest during construction. This gives an annual cost of \$ 21/kW-year (on a net 'sent-out' basis).

d) Maintenance and operation costs apart from fuel will not be less than \$ 4/kW-year for big new base-load plants (1).

This gives the following comparison with the nuclear estimates, expressed in terms of fixed costs and fuel costs (2):

Coal/oil \$ 25.00/kW-year + 7.0 to 8.4 mills/kWh (depending on location).

PWR	: \$ 60.00/kW-year + 2.7 mills/kWh	Plus a contingency of up to 25%
BWR	: \$ 50.00/kW-year + 3.3 mills/kWh	
PIPPA	: \$ 63.50/kW-year + 1.7 mills/kWh	

At 80% load-factor (i.e. 7000 hours/year) (3), this gives conventional power costs of *10.6 to 12 mills/kWh*, compared with *11 to 14 mills/kWh* for the first nuclear plants. In practice, the very low fuel costs of nuclear plant will keep them near the top of load despatching schedules through most of their useful life, whereas coal/oil plants with fuel costs of 7 to 9 mills/kWh will move down the load schedule as they get older, raising their costs as their load-factor falls and the cost of traditional fuels rises.

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(1) See I.C.A. report 'Economic Aspects of Electric Power Production in Selected Countries"–July 1955–page 21.

(2) The fixed costs for nuclear plants expressed as \$/kW-year can be derived from the 'Estimated Cost of Electricity' table by multiplying all unit costs except those for fuel by 7000 hours/year (80% load-factor).

(3) At 70% load-factor conventional power costs would be 0.5 mills/kWh higher, and nuclear costs about 1.0 mills/kWh higher.

Extra Capital Requirements and Obsolescence.

9. The investment required in nuclear plants on the basis given in para. 4 above may be compared with that for conventional thermal plants as follows (in \$/kW):

	PWR	BWR	PIPPA
Capital for nuclear plant (including interest during construction and fuel inventory)	450	360	460
Less capital for conventional plant (including interest during construction)	— 160	— 160	— 160
Extra nuclear investment	290	200	300
Less uranium fuel inventory (actual value through fuel cycle including fabrication costs) (1)	— 110	— 70	— 60
Extra nuclear investment excluding fuel	180	130	240

In subsequent calculations it is assumed that half of the reactors built will be of the PIPPA type and half PWR/BWR, which gives an average plant cost of about \$ 350/kW and a fuel inventory of \$ 75/kW (of which about \$ 25/kW is fabrication cost).

The rapid improvement foreseen for nuclear reactors might be supposed to make plants built at high costs in the first years obsolete before they 'wear out'. In fact this will not happen, because even the first reactors will have operation, fuel and inventory charges (which are the *terminable* costs) of only 3.5 to 5.0 mills/kWh, and these costs will fall over the plant's life as the fuel cycle is improved. So the total cost of future nuclear plants would have to be reduced by more than 50% before it would pay to shut down an early unit to replace it by a new one. This would not happen within the 15 year life allowed in the 13% capital charges assumed. So the first nuclear plants will continue to be operated, at the high load-factor which its low and falling incremental costs allow, until its maintenance costs and outage rise on account of phycisal age to the point where its *terminable* costs justify replacement by a new plant. This involves no assumptions about the future except that new plants built before 1975 will not realize total costs below 3.5 to 5.0 mills/kWh. By contrast, the high and rising

(1) Calculated from data given in 'Estimated Cost of Electricity' table, p. 68.

terminable costs of conventional thermal stations (8 to 10 mills/kWh) will tend to relegate them prematurely to peak-load and reserve duty.

Nuclear Fuel Problems.

10. It is apparent from the table given in para. 4 that the net cost of uranium is practically the same for all three reactor types (2.1 mills/kWh for PWR and BWR, and 2.0 mills/kWh for PIPPA). But nuclear fuels raise problems of supply as well as of cost, because the U.S. government is the only economic source of enriched uranium; such enrichment is essential for some reactors and desirable for most others.

Setting aside the advanced systems, the fuel cycles of reactors suitable for application during the next 10 years are all basically alike except that the moderator and fertile material employed demand different general levels of concentration of fissile material.

Operation at a higher level of enrichment costs more per gram of U-235 consumed, and for inventory charges. But this is generally offset by higher utilization of the fuel, burning Pu-239 generated to a greater extent, and reducing the incidence of fuel fabrication and processing costs. It also has significant effects on the materials that can be used (e.g. stainless steel is half the cost of zirconium today), and on reactor rating and efficiency.

Having selected a given reactor type, it is therefore most important that the designer should be free to optimize the concentration of his fresh and spent fuel; and in all likely cases this will involve a fuel feed from a diffusion plant to provide a concentration above that of natural uranium, at least until the heavy water reactor is available *or* recovered plutonium can be used as an economic alternative source of re-enrichment of depleted uranium, so reducing the natural uranium feed. It will also generally pay to return the uranium recovered from irradiated elements to a diffusion plant, except insofar as core design calls for a proportion of depleted fuel, or if the U-235 content is below the economic rejection level.

11. The six countries must envisage the possibility of building a low enrichment diffusion plant for this purpose. However, for the reasons given in para. 13 below, future requirements for U-235 are far from certain. In these circumstances, it is extremely advantageous to be able to get U-235 from the American plants at the very favourable terms announced by the A.E.C. on 18th November 1956, and so to avoid the high investment and electricity consumption of a diffusion plant until its necessity is clearly established. It is understood that the A.E.C. prices are firmly based on actual costs, including amortization of total capital investment. But they are probably between one-third and one-half of those which a first plant built elsewhere could achieve, on account of the vast scale of the American plants, the extremely low power costs (4 mills/kWh), normal U.S. government finance rates, and perhaps most of all on account of the very highly developed design and technology. There is, therefore, no basis for apprehension about the employment of enriched fuel on the ground that the A.E.G.prices are subsidized and therefore exert an artificial and unreliable effect on design.

12. It will always pay to process spent fuel, even if its uranium is too depleted to feed back to a diffusion plant, because the credit from its plutonium content—assuming that the present valuation is justified by development of economic means to re-use it—in all cases exceeds the cost of processing, by the equivalent of 0.6—0.8 mills/kWh. Moreover, it will pay to do this in Europe. Shipment of shielded spent elements to the U.S. or U.K. would cost about 0.2 mills/kWh, whereas the transport cost of processed material which no longer needs shielding is negligible. The optimum size of a chemical processing plant, on a throughput basis, is many times larger than that of a single reactor, so one plant can serve many reactors. An economic throughput for a Euratom processing plant will be reached when about one tonne a day of irradiated fuel is being discharged from the reactors. On the basis of recent U.S. and U.K. estimates the cost of such a plant will be about $ 20 million. The capacity of this plant could be doubled, in due course, at an additional capital cost of about $ 10 million; this would reduce the unit processing cost by 20% or more. By the time 15 million kW is in service, the processing load (assuming 50% PWR/BWR and 50% PIPPA reactors) will be about 10 tonnes a day. It is expected that there will be substantial further reductions in processing costs as additional larger facilities are provided to handle this load. Lower construction costs in Europe and substantial technical developments in the field of fuel processing also will contribute to the lowering of these costs.

A problem associated with all chemical separation plants is the handling and disposal of large amounts of radio-active wastes. A safe and yet economic solution to this problem is an essential part of a power reactor programme. Safe techniques have been developed for storing and disposing of wastes in the course of military plutonium recovery. The experts expect cheaper methods for disposal of large quantities of radio-active wastes to be developed successfully. The possible recovery and use of radio-active fission products, which are now produced on a limited scale but are in increasing demand for use by industry, may in the future produce some additional revenue.

13. Reverting to the question of fuel supply, there are several possibilities of reducing future requirements which could make extremely important contributions to Europe's needs after about 1965:

a) The heavy water system not only requires less than half of the PIPPA reactor's annual make-up of natural uranium, but it is probably the most economic way to use uranium below natural concentration.

b) There is a possibility for a big coordinated programme to cascade uranium from higher enrichment level reactors, via medium level, and on the heavy-water plants. This would avoid the cost of multiple conversions from nitrate to UF_6 and back to oxide or metal, and would reject the uranium finally with a very low U-235 content. As a consequence, higher charges for interest and for shipment to the U.S. for reprocessing would also be avoided.

c) When methods for remote fabrication of plutonium at reasonable cost have been developed, it will replace fresh fuel make-up almost in proportion to its Pu-239 content. At the same time it would permit operation of reactors at an enriched level without any uranium enriched in U-235, and with reduced natural uranium feed.

d) When the equally difficult problem of using U-233 has been solved, the introduction of thorium in place of U-238 will enable some classes of reactors to secure a conversion ratio around unity, which would reduce annual make-up to very small proportions.

Location of Nuclear Plants.

14. The insignificance of fuel transport costs will permit nuclear plant location generally to be optimized more fully than in the case of conventional thermal stations with respect to the geographical distribution of electricity loads and of the transmission net-work and other sources of supply. The choice of particular nuclear sites within the general locations so defined does, however, raise certain problems. In particular, reactors involve very heavy concentrated loads which impose limitations on foundation conditions. And they require about 50% more cooling water than conventional plants (1). Also, shipment of irradiated fuel to reprocessing plant in heavy lead containers requires good rail facilities, even though the tonnages are small.

However, the most important single factor in the choice of nuclear sites in the first years is likely to be safety. A serious reactor accident is a remotely improbable event (2), but dissemination of the radio-active material contained in a big power reactor over a wide area would have catastrophic effects if it did occur. The tendency to provide for exclusion areas and/or containment vessels, and to locate plants some distance from built-up areas, is therefore natural enough in view of our present lack of experience. The two experimental reactors which have so far got out of control in the course of risky experiments caused serious damage to equipment and protracted shutdowns, but neither personnel nor surroundings were affected.

U.K. authorities regard the present PIPPA design to be inherently safe on account of its low specific rating and the high thermal capacity of the system and, therefore, not to require a containment vessel. The first stations of this type are, however, not being sited in the immediate vicinity of large built-up areas.

U.S. authorities regard the PWR and BWR reactors to be inherently safe, particularly on account of their very high negative temperature coefficients. Present practice in the U.S. is nevertheless to use containment shells for all power reactors, except those built in isolated areas. Cost of $ 10 to $ 15 per kilowatt of installed capacity are included for this purpose in the estimates for the PWR and BWR.

No established policy exists in Europe for power reactors. In France, two gas-cooled power reactors at Marcoule (G-2 and G-3) will not have containment, whereas one gas-cooled unit located at Chinon (EDF-1) will be in a containment shell.

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(1) 28% not nuclear efficiency involves rejection of about 67% of the heat generated, compared with about 52% from a conventional plant of 33% net efficiency.

(2) See 'Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Plants' US AEC March 1957; and statements by US AEC Chairman I.L. Strauss and by H. L. Price in hearings before the U.S. Congressional Joint Committee on Atomic Energy on insurance and indemnity legislation on March 25, 1957.

ANNEX III

SCOPE FOR NUCLEAR POWER

1. Production of base-load electricity in big central power stations is the only application of nuclear power that can make an important contribution to the limitation of energy imports during the 10-year period with which this Report is primarily concerned. Urban district heating schemes may employ nuclear reactors in special cases, but extensive application for steam-raising or process-heating in industry is unlikely before 1970, because small reactors will have power costs much higher than large ones for a number of years. Nuclear-driven super-tankers may well be another important secondary development.

It is therefore essential to determine the amount of nuclear power which the electricity systems of the six countries would be able to accommodate. To this end, the projections of requirements and production by different types of power plant given in Annex IV have been prepared in consultation with authorities in each of the six countries. The total figures for the six countries are as follows (1):

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(1) Statistics for capacity are given in all countries at the end of each year, whereas output is given for the calendar year. However, for the present Report, we have found it more convenient to give both capacity and output figures on an end-of-year basis (with output figures corrected for seasonal variations).

	1955	1960	1965	1970	1975
	—	—	—	—	—
Net Capacity (eMW):					
Hydro-electric	19 443	23 800	30 040	36 030	43 230
Blast furnace gas	1 514	1 850	2 130	2 450	2 800
Lignite	3 678	5 000	7 500	9 700	12 000
Other thermal (1)	26 251	37 900	52 800	73 400	96 500
Total	50 886	68 550	92 470	121 580	154 530
Net Output (TWh/year):					
Hydro-electric	73	86	107	124	139
Blast furnace gas	8	9	11	13	15
Lignite	20	30	45	58	72
Other thermal (1)	90	141	208	302	410
Total	191	266	371	497	636
Fuel Consumption (Mt HCE/year):					
Other thermal	48	70	93	130	164

(1) This item includes pit-head power plants and cooperative stations of the mining industry which are based largely on low-grade coal. At the end of 1955 their net capacity amounted to 4 970 eMW and their output 25 TWh (see Annex I, para. 7 and Annex IV, para. 4).

2. In the present energy situation, it is clear that hydro-electricity must be exploited to the limit of its capacity, and the above figures represent maximum programmes in all countries. Likewise, the maximum possible expansion of lignite production will be devoted wholly to power production, for which it is particularly well suited economically. And the surplus of gas from blast furnaces has to be used on the spot in power stations. So it is the output required from 'other thermal' power stations —which will according to the above estimates have to provide 72% of the total rise of electricity from 1955 to 1975—that can be satisfied to a greater or lesser extent by nuclear power built instead of hard-coal and oil plant. The following table gives more detailed figures for this category for the period considered in the Report (the figures are for the end of each year):

End of year	*Capacity* (eMW)	*Load-factor* (hours/year)	*Output* (TWh/year)	*Fuel consumption* (gm/kWh)	(Mt HCE/year)
1960	37 900	3 720	141	500	70
1961	40 550	3 775	153	490	75
1962	43 300	3 820	166	480	80
1963	46 250	3 865	179	470	84
1964	49 400	3 905	193	460	88
1965	52 800	3 940	208	450	94
1966	56 500	3 980	225	440	99
1967	60 450	4 015	243	430	104

Scope for Nuclear Power.

3. The capacity of 'other thermal' plant which must be brought into service each year to meet these requirements is plotted in Fig. E. This defines the amount of nuclear power which could be accommodated within the electricity system of the six countries in these years, quite apart from technical and economic limits on the rate of construction achievable in practice.

Fig. E also includes a rough estimate of the further requirement for new capacity to replace old plants which will be taken out of service each year. It would be unrealistic to include this replacement plant in the 'scope' for nuclear power in the ten-year period with which we are concerned. Moreover, after 1967 there will be a limit on the *output* as well as on the capacity of nuclear plants, because it will pay to operate them at very high load-factors. For this reason, it is unlikely that as much as half of the 'other thermal' capacity required by 1975 (estimated to be 96,500 eMW) could be nuclear (1). At that level, nuclear plant would already be producing over 80% of the output needed from this category of power plants, if they were operating 7 000 hours a year. It will probably be essential to install an increasing proportion of specialized reserve and peak-load capacity in conjunction with a big nuclear programme—including additions to existing

(1) The output estimated to be required from other thermal plants at the end of 1975 is 410 TWh. If half of this capacity were nuclear (48,250 eMW), it would produce 338 TWh at 7 000 hours/year utilization, leaving only 72 TWh to be provided by the other half. If all of the low-grade coal output at that date (31 Mt HCE/year) were used to make electricity at a specific consumption of 400 gm/kWh, it alone would produce the whole of this balance.

storage hydro-plants, pumped storage, oil-fired Velox boilers and gas turbines. It will probably also pay at this stage to keep old thermal stations in reserve service longer, and to extend transmission grid links to provide the equivalent of extra reserve capacity, rather than reduce the utilization of nuclear plants.

This also means that the utilization of coal and oil stations built in the next ten years will fall steeply when nuclear capacity becomes a big proportion of the total, because their fuel costs will be high (and rising) by comparison with nuclear fuel costs (which are expected to fall).

The 15 million kW Target.

4. Within these limits imposed by electricity requirements and supplies, allowance must be made not only for the four years required to plan and build power stations, but also for the time required to organize a great new venture still confronting many unknowns, for physical bottlenecks, and for delays which are unavoidable when action depends on the aggregation of many individual decisions by public and private electricity organizations. This means that, even on a maximum programme, the rate at which nuclear capacity could be brought into service must be expected to rise progressively from a gradual start in 1960–61 when the first power reactor projects already started may come into service, and then to rise more slowly after 1965 as the limits defined in para. 3 above are approached. The form this build-up might take is illustrated in Fig. E.

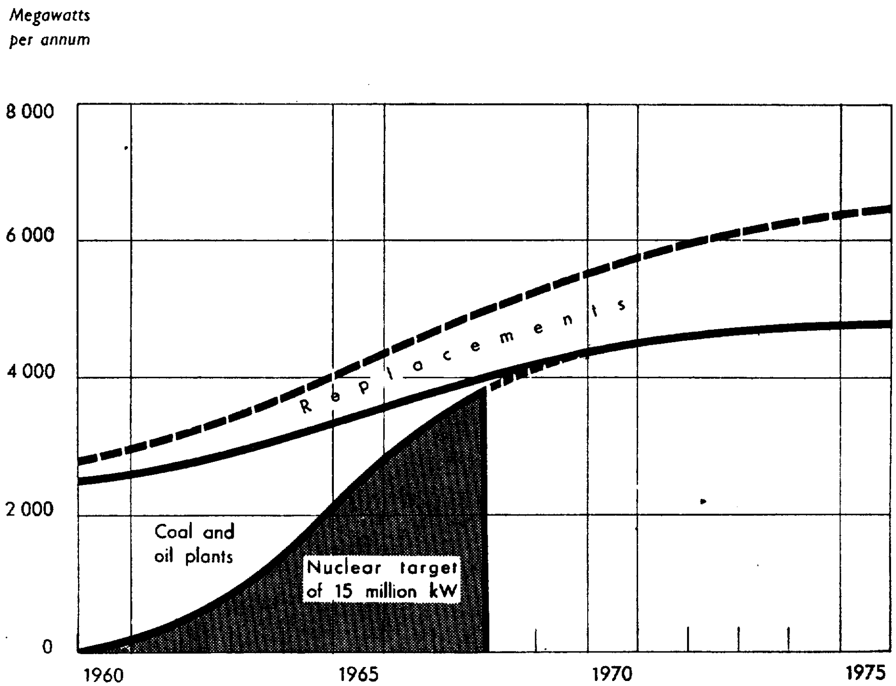
This rate of nuclear expansion, which is a practical maximum, would involve the installation of 15 million kW of nuclear plant by the end of 1967. This has been adopted as a target for Euratom, in order to stabilize our energy imports at the earliest possible date.

This target would release 40-45 million tons of coal equivalent a year by 1967-68, when net imports in the absence of nuclear energy would reach 205-210 million tons a year. This would level imports out at about 165 million tons a year, the point which would otherwise be reached in 1963, six years from now. If nuclear construction continued thereafter in the way suggested by Fig. E, the fuel saved might reach 125 million tons a year by 1975. On the basis of estimates given in Annex I, this would be sufficient to hold energy imports at the 165 million tons level in the later period.

FIGURE E

Capacity of thermal electricity plant brought into service each year

(excluding lignite and gas stations)



5. The amount of low-grade coal expected to be available for consumption by pit-head power stations by 1967 is about 28 million tons a year (1). As the following approximate figures show, there would still be ample scope for this material, even if all of it were used for electricity production (all figures refer to the *end* of each year):

	End of 1960	End of 1965 *Mt HCE/year*	End of 1970
Net energy imports of six countries:			
a) Without nuclear power	136	187	207
b) With nuclear power	136	164	164
Fuel released by nuclear plant	0	23	43
Fuel burnt in conventional plants (2)	70	70	61

(1) Cf. Annex I, para. 7.

(2) Cf. Annex IV, final summary table.

Comparison with the British Programme.

6. The United Kingdom is the first country that has launched a comprehensive nuclear power programme. Its similarity with the target proposed for Euratom is encouraging, and the differences between the two cases are significant.

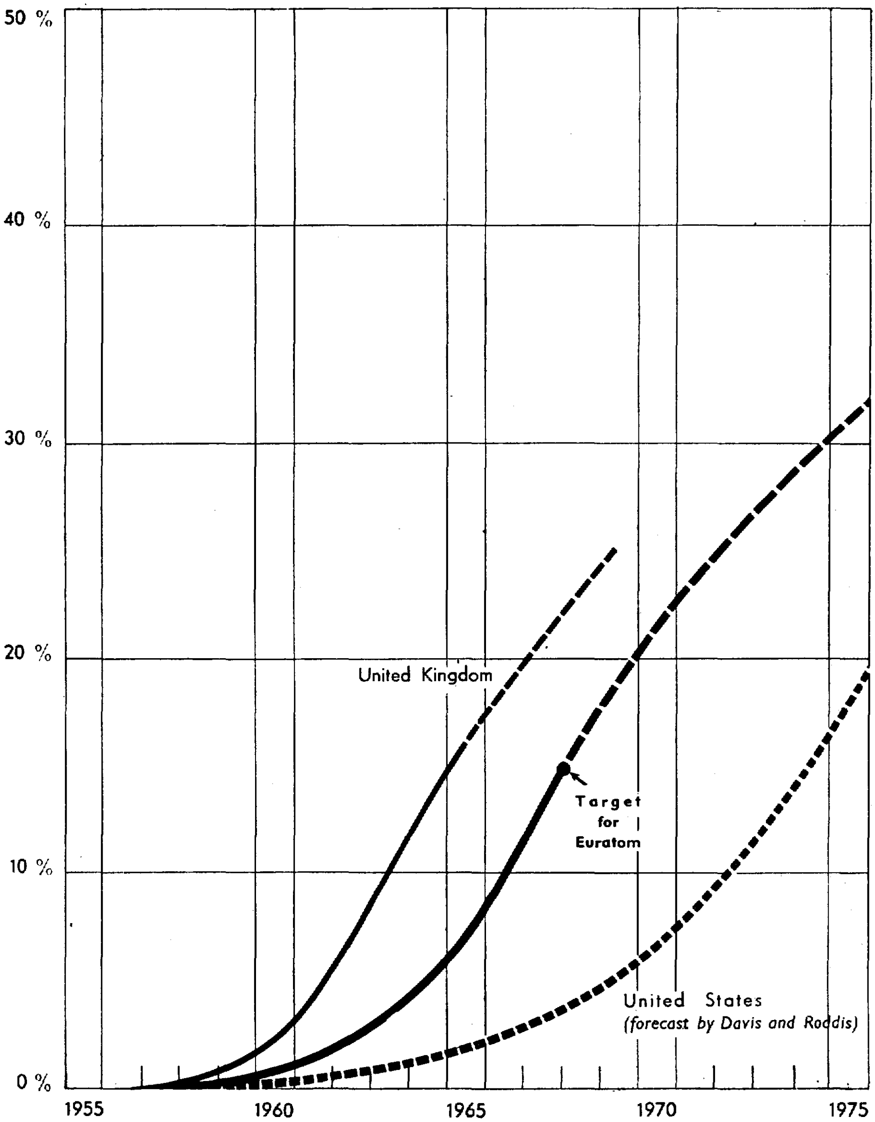
The programme first announced two years ago aimed to complete 1 500 to 2 000 eMW of nuclear plant in the 10 years to the end of 1965, and several industrial groups were formed at that time to design commercial versions of the prototype Calder Hall reactor. These designs so increased unit reactor capacity and strenghtened confidence in the general approach that the Government has recently decided to increase the programme to between 5 000 and *6 000 eMW* by the end of 1965. Further considerable increases of reactor rating are anticipated. 6 000 eMW is 15% of estimated system capacity in Great Britain at that date, corresponding to 15 million kW for the six countries at the end of 1967 (see Fig. F). This will enable British energy imports to be stabilized at their 1960 level (45 million tons a year of coal equivalent), compared with leveling-out at 165 million tons —in the 1963 level—for the six countries. In terms of electricity 30% of total U.K. output will be from nuclear stations by 1965, and the whole increase of output from 1960 will be met by nuclear power. The Euratom programme would not quite reach this point even in 1967, when 15 million nuclear kW would produce 25% of total output.

7. Our late start postpones the benefits, but it at least permits the rapid advances of reactor technology in these years to be exploited. Not being tied to a single reactor type in these conditions offers an important measure of protection in the first years before the best approaches can be clearly identified. In particular, access to American U-235 will realize the very considerable advantages of enrichment. Also, the fact that about a third of total capacity in the six countries is hydro-electric will make it easier to accommodate a big nuclear base-load than in the United Kingdom. It will permit more of the big proportion of collateral reserve capacity which must be installed in conjunction with nuclear plant to take the most convenient form of additional storage-hydro kilowatts, and in particular, of pumped storage. The necessity for this back-up is recognized in Britain, but the physical possibilities are limited by comparison with the Continent, and this will probably result in a higher load-factor for nuclear plant on the Continent than in the U.K.

FIGURE F

Comparison of nuclear programmes

(as % of total electricity capacity)



Nuclear Fuel Requirements.

8. Nuclear fuel requirements to realize our target of 15 million kW in ten years time can be estimated approximately by assuming for example that it comprises about one-half natural uranium reactors and one-half slightly enriched uranium reactors; and that plutonium and U-235 will not be recycled on an important scale before 1967. Allowances have been made for the time needed to fabricate fuel elements and for the amounts of material in process before, during, and after irradiation.

The quantity of natural uranium required for the total inventory for 7 500 eMW of natural uranium reactor capacity (assumed to be PIPPA type) would be about 15 000 tons. In addition, the total make-up to the end of the ten-year period (including an advance allowance for the following year) would be nearly 9 000 tons, and the make-up needed thereafter for 7 500 eMW of plant would be about 2 500 tons a year. The combined total of inventory and make-up would, therefore, be about 24 000 tons of natural uranium to the end of 1967. At $ 40 per kilogram of uranium metal, this would cost about $ 1 000 million, with an annual fuel make-up cost of about $ 100 million thereafter. During this period, the French and Belgian supplies are expected to increase from 1 200 to 2 500 tons a year and may amount to a total of nearly 15 000 tons. There is every reason to expect that intensive prospecting in the six countries will further increase this output. The costs of the material will, however, be a factor in determining the amount of natural uranium to be imported from other countries.

The quantity of slightly enriched uranium required for total inventory for 7 500 eMW of enriched reactor capacity (assumed to be half PWR and half BWR types) would be about 1 400 tons of uranium containing 2.6% U-235 and 1 700 tons of uranium containing 1.5% U-235. In addition, the total U-235 *consumed* to the end of the ten-year period (including an advance allowance for the following year) would be about 25 tons, and the U-235 consumed thereafter would be about 7 tons a year for 7 500 eMW of plant. The cost of this material (inventory plus consumption), according to the schedule announced by the U.S. A.E.C. on November 18th, 1956, would be approximately $ 1 000 million, with an annual fuel make-up cost of about $ 100 million thereafter.

On the same assumptions, the annual fuel bill when 15 million kW is in service would be approximately as follows:

	$ m./year
Material consumed (burn-up)	200
Fabrication of fuel elements	100
Inventory charge	90
	390
Less plutonium credit after deducting processing cost	— 65
	325

The recovery of plutonium from 15 million kW of such reactors would be about 9 tons a year, equivalent to between 5 and 6 tons of U-235 make-up. Therefore, development of economic means of fabrication for fuel elements containing plutonium would have an extremely important effect on European nuclear fuel requirements, reducing the 7 tons a year of U-235 consumption to a modest level, and facilitating enrichment of PIPPA-type reactors (and possibly even of heavy water reactors of some types).

9. It may be noted that 7 tons of U-235 (in PWR/BWR reactors), or 2 500 tons of natural uranium (in PIPPA reactors), would produce the same amount of electricity as 20 million tons of coal (or equivalent oil); and that in terms of heat content, the U-235 (or natural uranium) costs 17.5 cents/million Btu compared with 71 cents/million Btu for coal at $ 20/ton.

Investment in Nuclear Power.

10. The capital required for 15 million kW of nuclear plant can be approximated (on the same half-natural, half-enriched assumption) from the costs per kW given in para. 9 of Annex II. A conservative average for the first generation of nuclear stations is $ 350/kW, including interest during construction but excluding fuel inventory and taxes, and making no allowance for reductions of plant cost which can be anticipated for a big European programme during the next ten years. This gives a total investment of $ 5 250 million, compared with $ 2 400 million for the same amount of conventional plant at $ 160/kW (including interest during construction). The extra outlay for nuclear plant on this basis is therefore $ 2 850 million. Allowing for the progressive type of expansion illustrated in Fig. E, and for the fact that expenditure spreads over three years prior to coming into service, this excess would build up slowly over the ten years to a peak rate of $ 500-600 million about 1965 (ignoring plants to be commissioned after 1967); this would be 1.5% of estimated gross investment in the six countries in that year.

In addition, a total of some $ 1 100 million would be tied up in the value of nuclear fuel in reactors and other parts of the fuel cycle, including the cost of their fabrication into fuel elements. But this inventory investment is on a different footing from that in the plants themselves, because it represents a non-wasting asset of readily recoverable value; and in sofar as Euratom will be the owner and processor of these fuels, they may well be financed centrally, as is the practice in the U.S. and U.K.

Foreign Exchange Effects.

11. A substantial part of the first reactors built will have to be imported from the U.S. and U.K., including particularly their design and engineering. Enquiries in America and Britain indicated that the 'import content' might be as high as 50% at the start, but that it can be expected to fall to a low level within a few years when the rate of construction is much higher. Over the whole ten years, it is unlikely to exceed 20% of the $ 5 250 million invested, of $ 1 100 million to be paid in foreign exchange, with a peak rate below $ 200 million a year around 1964-65.

In addition about $ 2 000 million worth of nuclear fuels is required for inventory and make-up to the end of 1967, and about $ 200 million a year thereafter for make-up (less the credit for plutonium). The import cost for fuel would be half of these sums if Europe can produce 25 000 tons of natural uranium by 1967-68, assuming half of the reactors installed require enriched fuel from the U.S. If the latter were financed abroad, the foreign exchange bill for fuel would be less than $ 600 million in the first ten years, and perhaps $ 125 million a year thereafter, subject to reductions by the sale or use of plutonium (worth $ 65 million a year after 1967).

If 15 million nuclear kW is in service by 1967, the saving on the foreign exchange bill for imports of conventional fuels would exceed $ 2 500 million by that date, with an annual saving of $ 850 million thereafter, apart from the effect of further extensions of nuclear capacity. So, after incurring a debit of some hundred millions of dollars in total prior to 1965, as the unavoidable price to make a quick start possible, the *net* saving would rise rapidly to $ 600-700 million a year by the time 15 million kW of nuclear plant is in service.

ANNEX IV

GROWTH OF ELECTRICITY SYSTEM IN THE EURATOM COUNTRIES

Development Trends and Rates of Expansion.

1. In the last 30 years the production of electricity has expanded at an annual rate of 5 to 6%; it has thus doubled over periods of 12 to 14 years.

Trend of Electricity Production 1925-55

	Annual rate of increase (%)	*Increase in 10 years* (%)
German Federal Republic	6.1	80
Belgium	5.4	69
France	5.0	63
Italy	5.7	73
Netherlands (1935-55)	5.6	72

These rates were affected by the great depression and the war. In the post-war period the rates of increase of electricity production rose, doubling in ten years. Until about 1965 this rate of increase will still be maintained as the general trend, though there may be special circumstances in some countries which in the course even of this decade may diminish this rate somewhat. It is, therefore, not an easy matter to prophesy how the requirements for electricity will develop in the later years of the period we are now considering. It is, however, widely agreed that in twenty years' time requirements will at the least be trebled, and at most quadrupled. For the purpose of the present report we have adopted an estimate which, for the period up to 1975, represents more or less a mean between the triple and quadruple of the 1955 production figures, due allowance being made for special conditions in particular countries. Thus, the average annual rate of increase for the period 1955 to 1965 is estimated at about 7% and for the period 1965 to 1975 at 5.7%. This corresponds to the development trends which have obtained over the last 25 to 35 years.

Net Output of Electricity in the Six Countries (1)

Country	*Production 1955 (TWh)*	*Index figures*			*Production of Electricity (TWh)*	
		1955-65	*1965-75*	*1955-75*	*1965*	*1975*
German Fed. Republic .	74.4	200	175	350	149	260
Belgium	10.9	160	150	250	17	26
France	49.7	200	175	350	100	175
Italy	37.8	190	175	335	72	126
Luxembourg	1.1	150	150	280	2	3
Netherlands...........	10.6	190	175	331	20	35
Total	184.5	195	174	339	360	625

(1) The following definitions and abbreviations are used:

(*a*) Generating plant = publicly-owned power stations, independent industrial generators, pit-head power stations and railway power plants.

(*b*) Capacity = maximum *net* capacity at end of year, calculated at high-tension terminals.

(*c*) Electricity output = *net* delivery of electricity to the grid (exclusive of own consumption and transformer losses).

(*d*) Utilization = computed number of equivalent full-load hours per annum $= \frac{c}{b}$.

(*e*) Load-factor = number of utilized hours per annum as a percentage of 8,760 hours in a year.

(*f*) kW = kilowatt; MW = megawatt = 1000 kW.

(*g*) kWh = kilowatt-hours (= 860 Kcal);
TWh = terrawatt-hours (= 1000 million kWh).

Comparison with Estimates by the High Authority and O.E.E.C.

2. The total figures given above for the six countries agree closely with those given by the High Authority of the Coal and Steel Community in the document 'General Objectives for Coal and Steel' and also in the still unpublished document of its Mixed Committee 'Structure and Trends of Development in the Electricity Industry'. However, estimates for the production in individual countries differ much more on account of use of net instead of gross figures, and assumption in this report of maximum exploitation of hydro and lignite resources.

3. The Organisation for European Economic Cooperation (O.E.E.C.) estimates that in 10 years the output of electrical current will increase at an annual rate of 7%, whereas in the case of the second decade it adopts an optimistic estimate of a 7% rate of increase and a conservative estimate of a 5% rate of increase (1). These rates of growth agree with those adopted in the present Report.

The Role of Pit-head Power Stations.

4. The General Objectives Committee has made estimates for the expansion of pit-head power stations to 1975 on the basis of expected production of low-grade coal (see Annex I, para. 7). This group of power stations includes cooperative plants of the mining industry, which deliver a large part of their output into the public grid; and about one-fourth of the fuel they consume is saleable coal. Furthermore, a part of low-grade coal output is used for purposes other than electricity production, such as air compression at pit-head and gas generation. The high electricity estimates for these stations (given below) are based on the optimistic forecast of coal production, and should therefore be considered as a theoretical maximum.

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(1) *Europe's Growing Needs of Energy*, p. 34

Capacity and Output of Pit-Head Plants

	Year 1955	*1955*	*1960*	*1965*	*1970*	*1975*
		End of year				
	Net capacity (eMW):					
German Fed. Republic	.	2 254	4 495	7 000	10 300	13 300
Belgium	.	641	1 240	1 300	1 400	1 400
France	.	1 790	2 540	2 800	3 000	3 200
Italy	.	—	65	70	70	70
Netherlands	.	283	360	400	400	400
Total	.	4 968	8 700	11 570	15 170	18 370
	Net output (TWh):					
German Fed. Republic	11.1	12.2	23.8	37.0	52.4	68.5
Belgium	1.8	2.0	3.7	4.0	4.4	4.4
France	8.9	9.3	12.9	14.6	15.1	16.1
Italy	—	—	0.3	0.4	0.4	0.4
Netherlands	1.4	1.4	1.8	2.0	2.0	2.0
Total	23.2	24.9	42.5	58.0	74.3	91.4
Total Fuel Consumption (Mt HCE) ..		13.2	21.2	26.1	32.0	36.4

Tables for the Electrical Industry of the Six Countries.

5. The following tables showing the capacity, electricity output and fuel consumption are based on data from government departments, electricity boards or other authoritative sources; where we have made our own estimates, no objections have been raised by the above bodies to the figures utilized here.

The figures for capacity refer to the end of the year. The electricity output for 1955 is shown in brackets. The unbracketed figures of the output for 1955 and following years are adjusted to the end of the year. The data for the fuel consumption of thermal power stations have been taken from the energy balance-sheets of the countries concerned.

German Federal Republic

	Year 1955	1955	1960	1965	1970	1975
		End of year				
	Net capacity (eMW):					
Hydro-power	.	2 858	3 330	3 570	4 000	4 250
Gas-fired	.	412	525	620	690	800
Brown-coal	.	3 678	5 000	7 500	9 700	12 000
Other thermal	.	11 948	15 000	20 860	28 650	38 000
Total	.	18 896	23 855	32 550	43 040	55 050
	Net output (TWh):					
Hydro-power	(11.8)	12.2	14	15	16	17
Gas-fired	(1.9)	2.0	2	2	3	4
Brown-coal	(18.9)	19.5	30	45	58	72
Other thermal	(41.8)	43.2	60	91	126	167
Total	(74.4)	76.9	106	153	203	260
	Fuel consumption of other thermal stations					
Brown-coal power stations (*Mt HCE*)	520	10.1	15	21	26	30
Other thermal power stations (*Mt HCE*)	9.8	22.4	30	41	55	68
Gm (HCE)/kWh	22.5	520	500	470	440	410

Great progress has been made in the Federal Republic in the development of hydro-power stations; development capacity is estimated at 5 500 eMW of which a half will actually be utilized. The economic conditions for the hydraulic power still utilizable are relatively less favourable than for the capacity utilized to date. The slightly declining expectations for a future increase in output are reflected in a fall in the load-factor.

The capacity and output of brown-coal power stations are shown in the table at their maximum potential. The 1975 figures, moreover, should be regarded as representing the absolute upper limit for the exploitation of brown-coal deposits. The load-factor of brown-coal power stations is estimated, in accordance with their status as base-load stations, at 70%.

The capacity and output of power stations operated on blast-furnace gas are estimated in the light of the expected increase in the production of pig iron. As working hours in the iron and steel industry have been reduced, the load-factor of such plants should not rise substantially.

The other thermal power stations are at present almost exclusively coal-fired. The actual fuel consumption of the most up-to-date plants is nowadays about 400 gm/kWh. It is, however, hardly likely that the *average* consumption of all thermal power stations will fall below 400 gm/kWh within the next twenty years.

Belgium

	Year 1955	*1955*	*1960*	*1965*	*1970*	*1975*
		End of year				
		Net capacity (eMW)				
Hydro-power	.	48	72	72	72	72
Gas-fired	.	200	250	270	310	350
Other thermal	.	2 615	3 418	4 258	5 243	6 508
Total	.	2 863	3 740	4 600	5 625	6 930
		Net output (TWh)				
Hydro-power	(0.1)	0.1	0.2	0.2	0.2	0.2
Gas-fired	(1.3)	1.3	1.5	1.7	1.9	2.1
Other thermal	(9.5)	9.8	12.4	16.1	20.0	24.7
Total	(10.9)	11.2	14.1	18.0	22.1	27.0
		Fuel consumption of other thermal stations				
Mt HCE	4.8	5.0	6.0	7.0	8.5	10.0
Gm(HCE)/kWh	510	510	480	460	430	410

The forward estimate of electricity output is based on the assumption of an increase in industrial output of 3.5% per annum (mean figure) (1).

(1) See 'Evaluation de la part relative aux centrales électriques nucléaires dans les futures installations de production d'énergie électrique'; Ministère des Affaires Economiques, Bruxelles, 1956.

Utilization is relatively low at about 3 800 hours/year and in the next 20 years it will rise by 0.5% per annum. The capacity figures take into account peak requirements. The output of power stations operated on blast-furnace gas has been estimated relative to the increase in the output of pig iron.

France

	Year 1955	*1955*	*1960*	*1965*	*1970*	*1975*
		End of year				
		Net capacity (eMW)				
Hydro-power	.	7 548	9 250	13 250	18 100	23 000
Gas-fired	.	700	850	1 000	1 200	1 400
Other thermal	.	6 000	9 600	13 100	19 000	25 600
Total	.	14 248	19 700	27 350	38 300	50 000
		Net output (TWh)				
Hydro-power	(25.6)	26.5	32.0	45.0	58.0	70.0
Gas-fired	(3.6)	3.7	4.5	5.5	6.5	7.5
Other thermal	(20.5)	21.2	36.5	52.5	75.5	102.5
Total	(49.7)	51.4	73.0	103.0	140.0	180.0
		Fuel consumption of other thermal stations				
Mt HCE	12.1	12.5	20	26	35	46
Gm(HCE)/kWh	590	550	550	500	470	450

Only in the case of hydro-power stations has an optimistic estimate been assumed which reckons with the development of practically all of the hydraulic resources still available. France's hydro-power reserves are estimated as follows:

Economically possible production	70 TWh
Actual production	25.5 TWh
Ratio of actually utilized to potential hydro resources	38 %

On the assumption that the overall production of electricity will increase three and a half times from 1955 to 1975, the production of thermal power stations (excluding plants operated on blast-furnace gas) will increase sixfold. The great majority of these power stations are at present fired on coal; only 7% use oil.

Italy

	Year 1955	1955	1960	1965	1970	1975
		End of year				
		Net capacity (eMW)				
Hydro-electricity and geothermal	.	8 988	11 125	13 122	13 835	15 890
Thermal	.	2 118	5 600	7 000	13 000	17 300
Total	.	11 106	16 725	20 122	26 835	33 190
		Net output (TWh)				
Hydro-electricity and geothermal	(32.6)	33.7	40	47	50	52
Thermal	(5.2)	5.4	17	27	52	78
Total	(37.8)	39.1	57	74	102	130
		Fuel consumption of other thermal stations				
Mt HCE	2.2	2.3	7	11	19	28
Gm(HCE)/kWh	430	430	410	390	370	360

More than 80% of the production of electricity is produced by hydro and geothermal power stations. As, however, most of the hydro-power that can be economically developed is already being utilized, the future will see great structural changes in the electrical industry.

Hydro-power available for economic development	50	TWh
Electricity produced in 1955	30.80	TWh
Ratio of utilized to available sources	61	%

The hydro-power resources that can still be developed will operate under conditions that are becoming economically less and less favourable; this will be reflected in a tendency to build peak-load plants having lower annual load-factors.

The electricity output attributable to thermal power stations will in future rise to more than 60% of total production, and in the absence of additional domestic fuel supplies, almost all of this increase will probably be imported oil, except insofar as nuclear energy takes its place. Utilization of thermal power stations amounted in 1955 to about 2 500 hours/year. We have assumed that by 1975 it will have risen to 4 500 hours/year.

Luxembourg

	Year 1955	*1955*	*1960*	*1965*	*1970*	*1975*
		End of year				
		Net capacity (eMW)				
Hydro-power		1	16	22	22	22
Gas-fired		202	220	240	250	250
Total		203	236	262	272	272
		Net output (TWh)				
Hydro-power		0.003	0.04	0.07	0.07	0.07
Gas-fired		1.100	1.21	1.32	1.38	1.38
Total		1.103	1.25	1.39	1.45	1.45

Electricity is produced almost exclusively by power stations operating on blast-furnace gas from the iron and steel industry. There are further plans for developing the country's rather small resources in natural water power and longer-term plans also for a power station on the Moselle to be developed along with the canalization of this river.

Netherlands

	Year 1955	*1955*	*1960*	*1965*	*1970*	*1975*
		End of year				
		Net capacity (eMW)				
Thermal power	.	3 570	4 300	6 000	7 500	9 125
		Net output (TWh)				
Thermal power	(10.6)	11.0	15	21	28	37
		Fuel consumption				
Mt HCE	.	5.4	7	9	12	15
Gm(HCE)/kWh	.	490	460	440	420	400

The Netherlands has only thermal power stations, most of them coal-fired.

Totals for Six Countries

	Year 1955	*1955*	*1960*	*1965*	*1970*	*1975*
		End of year				
		Net capacity (eMW)				
Hydro-power	.	19 443	23 793	30 036	36 029	43 234
Gas-fired	.	1 514	1 845	2 130	2 450	2 800
Brown-coal power	.	3 678	5 000	7 500	9 700	12 000
Other thermal	.	26 251	37 918	52 800	73 393	96 533
Total	.	50 886	68 556	92 466	121 572	154 567
		Net output (TWh)				
Hydro-power	(70.2)	72.6	86	107	124	139
Blast-furnace gas	(7.9)	8.1	9	11	13	15
Brown-coal	(18.9)	19.5	30	45	58	72
Other thermal	(87.6)	90.5	141	208	302	410
Total	(184.6)	190.7	266	371	497	636
		Fuel Consumption of other thermal stations				
Mt HCE	46.4	47.6	70	93	130	164
Gm(HCE)/kWh	530	530	500	450	430	400

ANNEX V

I

Terms of Reference of the Committee.

INTERGOVERNMENTAL CONFERENCE
ON THE
COMMON MARKET
AND
EURATOM

Secretariat

Brussels, November 16, 1956

The Heads of Delegations at the Intergovernmental Conference on the Common Market and Euratom, acting on instructions from their respective Ministers of Foreign Affairs, on November 16, 1956, adopted the following resolution:

'The Ministers of Foreign Affairs hereby instruct a Committee consisting of

Monsieur ARMAND, Herr ETZEL and Signor GIORDANI

working within the framework of the Brussels Conference presided over by Monsieur Spaak, to report to them in two months' time on the amount of nuclear energy which can be produced in the near future in the six countries, and the means to be employed for this purpose.

'Accordingly, the Committee is to consult the authorities responsible who are to provide all cooperation necessary for the fulfilment of the Committee's task as regards forecasts of energy requirements and resources and atomic energy programmes projected in each of the countries concerned.

'The Committee is hereby authorized to ask the competent authorities in third countries for all such information as it may require for the fulfilment of its task'.

II

Joint Communiqué by the Department of State, the Chairman of the Atomic Energy Commission and the Euratom Committee.

February 8, 1957

1. A Committee appointed by the Governments of Belgium, France, the Federal Republic of Germany, Italy, Luxembourg and the Netherlands, which are negotiating at Brussels the treaty for a European atomic energy community (Euratom), concluded today its official visit in Washington. The Committee, composed of Mr. Louis ARMAND, Mr. Franz ETZEL and Professor Francesco GIORDANI, called on President Eisenhower, the Secretary of State, and the Chairman of the U.S. Atomic Energy Commission, and held discussions with officials of the Department of State and the Commission.

2. The Committee's task is to determine the extent to which atomic power can meet Europe's growing energy needs. The availability and cost of energy has become a limiting factor on the growth of Europe's economic strength and welfare. The Committee's review of the needs and possibilities has led it to adopt as an objective the stabilization of fuel imports early in the 1960's. To meet this target would require that nuclear power plants with a total generating capacity of 15 000 000 kW be installed within the next ten years.

3. Examination of the Committee's program indicates that its objective is feasible. Under present circumstances, the availability of nuclear fuels is not considered to be a limiting factor. A joint group of experts to be designated by the Committee and the Atomic Energy Commission will continue to examine the technical problems posed by the Committee's objective.

4. The Committee pointed out that the Atomic Energy Community (Euratom) which will result from the present Brussels negotiations provides the framework and the stimulus required to realize the Committee's objective. It would mobilize in Europe the technical and industrial resources required and would provide a political entity competent to afford adequate safeguards and to enter into comprehensive and practical engagements with the U.S. Government.

5. The U.S. Government welcomes the initiative taken in the Committee's proposal for a bold and imaginative application of nuclear energy. On February 22, 1956, President Eisenhower in announcing the allocation of 20 000 kilograms of U-235 for sale or lease outside the U.S. for peaceful purposes (principally power and research reactors) stated, 'significant actions are under way to create an international agency and an integrated community for Western Europe to develop peaceful uses of atomic energy. The United States welcomes this progress and will cooperate with such agencies when they come into existence.' The United States anticipates active association in the achievement of the Committee's objective, and foresees a fruitful two-way exchange of experience and technical development, opening a new area for mutually beneficial action on both the governmental and the industrial level and reinforcing solidarity within Europe and across the Atlantic.

III

Joint Communiqué by the United Kingdom Atomic Energy Authority and the Euratom Committee.

A Committee appointed by the Governments of Belgium, France, the Federal Republic of Germany, Italy, Luxembourg and the Netherlands, which are this month to sign a Treaty instituting a European Atomic Energy Community (Euratom), today concluded its visit to the United Kingdom.

The Committee, composed of Monsieur Louis ARMAND (France), Herr Franz ETZEL (Germany), and Professor Francesco GIORDANI (Italy), called on Lord Salisbury, the Lord President of the Council, and Lord Mills, the Minister of Power, and has held discussions with the Chairmen, Members and officials of the U.K. Atomic Energy Authority and of the Central Electricity Authority.

The Committee also spent a day at the Nuclear Power Plant at Calder Hall and has held discussions with representatives of the industries concerned with the United Kingdom Atomic Energy projects.

The Committee's task is to determine the extent to which atomic power can meet Europe's growing energy needs. The availability and cost of energy has become a limiting factor on the growth of Europe's economic strength and welfare. The Committee's review of the needs and possibilities has led it to adopt as an objective the stabilization of coal and oil imports early in the 1960's.

To meet this target would require that nuclear power plants with a total generating capacity of 15 million kW be installed within the next ten years.

The United Kingdom's dependence upon imported fuels although relatively less great than that of the six nations has led the United Kingdom to develop as quickly as possible the use of atomic energy for power.

The Chairmen and Members of the U.K. Atomic Energy Authority have described the United Kingdom's experiences in this field, which have enabled the United Kingdom to embark on a substantial programme of nuclear power.

The Atomic Energy Authority and the Euratom Committee have held discussion concerning the contribution which the Calder Hall type of reactor could make to the realization of the Committee's target and the assistance which the United Kingdom could give to the execution of such a programme. A group of experts from the Committee and the U.K. Atomic Energy Authority will continue to examine the technical aspects of the Committee's programme.

The U.K. Atomic Energy Authority declared its readiness to facilitate contacts between the United Kingdom firms and firms within the Euratom countries interested in the building of nuclear reactors. The Authority also declared its willingness to give such assistance as lies in its power towards the training of scientists and engineers. Places could be provided in the Authority's Reactor School at Harwell and later on at the Reactor Operation School at Calder Hall.

The Euratom Committee and the U.K. Atomic Energy Authority are convinced that the visit has prepared in a most useful way for cooperation between the U.K. Atomic Energy Authority and the European Atomic Energy Community on their future power programme.