FUEL BALANCE AND ATOMIC ENERGY IN THE USSR

by

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A B S T R A C T

The topic for this study in its present form was suggested to the writer by Dr. Hans Ernest Ronimois, who felt that the problems concerning fuel balance in the USSR are of particular interest at the present time, when the priority allocation pattern is being reorganized to give greater prominence to oil and gas and when a new form of energy, derived from nuclear reactions, is being introduced parallel with the old forms.

In a free market economy the extent to which various types of fuel are used in a given area at any particular time is determined by the demand for them. In the Soviet Union, on the other hand, it is arbitrarily decided by the planners.

In part one the study deals with the priority allocation in the fuel economy of the Soviet Union during the period of War Communism, NEP, and the successive Five Year Plans. Special consideration is given to the recent shift in priority allocation from coal to oil and gas and to the reasons which led to this shift.

Part two is devoted to considerations of atomic energy. The first chapter is an assessment of the resources of conventional fuels in the U.S.A., U.K. and Canada and the atomic programs undertaken in these countries. The rest of part two is devoted to the subject of nuclear research facilities, reactor

development program and atomic energy power stations in the USSR.

In the course of the study are exposed the economically disruptive effects arising from the arbitrary allocation of priorities within the Soviet fuel and power economy. Some of these have been brought to light by Soviet economists through the recent preparation of the unified fuel and power balance in the USSR.

The priority mix decided upon on the basis of a formally prepared fuel balance is a static form, incapable of self adjustment in consequence of current technological developments during the plan or in response to changes in demand. Consequently it cannot have the regulating properties of "value" in the free market economy.

The absence of a "dynamic regulating criterion" in a planned economy is concluded to be a grave handicap which is bound to continue to have a dislocating effect on the development of fuel and power resources of the Soviet Union. Without the criterion of "value" to regulate economic activity arbitrary decisions by the planners will continue to be necessary for the working of the economy and so, even with the unified fuel and power balance, the likelihood of misallocations, similar to those which occurred in the past is not eliminated, though their presence will probably be discovered earlier.

With regard to the introduction of atomic energy, it is felt that the Soviet Union is not as yet ready to consider it to the same degree as is being done in the U.S.A. and Canada, and this in spite of the fact that greater opportunities for the use of atomic power appear to exist in the USSR. The reason for this tardiness is thought to be shortage of nuclear fuels in the USSR also, probably, insufficient mastery of fuel utilization in the reactors.

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The character of the fuel economy in the USSR is being changed at present with all the haste that a centrally controlled system can enforce. The decisions that led to the perpetuation of an economically unsound fuel balance in the face of technological progress, the recent realization of past errors and the measures which are being undertaken to reshape the fuel balance, make the study of the fuel economy of the USSR of great interest.

The greater freedom of discussion now permitted by the Soviet authorities resulted in a flow of books and articles devoted to the problems of conventional fuels, containing valuable statistical information without which this study could not have been undertaken.

The availability of data in a Communist system often depends on the readiness of the authorities to take a definite stand on the given subject. This is the case with the production and use of conventional fuels. But as the Soviet planners are not yet ready to make a clear decision with regard to atomic energy, there has been little information published on this subject. Nevertheless, it is felt that the recent changes of approach in the fuel economy brought about through the preparation of the unified fuel and power balance ensure a place for atomic power in the Soviet economy in the future.

This work deals with the role that various forms of fuel play in the fuel balance of the USSR. Information on the availability of various types of fuel resources and on their production is included separately in appendices at the end.

Except for the section dealing with the fuel economies outside Russia, the present work is based on Soviet Sources and statistical information. All the translations of Russian texts, except where specifically stated to the contrary, have been prepared by the author.

PART ONE: CONVENTIONAL SOURCES OF FUEL AND POWER

CHAPTER I

SOVIET BALANCE OF FUEL AND POWER

- I -

The basic feature of a controlled economy is the allocation of priorities from the centre. To cause the economy to develop along such lines as are considered desirable, greater emphasis is given to selected fields of the economy, with the consequent result that the others receive less.

On coming to power in Russia the Communists set themselves the task of creating a centrally controlled economy. Though forced to retreat temporarily during the NEP period they returned to this policy with the introduction of the first Five Year Plan in 1928 and have pursued it ever since.

In preparing the five year plans of development they fixed the order of priority for each branch of the economy as well as the priorities within them and by this determined the investment as well as the production pattern. The aim of these priority allocations was to accelerate the industrialization of the Soviet Union and to make the national economy both self-sufficient, and powerful enough to provide the armed forces with the equipment they required. Thus, the machine industry and the other basic industries - iron and steel, fuel and electric power - were given the highest priority.

This study deals with the priority policies of one particular segment of the Soviet economy - the fuel and power industry. In the fuel industry different priorities were allocated to various forms of fuels at different periods. These are reflected in Table I, below, giving the fuel balance of the Soviet Union from 1928 to 1958 and to 1972.

(See Table I, p. 3)

From the above table it can be seen that:

(i) The highest priority has been alloted to coal industry. The production of coal increased steadily from 1928 on, and by 1950 its share in the fuel balance reached 66.1 per cent, compared with 50.3 per cent in 1913. However out of 261 million tons produced in 1950 nearly a third was made up of low quality coals, mined in the Moscow Basin, Urals, East Siberia and other places.

(ii) During this period the production of peat increased from 1.7 million tons in 1913 to 36 million tons in 1950 and its share in the fuel balance increased from 1.5 to 4.8 per cent. As a result of the government policy encouraging development of local fuels,(5) these fuels continued to play an important part and their combined share in the fuel balance in 1950 was 14.2 per cent.

(iii) This policy of favouring coal and local fuels was accompanied by neglect of the more economic forms of fuel, namely oil and gas. The share of oil in the fuel balance declined from

Table I

<u>Fuel Balance of the USSR</u>

(in physical units and percentages of the total)

Year	Coal Mil.t.	%	Oil Mil.t.	%	Gas Mil.m^3.	%	Peat Mil.t.	%	Shale Mil.t.	%	Wood Mil.t.	%	
1913	29.1	50.3	9.2	28.8	-	-	1.7	1.5	-	-	20.7	19.4	
1928	35.5	52.0	11.6	30.8	304.0	0.6	5.3	4.1	-	-	15.9	12.5	
1940	165.9	59.1	31.1	18.7	3219.1	1.9	33.2	5.7	1.7	0.3	79.3	14.3	
1945	149.3	62.2	19.4	15.0	3278.0	2.3	22.4	5.0	1.4	0.2	66.0	15.3	
1950	261.1	66.1	37.9	17.4	5760.9	2.3	36.0	4.8	4.7	0.4	64.9	9.0	
1955	391.3	64.8	70.8	21.1	8980.9	2.4	50.8	4.3	10.8	0.7	75.3	6.7	
1958	495.8	59.6	113.2	25.7	28084.5	5.4	52.8	3.4	13.2	0.7	76.5	5.2	(1)
1965 (2)	600 612	43.1	230 240	32.6	150000.0	17.6	71.0	3.1		0.6		3.0	(3)
1972 (4)		32.0		37.5		23.5							

30.8 per cent in 1928 to 17.4 per cent in 1950, while no attention at all was paid to gas until 1943.

- II -

This pattern of priority allocation continued from 1928 to approximately 1953. During the Fifth Five Year Plan (1950-55) a change occurred in the system of priority allocation in the fuel industry, resulting in a shift in the fuel balance. The change has been introduced gradually and can be said to be still in progress. The first step was to give higher priority to gas and oil, leaving the priority system within the hard fossile fuel group generally unaltered. The second step was to reassess the priorities within the latter group. In the European part of the country this reassessment has been in favour of better quality coals and against the low quality brown coals and peat.

The position of atomic energy is not clearly defined at present. Atomic power development was accorded high priority in the plans of earlier years (from 1954 to 1958) but with the development of the gas and oil industries it became clear that in the immediate future electric power could be obtained more economically from gas and oil fuelled thermal power stations than from atomic power stations in their present state of development. As a result the priority for the construction of atomic power stations has been scaled down.

As can be seen from Table I, by 1955 the share of coal in the fuel balance declined to 64.8 per cent and to 59.6 per cent by 1958. It is planned that by 1965 its share will amount only to 43.1 per cent. Similarly, the share of local fuels declined to 11.7 per cent in 1955, 9.3 per cent in 1958 and is expected to account for 6.7 per cent in 1965. In absolute terms, however, the output of coal and local fuels will continue to increase. The current 7-year plan, as originally presented, provided for a coal output in 1965 of 600 to 612 million tons, compared with 495.8 million tons for 1958, and the extraction of peat was to be increased by 1965 to 71 million tons, compared with 52.4 million tons in 1958. It is possible that as a result of very recent discussions(6) some reduction will take place even in the absolute output of these fuels, particularly where production of low quality coals in the Western part of the country is concerned. According to a recent statement,(7) during 1961 the output of coal is, for the first time since the early days of the regime, not to exceed the level for the previous year, i.e. 511.7 million tons.

The table also shows that following the change in priority allocation the share of oil in the fuel balance increased from 17.4 per cent in 1950 to 21.1 per cent in 1955 and 25.7 per cent in 1958. The present 7-year plan provides that the share of oil in the fuel balance is to be increased to 32.6 per cent by 1965 and the output in absolute terms is to increase from 113.2 to 230-240 million tons. The increase in the importance of natural gas will be even greater. Its share in the fuel balance grew from nothing in 1943 to 2.4 per cent in 1955, 5.4 per cent in 1958 and is to increase to 17.6 per cent in 1965.

In absolute terms the output of gas in 1955 was 8,980.9 million cubic metres. By 1958 it rose to 28,084.5 million cubic metres. The planned output for 1965 is 150,000 million cubic metres.

Thus, according to the present plan, the combined share of coal and local fuels in the fuel balance will decline from 80.3 per cent in 1950 to 49.8 per cent in 1965, while that of oil and gas together will increase from 19.7 per cent in 1950 to 50.2 per cent in 1965.

The future decline in the importance of coal and local fuels can be seen even better from the overall fuel and power balance (see Table II). The combined share of coal and local fuels is to drop from 69.7 per cent in 1957 to 36.5 per cent in 1972, while that of oil and gas, together with the hydro-electric and atomic power, are to increase from 30.3 per cent in 1957 to 63.5 per cent in 1972. The share of coal is to decline during the same period from 60.8 to 32.2 per cent, while the combined share of oil and gas is to increase from 27.4 to 57.7 per cent. By 1972 the share of oil alone in the fuel and power balance is to be greater than that of coal.

The re-arrangement of priority allocations, which resulted in the structural shift in the fuel balance was made in approximately 1953; that is, nearly 6 years before the preparation of a unified fuel and power balance for the country as a whole. This balance was completed at the end of 1959 or the beginning of 1960. As a result of this unified fuel and power balance further adjustments will probably be made. The output of peat and of low quality coal in the Moscow Basin, in the Urals and even in the less productive mines in the Donbass is likely to be curtailed.

Table II

1957 and 1972

Fuel and Power Balance of the USSR - in percentages[8]

	Coal	Oil	Gas	Peat	Shale	Wood	Hydr.E.P.	Atomic P.
1957	60.8	23.4	4.0	3.8	0.7	4.4	2.9	-
1972	32.2	34.4	23.3	2.4	0.6	1.3	2.6	3.2

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The issue of fuel priorities is of great significance to the Soviet economy. In the USSR over 19 per cent of all capital investments is allocated to the fuel and power industries. One third of basic capital equipment (osnovniye proizvodstvennie fondi) is in fuel and power and 9.5 per cent of the total labour force is engaged in this field.[9] Annual expenditure on extraction, transportation and preparation of fuels amounts to 100 billion roubles.[10] Over 36 per cent of the entire cost of the production of cement goes to cover the cost of fuels. In the building industry this share is 13.8 per cent, in the iron and steel industry 17.1 per cent, in ono-ferrous metals 19.1 per cent, in railway transportation 22.4 per cent, in road transport 17.3 per cent.[11] By altering the priority mix in favour of the more economic types of fuels, the productivity in the fuel economy as a whole can be raised without any additional investments. As long as this was not done, the Soviet economy was being provided with expensive fuels.

The pattern of Soviet priorities in fuel and power, therefore, deserves closer attention. In this study it is proposed to deal with the Soviet priority policy in two parts.

Part one will consider how priorities were decided in the Soviet Union, how it came about that coal received the highest priority and how the priority shifted to other fuels around 1950-1953.

In the course of the study the priority-determined fuel balance of the USSR will be compared with the balances of freely competitive fuels of the USA, UK and Canada.

Part two of the study will deal with the expected role of the new source of energy - atomic power. It presents first a summary view of atomic development programs in the USA, UK and Canada and then sets out the atomic power development and research facilities of the USSR. A conclusion is then drawn through analysis of the Soviet atomic power development and research program and by comparison with the situation in the three Western countries.

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5. By local fuel is meant wood,shale,peat and low quality coal.

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CHAPTER II

SOVIET FUEL BALANCE 1918-1953

(I) The Starting Point

The fuel industry was among the first to be affected by nationalization and priority policies. By the decree of the 28th June, 1918 all major enterprises in key industries were nationalized. Paragraph 1 of the decree read:-

> "All joint stock enterprises extracting fuels (coal, brown coal, lignite, oil shale, anthracite, etc.) for the purpose of decisive struggle with economic and supply dislocation and of strengthening the dictatorship of the working class and the village poor, are declared by the Council of People's Commissars to be the property of the state".[1]

The same decree provided for the nationalization of, among others, the enterprises of the electrical industry.

Nationalized fuel enterprises were administered by the VSNKh as though they were all branches of one firm, and in some isolated cases, directly by local authorities. To co-ordinate the activity of scattered nationalized enterprises, Committees were created - the Peat Committee, the Firewood Committee, the Oil Committee and others.

On the 4th March, 1919, on the initiative of Lenin, who attached particular importance to electrification, the Central Electrical Committee (Ts.E.K.) was created. A year later, on the 24th March, 1920, the Ts.E.K. was re-organized into a special State Commission for the Electrification of Russia[2]

(Gosudarstvennaya Komissia po Elektrifikatsii Rossii - GOELRO) whose work had an important bearing on the subsequent industrialization and on the development of the fuel industry.

During the winter of 1918-1919 the fuel situation in Russia was described as catastrophic.(3) The reasons for this were the general administrative disorganization brought about by the war and the revolution, the fact that parts of the country were in the hands of groups hostile to the regime, disorganization of transport, shortage of rolling stock to transport available reserves of fuels, and shortage of working and investment funds. These difficulties were made worse through lack of trained administrative personnel and the ignorance of the leaders in matters of economic administration.

The total production of basic industries declined to one seventh of the pre-war level, while the number of workers declined by 36 per cent. In some branches of industry the situation was even worse. Due to government efforts the situation in fuel industry, although critical, was better than elsewhere. Given below are output figures for 1913 and 1920,(4) (in millions of tons):-

	1913	1920	1920/1913
Coal	29.1	8.6	23.4
Oil	9,243,234	3,831,282	41.4
Peat	1,556,100	1,520,064	97.7

(II) The Period 1918-1921

During the period of war Communism the priority mix for the fuel industry was forced upon the government by circumstances. Lack of funds brought about a decline in coal production, especially where mines were damaged and required capital investments. The same was true of the oil industry. The fuels which could be produced without much capital expenditure and could be brought to the urban centres, were peat and wood and it is upon these that the government concentrated its attention.

The high priority given to peat and wood, however, was considered a temporary expedient only, as can be seen from the GOELRO Plan submitted to the VIII All Russian Congress of the Soviets. It envisaged that during the following ten to fifteen years thirty power stations of a total capacity of 1.5 million kw. would be constructed in the Soviet Union and that, compared with 1913, there would be an increase in the production of basic industries 1.8 to 2 times.

> "Plan GOELRO was not confined to general considerations of the directions of development of national economy, but followed its proposals to the finalized blueprint calculations of power stations, to mechanization and electrification of production processes, taking into account, for example, the comparative advantages of using various types of fuel and hydroelectric power, at the same time working out the most up-to-date methods for the best utilization of various fuel resources, etc. Thus the Plan GOELRO was a general, and at the same time, a concrete, national economic plan, all its sections were integrated and balanced, calculations were made of material and financial expenditures for the realization of the planned measures"(5)

The main objective of the plan was to develop, on the basis of electrification, heavy industry in general and ferrous and metallurgical industries in particular, as well as the fuel industries needed for them. The main GOELRO targets were:(6)

	1913	1920	Goelro
Production of Pig Iron Mil.Tons	4.2	0.116	8.2
Production of Steel " "	4.2	0.194	6.5
Production of Coal " "	29.1	8.6	62.3
Capacity of Regional power Stations (thousand kw.)	177	-	1750

It should be remembered, however, that unlike the future Five Year Plans, GOELRO was much less restricted by fixed time limits. The duration of the plan was designated by a vague "during the following 10-15 years". It was, therefore, in fact a broad outline of a future programme.

In the absence of the automatic regulating forces present under market economy, allocation of resources was made on the basis of arbitrary decisions by the leaders. Electrification became the main objective. Speaking at the Moscow Regional Party Conference on 20th January 1920, Lenin introduced his famous slogan - "Communism is the Soviet Government plus electrification of the entire country".(7) Commenting on the GOELRO Plan in 1921 Stalin said "We must at once get down to work. We must allocate to this undertaking one third of our effort - two-thirds will go to our current needs".(8)

During the first two years of the Communist regime, the economic activity of the country was rapidly declining. Being aware of the growing unrest in the country Lenin decided on a new course, which meant at least partial return to the traditional market economy. The new course he called New Economic Policy - NEP.

It was introduced at the 10th Congress of the All-Russian Communist Party held in March, 1921.

(III) The Period 1921-1928

Re-introduction of the money system, trading and taxation, coupled with energetic measures to arrest inflation led to the establishment of a degree of stability and accumulation of working and investment funds in government hands.

Return to market economy during NEP was only partial. The government retained control of the key industries. In the fuel industry the large scale industrial enterprises were left in government hands.

> "During the early years of reconstruction, the capital expenditures were directed to the fuel and light industries, as was necessary for their rapid reconstruction. Particularly vigorous was the construction work in the oil industry, which during this period received approximately one-third of all capital investments in the state industry of the USSR"(9)

As soon as the fuel crisis was surmounted the attitude towards fuel industry changed. The government now shifted its main attention to the re-establishment of metallurgical and machine building industries.

> "Without creating in our country the necessary reserves of raw materials and fuel we could not even think of reconstruction of industry. This necessitated first of all substantial tempos of development in coal and oil industries, in extraction of iron ores, production of electrical power and reconstruction of iron and steel industries"(10)

The priority allocation in the fuel industry during the early part of the NEP period is reflected in the output figures for various types of fuels given in the table overleaf.(11)

	1913	1925	1925/1913
Electric Power (bil.kwh.)	1.94	2.9	149.4
Coal (Mil.tons)	29.1	17.0	59.1
Oil (Mil.tons)	9.2	7.5	81.5
Peat(12) (Mil.tons)	1.7	2.7	160.0

It must be remembered, however, that the growth in the production of peat was to a considerable degree due to the presence of small scale enterprises, which grew as a result of NEP.

Until 1928 investments in state industry constituted an attempt at influencing the development of the national economy rather than controlling it, as came later. The centralized capital investments during 1923/24 - 1927/28 period amounted to only 11.1 billion roubles, as against 15.4 billion roubles invested by enterprises, the bulk of which came from agricultural farms and private industrial and trading enterprises.(13)

During this period government policy with regard to economic development was still based on considerations of a general rise in the level of production, though, as can be seen from figures given overleaf, centralized investments were definitely channelled into basic industries, which included fuel industry as well. With the introduction of the first Five Year Plan the policy changed to ensure a restricted rise of the level of productions only.

Centralized Investments 1925/26 - 1927/28 (14)

		1925/26 In mil. R.	1925/26 in %	1926/27 In mil. R.	1926/27 in %	1927/28 In mil. R.	1927/28 in %
Total		781.5	100	1094.9	100	1464.4	100
Group A :	Metal	181.6	23.2	256.9	23.5	338.6	23.1
	Oil	136.0	17.4	174.0	15.9	206.1	14.1
	Coal	76.4	9.8	146.9	13.4	140.9	9.6
	El.Techn.	31.6	4.0	81.7	7.5	168.3	11.5
Group B :	Textiles	123.7	15.8	162.3	14.8	220.0	15.0
	Food	65.7	8.4	59.8	5.5	91.2	6.2

(IV) The Period 1928-1953

With the introduction of the first Five Year Plan, the government attitude to planning changed. Stalin, who was being successful in gathering power in his hands favoured complete control of economic life by the government and the elimination of the limited market economy permitted since the introduction of NEP. The absolute control of the government was to be used in order to carry through the industrialization of the country. Stalin also laid down the lines along which industrialization was to be carried out.

> "Not every type of industrial development represents industrialization. The task of industrialization is not only to increase the share of industry in our economy as a whole, but also, in the course of such an increase assure our country, surrounded by capitalist states, of economic independence and safeguard it from becoming an economic appendage of world capitalism."(15)

This meant that from then on industry was to be developed according to political considerations which, naturally, were to be defined by the policy makers.

For the fuel industry, and for the priority mix within it, this had a very important consequence, for it was to be subordinated in the future not to the needs of the national economy as a whole, but to the needs of that portion of it which the leaders considered important, that is - to the heavy industry.

From that time on it was held that "the fuel and power branches of industry are important branches of heavy industry for they determine to a great degree the tempo and the level of development of the Socialist economy, in particular of industry".(16)

Besides subordinating the fuel industry to the requirements of heavy industry, the leaders took another decision which had an important bearing on the future development. They decided to give first priority to coal, rather than oil.

With the introduction of rigid planning, coal, with precisely estimated industrial reserves, appeared more reliable as fuel, compared to oil. It also was cheaper to produce, although this advantage was soon lost.

Once the priority mix for the fuel had been decided upon in the course of preparation for the first Five Year Plan, it remained unchanged until after Stalin's death. During the succeeding plans the share of oil in the fuel balance declined while that of coal increased as new coal basins were developed as a result of deliberate policy.

Addressing the XVI Congress of the All Union Communist Party (b) in June 1930, Stalin said:-

> "At present our industry and our economy are based mainly on the coal-metal base in the Urals. Naturally, without such a base industrialization of the country is unthinkable. The Ukrainian coal-metal base serves us as an indispensable base. But can this base in the future satisfy all, the South and the Central parts of

> the USSR, the North, the North-West, the Far East and Turkestan? All the data tell us that it cannot. The new factor in the development of our national economy is that this base has already become inadequate for our needs. Thus, while continuing to expand this base, we should at the same time start to create a new coal-metal base. The Ural-Kuznetsk combine shall become such a base - the combination of Kuznetsk coking coal with Ural ore". (17)

It is difficult to imagine what the result would have been if Stalin, faced with inadequate supplies of coal from Donbass, had decided, instead, to give higher priority to oil industry - probably leading to a much earlier development of gas as well. The repercussions of such a step on road construction, railway transport, chemical industry, engineering and other branches of the economy would have been incalculable.

The development of the Kuznetsk coal basin was followed by the development of the Karaganda coal basin and others. Decisions as to the size of industrial enterprises were made by political leaders arbitrarily. Ordzhonikidze described the process of decision as follows:-

> "Comrade Stalin asked about the capacity of metal plants in the U.S.A. He was told that large plants in the U.S.A. produced 2½ million tons of pig iron a year. Comrade Stalin said - 'We must build such a plant here, first of all for 2½ million tons and then for 4 million tons.' The Party and the country decided to build such a plant." (18)

The newly developed coal basins were situated far from existing industrial centres, resulting in an increase in the distance of coal haulages, which put an unduly heavy strain on the railways carrying the bulk of it, and at the same time resulted in an increase in costs.

Coal from the Kuznetsk basin had to be carried over distances of 2500 km. to Urals, and from the two Karaganda basins over 1200 km. to Urals and 3000 km. to Central Asia. Coal from Donetz was being carried over a distance of 1700 km. to Leningrad and 1500 km. to the Volga Region. Pechora Basin coal was carried to Leningrad over a distance of 1700 km.

To reduce enormous, and rapidly growing, costs of transportation the government advocated greater use of local fuels - peat, brown coal and lignite, wood and oil shale. As a result the production of these local fuels increased very rapidly. (See table below.) No effort, however, was made to develop the oil industry.

In the table below are given the outputs of peat, wood, shale and Moscow Basin coal for 1928, 1940 and 1950. The last one is the most important basin of low quality coal developed by the government to reduce haulages of coal to the Moscow area.(19)

	Peat		Wood (20)		Shale		Moscow Basin Coal (21)	
	mil. tons	% of F.B.	mil. tons	% of F.B.	mil. tons	% of F.B.	mil. tons	% of C.O.
1928	5.3	4.1	15.9[a]	12.5	-	-	1.3	3.2
1940	33.2	5.7	79.3	14.3	1.7	0.3	10.1	6.1
1950	36.0	4.8	64.9	9.0	4.7	0.4	30.9	11.8

F.B. - Fuel Balance C.O. - Coal Output

a. The bulk of the wood supplying was handled by small scale enterprises outside the socialized sector.

In the U.S.A. a shift was taking place from solid to liquid and gas fossil fuels with a higher calorific content and

and lower cost of extraction. In the USSR the trend was towards the greater use of solid and more expensive fuels. Given below are the figures of mineral fuel balances in the USSR and U.S.A. (in % of total) for the period 1913 to 1955 (i.e. without wood). The opposite trends of fuel consumption of the two countries are represented in the table below.(22)

	Coal		Oil		Nat. Gas		Peat		Shale	
	USSR	USA	USSR	USA	USSR	USA	USSR	USA	USSR	USA
1913	65.3	87.9	32.8	8.3	-	3.8	1.9	-	-	-
1927/28	62.3	71.0	34.4	21.7	0.8	7.3	2.5	-	-	-
1932	59.7	62.5	32.2	27.0	1.3	10.5	6.7	-	0.1	-
1937	67.1	56.8	25.0	31.3	1.6	11.9	6.2	-	0.1	-
1940	70.1	58.4	21.7	29.3	1.9	12.3	6.0	-	0.3	-
1950	73.2	38.8	18.9	36.4	2.2	24.8	5.0	-	0.7	-
1955[b]	70.4	32.7	22.5	38.7	2.2	28.6	4.2	-	0.7	-

b. U.S.A. figures for 1954.(23)

As can be seen from the figures above, the combined share of hard fossil fuels increased from 67.2 per cent to 78.9 per cent between 1913 and 1950 in the USSR and declined from 87.9 to 38.8 per cent in the U.S.A.

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21. Overall coal output.

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CHAPTER III

EMERGENCE OF THE NEW PRIORITY PATTERN SINCE 1953

- I -

In a country where decisions on prospective development are arbitrarily made by the leaders and the Party on political grounds, the pointing out of past or present mistakes by economists or administrators at a lower level can be a risky proposition. Immediately before the war and more particularly after the war, there appeared in the Russian economic press signs of awareness that the question of choice between alternatives, the question of priority allocation, is a complicated one and that in the past not enough attention had been paid to various economic factors entering into calculations. S.G. Strumilin, B. Chernomordik, P. Mstislavsky, V.V. Novozhilov and others advocated various new approaches. Early in 1952 T.S. Khachaturov called for a number of free discussions to take place during 1952, and the "Voprosy Ekonomiki" went as far as to promise such a discussion. But the question of effective utilization of resources was raised on a theoretical level and did not effect allocation policy in fuel or any other industry. Any re-examination of the fuel industry priorities would have made it necessary to submit to criticism the policies pursued in the past. This, under prevailing conditions, was not possible. The decision to give high priority to coal rather than to oil and to develop local fuel resources rather than the more economical oil and gas had been supported by Stalin and the Party since the introduction of the First Five Year Plan, and changes could only be made very gradually, without castigating past policies.

It was, therefore, due to the political atmosphere described above and not to any lack of liquid fuels that the coal priority policy was continued for so long.

- II -

The priority allocated during Stalin's lifetime to coal was not imposed on the Soviet economy by uncertainty as to available deposits of liquid fuels. Russian planners were fully aware that the USSR share in world fuel resources amounted to 55 per cent in peat, 54.8 per cent in oil, 28 per cent in water power and 20.7 per cent in coal. In 1950, at the end of the 5th Five Year Plan, USSR produced 261.1 million tons of coal (which constituted 66.1 per cent of the country's fuel balance), 37.9 million tons of oil (constituting 17.4 per cent of the fuel balance), 5,760.9 million cubic metres of gas (2.3 per cent of the fuel balance), 36 million tons of peat (4.8 per cent of the fuel balance), 4.7 million tons of oil shale (0.4 per cent of the fuel balance).(1) In 1950 hydro-electric power stations contributed 12,961 million kwh. of electric power.

In spite of the fact that considerable liquid fuel resources were available, it was the solid fuels that were used. Neither did the Soviet attempt to reduce costs through complex utilization of fuels tackle the basic question of balanced utilization of all available resources.

As a result of the controlled development of the fuel industry, which took place during the period of industrialization, the structure of the fuel balance radically changed in favour of hard mineral fuels. In the total output of mineral fuels by themselves, calculated in conventional fuel units, the share of coal increased from 65.3 per cent in 1913 to 73.2 per cent in 1950, due to the coal industry being given first priority. The share of oil declined from 32.8 per cent to 18.9 per cent, that of natural gas increased from nothing to 2.2 per cent, the share of peat increased from 1.9 to 5 per cent and of shale - from nothing to 0.7 per cent.(2)

The oil industry was neglected so badly that even in 1958, five years after it had been given the highest priority, its share in the overall fuel balance was still lower than in 1913. The share of coal, when considered as a furnace fuel was even higher. As late as 1955 it was still more than 77 per cent, while that of oil was 7 per cent, wood 7 per cent, peat 6 per cent, natural gas 2 per cent, and shale 1 per cent. This was due to the fact that oil was used extensively as raw material in the chemical industry, as basic fuel for tractors and for lighting purposes.(3)

- III -

It was only after Stalin's death that the problem of efficient utilization of all available alternative fuels was placed on the agenda of the Soviet planners. This revealed great possibilities of cost reduction of fuels, particularly by comparison with the fuel economy of the USA. A. Probst and other Russian economists came out with their suggestions for improvements, which, however, give an impression that although they realized that the cost structure was wrong, they did not know what really were the causes of difficulties.

It is interesting to observe that it was mere confrontation of the two fuel balances that led Probst and others to recommend a series of measures before they compiled a unified fuel balance for their economy. These preliminary solutions centered around the task of reducing the excessive costs of transportation through development of local fuels and not yet through substitution of coal by oil and gas. For example A. Probst stated:-

> "To eliminate long distance, irrational haulage of fuel it is necessary first of all to work out a correct schedule of geographical locations of all branches of the fuel industry, considered from a long term point of view, and a schedule for regionalizing the consumption of the individual types of fuels. Particular attention should be paid to improvement in the compilation of fuel balances, presenting the foundation for planning the fuel supply for the entire country. In this connection it is essential to note that <u>we not only have no unified fuel-power balance, but that we even lack a unified fuel balance by itself, since during recent years the balances of hard fuels and liquid fuels (light products) have been compiled separately, without sufficiently relating them with one another.</u>(4) Besides, these balances, did not include scores of millions of tons of fuel consumed by the population and did not take into account secondary sources of fuel.(5)

Detailed remedies of this preliminary nature included the following:-

(i) to expand production of local fuels to eliminate long distance haulage of high quality coals. In this connection further development of the peat industry was particularly strongly recommended in order to satisfy the needs of the local population and industry, and reduce consumption of wood, dung, brushwood and straw, which were rightly considered the most costly of fuels in terms of labour expenditure.

For this reason it was recommended that in the immediate future a considerable proportion of wood, used by the town population (in the first instance, of the European part of the USSR), should be replaced with local mineral fuels - coal and peat.

It was also recommended that the rapidly expanding demand for fuel for agriculture, MTS, and the needs of the rural population, should be met by wider utilization of peat, which should be provided for several thousands of thermal power stations soon to be constructed to serve agriculture. These stations were expected to require 10 million tons of peat annually. In connection with this it was said:-

> "One of the real achievements in the fuel economy of the USSR is the extensive development of the peat industry. Within a considerable part of the central region peat can be used economically more effectively than Moscow Basin coal. In this area cost of production of peat (average of all types of production) in 1953 was 25.7 per cent lower than the cost of the equivalent amount, in terms of calorific value, of Moscow coal, while the cost of milling-peat was 34.6 per cent lower. Compared with firewood, peat is 2-3 times cheaper.
> <u>Further mineralization of the fuel balance of the European part of the USSR and reduction in the consumption of wood requires development of peat extraction.</u>"(6)

And again -

"During the 6th FYP peat extraction should be increased both for industrial purposes and to satisfy the needs of the population and agriculture. For this reason it is essential first of all to organize production of peat briquettes. This would provide on the one hand a high quality fuel for everyday needs and on the other utilize milling-peat, the production of which is most mechanized and therefore least costly"(7)

(ii) While advocating development of local fuel resources and in particular peat, it was also urged that efforts should be made to develop the natural gas industry, which provides the most economical fuel. According to data for 1953 the cost of the natural gas in the Central Region, brought there over a distance of 1200 km. was 1.5 to 2 times lower than either Donbass coal, brought from just as far, or the local fuel, such as Moscow Basin coal or peat. To prove this the following figures were given:-

Comparative Costs of Various Types of Fuels in the Central Region of USSR.(8)

(Calculated in conventional fuel units)

	Cost at place of Extraction	Distance transported kms.	Cost at the place of use, including transport cost, in % of cost of natural gas.
Natural Gas	100	1200 - 1300	100
Donbass Coal	730	1200	172.5
Moscow Basin coal	1066.5	200	207
Peat (average all methods of extraction)	644.7	20	153.4
Milling peat	446.6	20	123

It was pointed out that:-

"In spite of the undeniable economic advantage and the enormous geological reserves of natural gas, its development in the USSR was not satisfactory. In 1950 the share of natural gas in the overall output of mineral fuel

> (calculated in terms of conventional fuel) amounted only to 2.2 per cent. During the 5th FYP the share of natural gas did not increase. The directives of the XIX Congress of CPSU, held in October 1952, to increase the output of natural gas by 80 per cent, were not complied with" (9)

It must be added that right up to 1955 the gas industry did not receive enough attention.

In order to expand the output of the gas industry it was advocated that prospecting for oil and gas should be undertaken on a much wider scale than had been heretofore.

> "It is necessary to emphasize that excessive fear of the risk in drilling and the desire to avoid altogether expenditure on 'dry' (unproductive) drillings often results in large losses for the national economy, exceeding many times expenditures on such drillings. As a result of it the economy is being deprived of the cheapest and the most effective fuel".(10)

(iii) Increased production of oil was also urged. To justify this it was said that the decision to favour the production of coal as against oil was taken in the early years of industrialization when it was more expensive to produce oil than coal. Since then the cost of oil production has declined faster than the cost of coal production and by 1956 it was 2.6 times lower than the cost of producing coal (calculated in terms of conventional fuel). Yet from approximately 1932 to 1953 the share of oil in the balance of mineral fuels steadily declined. The following figures were given to compare the costs of producing 1 ton of oil in percentages of the cost of production of 1 ton of Donetz coal (Average for USSR).(11)

1927/8	107
1940	58
1954	55

During the period of industrialization the growing demand by branches of the national economy, and transport in particular, for liquid fuel was met by improved methods of processing crude oil and by restrictions and reductions in the use of liquid fuel and replacing it with coal. "In 1936 alone, Kaganovich is credited with having converted 1400 locomotives from liquid to solid fuel burning."(12) For the shipping industry, while in countries outside Russia coal was being replaced by oil, Russia continued to build coal burners. In industry too, oil as a technological fuel was often replaced by coal.

> "It is necessary to check thoroughly the comparative advantages of using oil and coal as technological fuel in every branch, every region and every type of equipment or process.
> The proposed absolute increase and relative growth in the use of oil in many fields would lead to the increase of its share in the fuel balance and result in an improvement of productivity in the extraction of fuel as a whole."(13)

These recommendations to increase production of natural gas and oil were supported by references to costs of production and to past experience in the USA. Examples and statistics from the American fuel balance, proving the advantages of the course advocated were freely cited in the Russian economic literature. This is not the case with the other types of fuel, namely wood, peat, coal and shale, where only experience in Russia is cited.

(iv) It was assumed then that coal, which in 1955 accounted for 70.4 per cent of mineral fuel produced in the country, would continue to play the dominant role in the Russian fuel economy, even though its share in the future balance would somewhat decline. This is partly due to the fact that thermal and thermification power stations were expected to continue to use mainly coal.

The dominant position which coal was to continue to occupy was also partly ascribed to the location of fuel reserves in the USSR. In the East of the USSR there are large reserves of coal often close to the surface, but little oil. Thus it was assumed that the absolute volume of coal production would increase considerably. The 6th FYP provided for a 1960 coal output of 593 million tons - 122 million tons of which was to be obtained from open cast mines (The total output in 1958 was 495.8 million tons,[14] and in 1959 - 522.7 million tons.[15]).

As well as suggestions for the alteration of the fuel balance structure, there was criticism of the pricing of various fuels.

> "At thermal power stations working on Moscow Basin coal, the expenditure of fuel per 1 kwh. of energy produced is 2.5 to 2.8 times more than in power stations where Donbass coal is used. Using this coal necessitates larger supplies of fuel, additional expenditure to remove ashes and other expenses. According to data from the All-Union Technical Institute given in the table below the cost of power production by a power station of 600,000 kw. at the pithead is 60 per cent higher when working on Moscow coal, than on Donbass coal. Over a period of five years such a power station suffers a loss of 800 million Roubles which is enough to construct a new power station of the same capacity working on Donbass coal."[16]

Cost of production of 1 kwh. in kopecs.

	On Donbass coal	On Moscow Basin coal
Fuel	3.860	7.710
Amortisation and repairs	1.141	1.168
Energy for own use	0.808	1.025
Wages and allowances	0.330	0.337
Other expenses	0.427	0.435
	6.566	10.675

B. Naymanov pointed out that the prices were fixed incorrectly and that Kuzbass coal, compared to Donbass and Moscow Basin coals was underpriced by 35 to 40 per cent.(17)

Special attention was drawn to the advantages of open-cast mining. The situation in the coal industry was summed up as follows:

> "The Eastern region, which commands over 90 per cent of all potential fuel reserves (including coal), at present consumes 23.2 per cent of overall coal production and produces 34.4 per cent. This divergence between the location of coal reserves and the location of coal extraction as well as divergence between the places of extraction and consumption of fuel results in large losses within the national economy.
> It is necessary to liquidate the disadvantages of the present locations of production and consumption of fuel by more energetic transfer of new industrial construction Eastwards. It is essential to combat decisively the lack of appreciation of the colossal losses resulting from supplying European territories with fuels which are here more costly than in the East."(18)

(v) Finally, the 6th FYP provides for an increase in the output of shale of not less than 76 per cent.

In conclusion, these preliminary measures advocated an increase in the production of all types of fuels, with the exception of wood, straw and similar fuels. The Soviet economists found it difficult to make up their minds what fuel to choose in preference to others.

> "The Soviet Economists are faced with a number of problems in the further development of the fuel economy of the USSR. To determine the economic advantages of various types of fuels, now and for the future, it is essential to determine the question of initial economic indices for extraction, transportation and utilization of fuel, on what method these indices are to be determined and compared, how to analyze their changes, and so on".(19)

It was these difficulties that led them to the unified fuel balance.

In 1957 the 6th FYP was discontinued and in its place was introduced the 7-year plan. Introducing this plan at the Special 21st Congress of CPSU, held in January 1959, N.S. Khrushchev said: -

> "In the fuel industry we have adopted the line of giving priority to the development of oil and gas extraction and refining. In 1965 the production of oil will rise to 230-240 million tons, or more than twofold, and the output of gas will increase approximately five times, reaching 150,000 million cubic metres per year. The share of oil and gas in the total output of fuel will grow from 31 to 51 per cent, while that of coal will correspondingly decrease to 43 per cent."

He also added, however, that -

> "While developing the oil and gas industry we must not lose sight of the coal industry. Although the rate of growth in coal production will be much slower than in the preceding 7 years, output will, nevertheless, rise 21 to 23 per cent, mainly due to the increase in the extraction of coking coals in the Donbass, Kuzbass and Karaganda basins, and also the cheap industrial coals in the Eastern areas"(20)

Khrushchev's statement was already a far cry from assigning to coal a special place in the fuel balance, and it was clear that the new policy would bring the structure of the Russian fuel economy very much nearer to the one seen in the United States.

- IV -

Recognition of the Importance of the Cost Element.

The change introduced by Khrushchev was of great significance. It marked a definite break with the traditional practice of measuring economic efficiency through the comparison

Administration of the USSR) with the task of "compiling planned and realized fuel and power balances for the country as a whole and for individual economic regions within it".

Such a plan was duly produced.

The Unified Balance of Power Resources was based on: -

a) interchangeability of various types of sources of power when in use,

b) the possibility of converting one form of energy into another,

c) the possibility of combined production from a single source of various forms of energy (for example - simultaneous production of heat and power at the thermification power stations) and

d) using the same source of energy for various purposes (for example - use of electricity as prime mover and for technological needs).

It was realized that to prepare a unified balance it is necessary in all cases to choose one or another source of power to satisfy needs, and to decide on the correct allocation of power resources between various uses. As the number of sources and the range of uses is increased the problem becomes more and more complicated. An effective solution could only be found by taking an all sided account of all the available resources on the one hand and all the requirements on the other - i.e. on the basis of a unified power balance for the entire national economy.

It was claimed that with the aid of such a balance an inter-industry and inter-regional relationship in the field of production and consumption could be worked out, which would allow for optimal satisfaction of power needs combined with maximum economy of productive resources in power industry branches. This would insure a high rate of economic development on the basis of economical power balances. Due to interchangeability and mobility of power resources the unified power balance represents the unity in production, distribution and use of all resources and types of power, reduced with the aid of coefficients to a common evaluation. The power balance of the national economy can be represented as in schedules A and B attached below.

In schedule A, subdivided into sources, we see the unified power balance linked up with the natural resources of the country and its various regions (the reserves of fuel, hydroelectric resources and others). Schedule B classifies power in the forms acquired by it to determine the needs of the national economy in heat, mechanical, electrical energies inasmuch as the power is used in these forms in production or for general purposes. The schedule B classification is also necessary to estimate the amount of equipment (steam and internal combustion engines, turbines, and so on) which is necessary to produce the appropriate form of energy. Through the intermediary of schedule B the balance of power is also coordinated with the balance of installed capacity of power.

The columns in the expenditure section of the balance reflect distribution of power according to:

a) Economic purposes

b) Branches of economy

of the rate of increase of the productivity of labour within a given branch of industry over a period of time. For the first time the problem was faced squarely and a new approach was made through the consideration of maximum effect at a minimum cost for the entire fuel economy. It is obvious, however, that only approximate estimates of comparative costs could be made at that time as no combined fuel and power balance had as yet been prepared. The new approach was officially summarized by S. Feld in Voprosy Ekonomiki in March 1960. The author stressed the need for a unified, coordinated fuel balance for the country as a whole, a point made by A. Probst four years before, but about which, apparently nothing was done.

> "The criterion for the long range planning in various branches of the economy and for the economic regions of the country should be, to a considerable degree, based on the necessity of utilizing all power resources <u>in their most rational combination</u>. In the course of interbranch subdivision of power resources and constant changes in the rate of growth of the individual branches, the problems of coordination of production and of its power resources becomes very complicated. The problem cannot be solved by means of isolated power balances, since in the isolated power balances the production, distribution and utilization of various power resources are considered separately from one another. To solve this problem it is necessary to prepare a single power balance for the national economy. The preparation of a single power balance is the way to unify and interrelate separate balances prepared according to the types of power resources (balances of coal, oil, electric power, etc.). <u>On the basis of an all sided inner interrelation of these balances, the necessary coordination in the development of various branches of power resources for the country as a whole, and for individual economic regions can be attained</u>."(21)

S. Feld then says that in response to the need for the overall fuel balance, at the beginning of 1959 the Government had entrusted the Gosplan and Ts.S.U.SSSR (Central Statistical

SCHEDULE "A"

Balance of Power Resources (in bil. kwh)

	RESOURCES				EXPENDITURE										
					Converted into types of energy					losses					
					thermal power		mechanical power								
	Stocks at the beginning of the period	Production	Imports	Total Resources	Total	Including used eventually as heat	Total	Including used eventually as mechanical energy	Total (without double counting)	In the course of extraction, processing and transporting	Whole generating	Total	Export	Stocks at the end of the period	Total expenditure
1	2	3	4	5=2+ +3+4	6	7	8	9	11=7+ +9+10	12	13	14= 12+13	15	16	17=11+ +14+ +15+16
I Hard fuel: types[1]															
II Liquid gas fuels: types[2]															
III Water power															
IV Nuclear power															
V Wind energy															
VI Sun energy															
VII Geothermy[3]															
VIII Drought cattle															

1. Coal, peat, shale, firewood
2. Oil, natural gas, factory gas
3. Utilization of subterranean steam and hot water. According to Academician M.A. Lavrentyev the entire Kamchatka could be heated in this manner. Voprosy Ekonomiki 1960 III p. 17

SCHEDULE "B"

Balance of Types of Energy (in bil. kwh).

	Thermal Energy[2]	Mechanical Energy	Electrical Energy	Total
A. Production[1]				
B. Expenditure				
a). Gainfully utilized energy				
I. 1) For production purposes				
Including				
In industry and building of which				
technological purposes				
prime mover power				
heating and lighting				
2) In goods transport				
Including as prime mover				
3) In agriculture				
Including as prime mover				
4) In other branches				
Total				
Including				
For technological purposes				
As prime mover				
As heating and lighting				
II. For non-production needs				
Including: for population needs				
for passenger transport				
Total				
Including: prime mover				
heating and lighting				
Total of gainfully utilized energy				
Including: technical needs				
prime mover				
heating and lighting				
b). Losses of energy in transmission				
Total used				

1. Without double counting i.e. columns 7,9,10 and 11 Schedule A.
   Voprosy Ekonomiki I960 III p. 16

2. Could be further subdivided into high and low potential.

c) Technical uses (as a prime mover, for technological purposes, and others).

Care must be taken in treating energy appearing several times, when transformed from one form to another. The repeated or secondary forms must be included for calculations necessary to estimate equipment needs, while only original (nett) output should be taken for measuring productivity, total output and so forth.

- V -

One of the controversial points in the preparation of a unified power balance is the question of reducing various resources and forms of energy to a common measurement.

As the overall equivalent of energy in the final calculation either a thermal or electrical measurement unit could be selected. The electrical equivalent possesses a number of advantages, explained by the universality of electricity. For this reason kwh. potentially more than any other unit answers the requirements as a universal equivalent of energy and it also has a common base with the measurements of the capacity of electrical equipment and motors. This gives it a single standard for defining power capacities and the degree of their exploitation. Additionally the same electric standards are acceptable in all countries, which is not the case with thermal units.

Nevertheless, whether thermal or electrical standards are to be used depends on the processes and purposes of investigations. When analysing the heat producing capacity of the combined power balance it is preferable to use a conventional fuel unit or "kg/calory".

To reduce various sources and forms of energy to a common measurement the following indices are taken:-

i. The weight equivalent of a unit of energy resource is measured in number of kilograms of extracted fuel which on the average are required for the production of 1000 kwh. of potential energy contained in all power resources (kg/1000 kwh.).

ii. Average labour equivalent of a unit of energy is measured in terms of average expenditure of man/labour days necessary to produce 1000 kwh. of potential energy contained in power resources (man labour days/1000 kwh - man l.d./kwh).

iii. Average cost of the unit of energy is measured in terms of average expenditure in money necessary for the production of 1000 kwh. of energy contained in power resources - Rouble/1000 kwh.

For the qualitative designation of the balance of fuel it is more convenient to use indices based not on the unit of labour/kwh, but on heat producing capacity of 1 kg. of extracted fuel. Such indices could be:-

a) Amount of heat produced on an average by 1 kg. of extracted fuel (kcal/kg.)

b) The average requirement of labour for one conventional ton of extracted fuel (man l.d./1 ton) or labour equivalent for 1 million calories (man l.d./ 1 million cal.)

c) Average cost of 1 conventional ton of fuel extracted (Rouble/ 1 conventional ton) or cost of one million calories (R/1 mil. calories).

The weight of fuel resources corresponding to 1000 kwh of energy varies greatly in different branches of the power industry. The full electrical equivalent of 1 kg. of coal is approximately 8 kwh., consequently 1000 kwh. of energy corresponds to 125 kg. of this fuel.[22] The corresponding electrical equivalent of oil is 12 kwh/kg. and the weight equivalent is 83 kg./1000 kwh; of peat 4 kwh/kg and 250 kg./1000; oil shale 3 kwh and 333 kg/1000 kwh; wood 4 kwh/kg and 250 kg/1000; nuclear fuel 22850000 kwh/kg. and 0.0000438 kg/1000 kwh.

Having prepared a unified fuel balance (See table overleaf) the Russians noted that the structural character of their fuel and power balance was moving in a direction opposite to the rest of the world.

Due to technological improvements in the utilization of fuels and a shift from low calory content to high calory content, for the world as a whole, the average amount of fuel necessary to produce 1000 kwh. declined between 1860 and 1953 from 211.7 kg. to 112.3 kg. The gain due to the shift from low to high calorific value fuels amounted in 1953 to the equivalent of 2391.6 mil. tons of conventional fuel. During this period the world first moved away from using wood to using hard mineral fuel and is at present moving away from hard mineral fuels to the preponderent use of soft mineral fuels. The Russians themselves estimate that the peak of this phase will occur sometime in 1970ies, when the world will move to the next stage - the predominant use of nuclear energy. Soviet Union however, in their past fuel policy, did not follow this course.

Contrary to tendencies in the development of fuel and power industry in the rest of the world, in the USSR the share

TABLE III

DEVELOPMENT OF THERMAL AND WEIGHT EQUIVALENT OF THE FUEL
AND POWER BALANCE OF THE USSR, 1913 - 1958

	Coal in mil. t.	Oil in mil. t.	Gas in mil. cub. in.	Peat in mil. t.	Oil Shale in mil. t.	Wood	TOTAL FUEL in mil. t.	TOTAL FUEL in 10^{12} cal
1	2	3	4	5	6	7	8 = 2+3 +5+6+7	9
1913	29.1	9.2	-	1.7	-	20.7	60.7	321.3
1928	35.5	11.6	304.0	5.3	-	(15.9)	(68.3)	(379.4)
1940	165.9	31.1	3219.1	33.2	1.7	79.3	311.2	1663.9
1945	149.3	19.4	3278.0	22.4	1.4	66.0	258.5	1295.0
1950	261.1	37.9	5760.9	36.0	4.7	64.9	404.6	2178.4
1955	391.3	70.8	8980.9	50.8	10.8	75.3	599.0	3359.3
1958	495.8	113.2	28084.5	52.8	13.2	76.5	751.5	4408.0

TABLE III

DEVELOPMENT OF THERMAL AND WEIGHT EQUIVALENT OF THE FUEL AND POWER BALANCE OF THE USSR, 1913 - 1958 (continued)

	Average heat producing capacity of the fuel cal/Kg	All fuel in bil kw/h	Hydro energy in bil. kw/h	All power resources in bil. kwh	WEIGHT EQUIVALENT Kg/1000 kwh	WEIGHT EQUIVALENT in % of 1913
	10=9:8	11	12	13=11+12	14=8:3	15
1913	5293	373.6	0.035	373.6	162.4	100.0
1928	(5555)	441.2	0.4	(441.6)	(154.7)	95.3
1940	5345	1934.9	5.1	1940.0	160.4	98.7
1945	5010	1505.9	4.8	1510.7	171.1	105.4
1950	5384	2533.0	12.7	2545.7	158.9	97.7
1955	5608	3906.4	23.2	3929.6	152.4	93.8
1958	5866	5125.6	46.5	5172.1	145.3	89.5

1. Sources: Voprosy Ekonomiki 1960. III. p. 23.
   based on Promishlennost' SSSR. 1957. pp. 133, 140, 153, 165, 166, 171.
   Pravda 16.11959. On the results of the fulfilment of the State Plan for the Development of National economy during 1958.
   Column 9. Obtained by computing conventional fuel 1t. = 7000 cal.
   Column 11. Data on fuel in electric units (col. 11) were obtained by re-computing fuel calculated in thermal units (col. 9) at 1 kwh = 860 Kcal.

2. Weight of wood in natural form (col. 7) was calculated assuming that 1 t. of wood in natura = approx. 0.43 t. of conventional fuel.

of coal and local mineral fuels in the total extraction of fuel not only did not decline, but on the contrary, increased from 51.8 per cent in 1913 to 69.8 per cent in 1955. At the same time the share of the high calorific value fuels - oil and gas - declined in the fuel balance of the USSR from 28.8 per cent (in 1928 it even reached 30.8 per cent) to 23.5 per cent.

Thus the Soviet trend in the fuel industry followed the world trend only insofar as it moved away from the use of wood, but while the rest of the world was changing to oil and gas, Russia followed a deliberate policy of boosting up the coal industry. Until 1953 the share of coal and peat in the national balance of fuel continued to grow, with the result that while the world average heat-producing capacity increased from 5812 calories per kg. in 1913 to 7520 in 1953, an increase of 29 per cent, the figures for the USSR were 5293 and 5608,[23] an increase of less than 6 per cent. Weight equivalent in the USA declined between 1913 and 1953 from 147.5 to 112.3 while in the USSR the change was from 162.4 to 152.4. (See table below)

Average Weight Equivalents in Fuel and Power Balance[a] of the USSR and USA in kg. per 1000 kwh.

Year	1913	1953	Reduction in no. of kg. required to produce 1000 kwh.
USSR[b]	162.4	152.4	10
USA	147.5	112.3	35.2
Excess of the USSR Weight equivalent over that in the USA	14.9	40.1	25.2 Increase in difference between the weight equivalent in the two countries.

(a) Prepared on the basis of Table III

(b) Soviet figures for 1913 and 1955

The reason for this was the slowness to move to the more economical non-solid fuels, the tendency to replace wood with coal, peat and other fuels of low calorific content.

What were the causes of this development?

S. Feld gives the following answer.

> "It was caused by the fact that for many years the development of the fuel balance of the USSR was orientated on the predominant use of coal, including brown coal of low calorific content, and also to a certain extent of peat. At the time the line was justified on grounds that it was necessary in every way to develop local fuel resources; this however, without proper economic calculations of the expenditure of labour and material and money spent on the exploitation of these resources.
>
> The resulting economy in transport costs repaid only to a small degree the extra costs and investments necessitated by the unfavourable natural conditions and most of all by the low calorific content of the local fuels. These mistakes would not have occured if the order of priorities for fuel consumption within the country as a whole was always prepared on the principle of priority of national interest over local. The basic criterion of this, all-national, approach, both in this particular case and elsewhere, is the need to safeguard increases in the productivity of productive forces as a whole, the all-sided evaluation of all labour expenditures both on production and on transport"[24]

To put it in another way, the author advocated the need to consider overall minimum costs for the entire fuel economy.

It is sometimes claimed that the original decision to develop the coal industry was based on insufficient information about the extent of available natural resources of oil. Yet even before the war it had been stated by the Russian experts that the USSR had the largest reserves of both oil and gas in the world.

> "The shortage of investigated resources of industrial type was due to slow development of geological research in oil and gas, probably caused by incorrect decisions with regard to fuel consumption in the country. A considerable part was played in this by the bureaucratic administration of industry. It is a known fact that in the past the administration of fuel and power was split between a number of ministries, each principally interested in the development of the branch subordinate to it. In the course of this the need to develop the fuel and power industry as a whole was considered to a lesser degree than the development of individual sectors. In many cases, the division of labour between branches of the fuel industry did not favour the growth in productivity of the productive resources. The overwhelming proportion of the labour force even today is concentrated in the coal, peat and wood industries - i.e. in those branches where the productivity of labour is the lowest."(25)

The Soviet economists were obviously startled by what they discovered when they compiled the unified fuel balance for the country as a whole. In this connection it was said that:-

> "The theoretical value of the decision to reorganize the fuel balance lies in the fact that it makes it possible to uncover on the example of one of the leading branches of national economy the organic, internal link between the division of labour and the level of its productivity. As a rule this link is considered in our literature from one angle only; namely -- <u>that the relation of the rates of growth in the productivity of labour in various individual branches is one of the deciding factors of the inter-branch division of labour. But there is the other aspect of this problem: distribution of productive forces between the branches of economy and areas of the country in its turn determines the achieved level of the productivity of the productive forces</u>. To put it in another way, the expenditure of labour necessary to produce a given volume of goods depends also upon the subdivision of labour between the branches of production and the economic regions.
>
> Taking fuel economy as an example it has been shown above that under certain historical conditions the reshaping of branch structure can be a powerful factor in reducing expenditure of labour, i.e. in raising its level of productivity."(26)

The recently started reorganization of the fuel economy of the USSR, expressed mainly in the high priority awarded to the development of gas and oil industries, has caused

TABLE IV

CHANGES IN HEAT AND WEIGHT EQUIVALENTS OF RESOURCES ENTERING FUEL AND POWER BALANCE OF THE USSR IN 1958-1965

Quantitative and qualitative indexes of fuel and power Balance	Unit of measure	1958	1965 Plan	1965 Plan as % of 1958
1. Extraction of fuel physical quantities	mil. t	751.5	1030.7	137.2
2. The same converted into calories	10^{12} kcal	4408	7620	172.9
3. Average heat producing capacity of fuel (2:1)	kcal/kg	5866	7393	126.0
4. Extraction of fuel converted into kwh.	bil. kwh	5125.6	8859.9	172.9
5. Production of water power	bil. kwh	46.5	91.6	197.0
6. Total power resources (4+5)	bil. kwh	5172.1	8951.5	173.1
7. Weight equivalent of power resources (1:6)	kg/1000 kwh	145.3	115.1	79.2

the average heat-giving capacity of Soviet Fuel to increase between 1955 and 1958 from 5,608 cal/kg. to 5,866 cal/kg., while the weight equivalent correspondingly dropped from 152.4 to 145.3 kg./1000 kwh. i.e. by 7.1 kg. as against 2.3 kg./1000 kwh. achieved between 1928 and 1955. (See table III Development of thermal and weight equivalent of the fuel and power balance of the USSR, 1913 - 1958.) As can be seen from the table below even greater changes in the structure of the fuel balance are to take place during the next 7 years.

Structure of the Fuel Balance of the USSR 1958-1965 (in%).[27]

	Coal	Oil	Gas	Peat	Shale	Wood	Total
1958	59.6	25.7	5.4	3.4	0.7	5.2	100%
1965	43.1	32.6	17.6	(3.1)	0.6	3.0	100%

The share of oil and gas in the fuel balance will amount in 1965 to 50.2 per cent, and as a result the increase in the extraction measured in calories will be greater than in the physical volume.

The average heat giving capacity of fuel in 1965 will reach 7,393 cal/kg., an increase of 26 per cent over 7 years, against 6 per cent achieved between 1913 and 1955, and the weight equivalent will drop to 115.1 kg. - a drop of 20.8 per cent between 1958 and 1965. (See table on Changes in heat and weight equivalents of fuel and power resources of the USSR, 1958 - 1965).

Improved indices of heat giving capacity will be reflected in the increased productivity of labour in the production of power resources. In 1956, average labour expenditure in the USSR to produce 1 ton of oil was 0.334 days, 0.728 days for 1 ton of coal. Bearing in mind that the average heat-giving capacity of oil is 10,000 kcal/kg. and of coal 5560 kcal/kg. the heat giving capacity of 1 ton of conventional fuel extracted in oil industry equals 0.234 labour days and in the coal industry - 0.917 labour days. Thus, considering labour requirements alone, the cost of producing coal was in 1956 more than 2 times greater than the cost of producing oil, while the number of calories obtained from burning one kg of oil was nearly twice as large as could be obtained from 1 kg of coal. Consequently in terms of labour requirements coal was approximately 4 times dearer than oil. This is why the reorganization of the structure of the fuel balance to give more weight to liquid and gas fuels with higher heat giving capacity would lead to a reduction in labour requirements necessary to produce a given amount of fuel in terms of calories. (See table V on Structural changes in the Fuel Balance and labour Requirements to produce 1 ton of conventional fuel, 1958 - 1965).

As can be seen from table V due to reorganization of the fuel balance alone, the labour requirements to produce 1 ton of conventional fuel will decline over 7 years by 0.248 labour days, i.e. almost 25.9 per cent.

In 1965 the fuel extraction of the USSR in thermal units is expected to reach approximately 7620 x 10^{12} kcal.,

TABLE V

STRUCTURAL CHANGES IN THE FUEL BALANCE AND LABOUR REQUIREMENTS TO PRODUCE 1 TON OF CONVENTIONAL FUEL IN 1958-1965.

Fuel Resources	Labour required to produce various fuels in 1956	1958 Structure of Extraction %	1958 Average labour requirement for all types of fuels and its components	1965 Structure of Extraction %	1965 Average labour requirement for all types of fuel and its components
1	2	3	4 = 2x3	5	6 = 2x5
Coal	0.917	59.6	0.547	43.1	0.394
Oil	0.234	25.7	0.060	32.6	0.076
Gas	0.066	5.4	0.004	17.6	0.012
Peat	2.237	3.4	0.076	(3.1)	(0.069)
Shale	1.559	0.7	0.011	0.6	0.009
Wood	5.000	5.2	0.260	(3.0)	0.150
Total	----	100.0	0.958	100.0	0.710

or 1090 million tons of conventional fuel.[28] The saving in labour days due to the drop in labour requirements will amount to (1090 million tons x 0.248 labour days) nearly 27 million labour days, or counting 270 days as a working year, equivalent to a saving in the labour force of almost one million people.

- VI -

At present the fuel industry employs nearly 1,300,000 workers and another 600,000 are engaged in the wood industry. A drop in labour requirement as indicated above, coupled with the planned increase of 72.9 per cent in the productivity of labour would make it possible to realize the planned increase in the output of fuel with practically no increase in the labour force.

The negative point of the present fuel balance is not only the large role played in it by coal, but also the extremely important position occupied by peat and wood. The influence of peat and wood on the index of average labour requirement for fuel extraction as a whole is much greater than their share in the fuel balance. Sharp differences in labour requirements for the production of gas, oil, coal and other fuels, result in the fact that the distribution of labour consumption between the branches of the fuel industry does not correspond to the proportions these branches occupy in the total fuel production.

In 1958 the coal industry accounted for 59.6 per cent of total fuel production and 57.1 per cent of all labour expenditure. For the oil industry corresponding figures were 25.7 and 6.3, for gas 5.4 and 0.4, for peat 3.4 and 7.9, for oil-shale 0.7 and 1.1 and for wood 5.2 and 27.2 per cent. The oil and gas industries jointly employed 6.7 per cent of the total labour force and produced more than 30 per cent of all fuel, while peat and wood industries employed over 35 per cent of the labour force and produced only 8.6 per cent of fuel. This means that approximately 150,000 workers employed in the oil and gas industries in 1958 produced 3.4 times more conventional fuel than nearly 700,000 workers employed in the peat and wood industries.

> "In this connection the question arises whether there is any sense in continuing to use wood and, in many cases, peat as fuels. Compared with oil and gas, expenditure of labour in these branches looks more like a squandering of national productive forces, which amounts to scores of millions of labour day units every year.(29)
> The output of wood should be reduced. It is better to use timber industry by-products for the production of cellulose. Peat should be produced only under the most favourable conditions, to be used in power stations specially constructed for the purpose. Local peat industries should be used to produce fertilizers."(30)

The structural shift in the fuel and power industry should make it possible not only to increase the productivity of labour, which can be seen from the reduction in the amount of labour used, but also to economize in the overall expenditure of productive forces, measured to a certain degree by the index of the costs of production. Improvement in this index would express the second important result of the growth in the heat-giving capacity of the extracted fuel and the corresponding

TABLE VI

STRUCTURAL SHIFTS IN THE FUEL BALANCE AND COSTS OF PRODUCTION OF 1 TON OF CONVENTIONAL FUEL IN 1958-65

	1958			1965		
Fuel Resources	Cost of production of various types of fuels in 1956 (in R. and K. per 1 t. of conventional fuel)	Structure of extraction %	Average cost for all types of fuel and its components (in R. and K. per 1 t. of conventional fuel)	Structure of extraction in %	Average cost of prod. of all types of fuel and its components (in R. and K. for 1 t. of conventional fuel)	Difference in costs between 1958 - 1965 caused by Structural shift (± in R. and K. per 1 t. of conventional fuel
1	2	3	4 = 2x3	5	6 = 2x5	7 = 6 - 4
Coal	81.81	59.6	48.76	43.1	35.26	- 13.50
Oil	28.92	25.7	7.43	32.6	9.43	+ 2.00
Gas	12.36	5.4	0.67	17.6	2.18	+ 1.51
Peat	86.52	3.4	2.94	(3.1)	2.68	- 1.26
Shale	148.32	0.7	1.04	0.6	0.89	- 0.15
Wood	245.00	5.2	12.74	(3.0)	7.35	- 5.39

1. According to calculations by the same author the average cost of production of all resources (including water power) per 1000 kwh will decline only as a result of structural changes in the fuel economy from 9 R. 17 K. in 1958 to 7 R. 23 K. in 1965, i.e. by 21.2%

2. Source: Voprosy Ekonomiki. March 1960. p. 29.

KEY: R. Roubles K. Kopecks

reduction in the average weight equivalent of power resources. (See table VI - Structural Shift in fuel Balance and cost of production of 1 ton of conventional fuel 1958-1965.)

If we take as a base for our calculations the fuel costs prevailing in 1956, the average expenditure for 1 ton of conventional fuel will decline from 73.58 Roubles in 1958 to 57.79 Roubles in 1965, i.e. by 15.59 Roubles, or 21.5 per cent over 7 years.

According to preliminary calculations, the output of all types of fuel in 1965 will reach approximately 1090 million tons of conventional fuel, and therefore the saving resulting directly from this structural change will be (1090 x 15.79) 17.2 billion Roubles in 1965 alone. In a recent Soviet publication this saving is presented in the following way.

> "The total savings for the national economy that would result from the measures that are being taken during the current 7 year plan to improve the structure of the fuel balance would, according to preliminary estimates, amount to approximately 125 billion Roubles, i.e. equal to the total amount earmarked for the construction of power stations and electric and thermal networks."(31)

Apart from the reduction of production expenses, accelerated development in the gas and oil industries will make it possible to save energy in consumption, mainly through smaller losses of energy. Thus, for example, switching rail-way lines to diesel and electric traction instead of coal burning steam locomotives, will make possible a fivefold increase in the coefficient of utilization of power resources. Considerable increases in the coefficient of utilization can also be attained in shipping and other fields.

- VII -

Disproportions which have developed in the fuel industry over the twenty-five years preceding 1955 have now been ascribed to the lack of a unified fuel balance, to bureaucracy and to the development of the fuel industry by ministries rather than for the country as a whole. It must, however, be pointed out that it is during this period that planning from the centre was developed. It is difficult to believe that Gosplan, a body that has prepared one Five Year Plan after another has been prevented by ministerial sectionalism from producing a unified balance. Yet as stated by A. Probst(32) <u>no such balance existed in 1956</u> and it was only in 1959 that a commission was set up to prepare one.(33) One might ask what was the reason for the slowness in developing the oil industry. A probable answer to this is that long range planning, though a valuable thing for guidance, contains within itself, under a system of rigidly determined priorities, an element of restraint with regard to the progressive evolution brought about by the constant interplay of relative costs in various industries. These costs in the past have been continuously reduced by technical improvements and competition. This restraint is particularly strongly manifested in an absolute dictatorship as existed in the USSR towards the end of Stalin's life, when a call for the revision of previously approved policy could have been interpreted as criticism or even opposition. For example, how could anyone criticise the existence of local basins producing high cost coal and peat when Lenin, Stalin and the Party have repeatedly called for their development.

There is ample evidence to show that since 1953 conditions allowing for greater freedom of discussion have been created, which permitted the disclosure of existing disproportions within the fuel industry. The existence of the disproportions was conclusively demonstrated through the reduction of all types of fuel to a common denominator - a conventional fuel unit. But the discovery of disproportions in the past is not a guarantee for a correct structure of economy in the future. Besides, fuel economy is only one of many fields, and it is affected by the situation in other branches.

Can a unified balance be prepared for other industries, such as iron and steel, transport, chemical, machine building, and others, and finally can all these industries be reduced to a common yardstick for the purpose of comparison?

The answer is no. If, however, it could be done, then industries could be set side by side as has been done with the branches of the fuel industry and the ones that require capital and labour expenditure least could be made to expand, as is being done with oil and gas, while the others might be allowed to decline; provided of course that the economic factors are allowed to operate, which is not necessarily the case, despite the realization of the disproportions. The priority mix under a centrally controlled economy is determined not

not only by economic but also by political considerations.

In a centrally planned economy the prices are set by planners and so are supply and demand. Where prices are thus fixed, and because the bulk of profit goes to the state, the industries with low costs (as for example oil and gas industries in the USSR in the past) would not be able to make use of their advantageous position to expand. The change in output is dictated not by an increase in demand motivated by lower prices, but by government decision based on other considerations. Low costs would lead primarily to an increased government revenue and not to an expansion of the given industry, the size of which is determined by the plan beforehand.

Under conditions where, through deliberate policy, the government disrupts the natural balance of prices, it is faced with the impossible task of determining for every commodity the supply, demand and price as well as cost and profit. In the absence of a free market there are no forces to point out the wrong decisions, and wrong decisions become multiplied as their repercussions are incorporated in the succeeding plans.

To-day Russian economists must decide at what rate, how much and for how long the oil and gas industries are to be allowed to expand and other fuel industries to decline or mark time. Outputs, demands, costs and prices must be all planned in advance. Who is to make the decision as to what these should be and on what basis?

- VIII -

A new form of energy - nuclear energy - has come into existence. In the free market economy, apart from the initial stages where research and development of atomic energy have been sponsored by the government for strategic and political considerations, the position of nuclear energy would be determined by the interplay of forces in the economy, i.e. by its value.

In the 'Economic Problems of Socialism in the USSR' Stalin, who is still considered an outstanding theoretician, said:-

> "The sphere of operation of the law of value in our country is strictly limited, and thus under our system the law of value cannot function as the regulator of production"(34) .... and again .... "the law of value is limited by social ownership of the means of production, and by the law of balanced development of the national economy, and is consequently also limited by our yearly and five-yearly plans, which are an approximate reflection of the requirements of this law"(35) .... "In brief, there can be no doubt that under our present socialist conditions of production, the law of value cannot be a 'regulator of proportions' of labour distribution among the various branches of production"(36)

There are a number of ways in which the government can control production, consumption, or both. For example, in the past, to discourage consumption of oil products the government raised the price and at the same time took other measures to restrict the consumption. The firms allocated oil products received them whatever the price, and the ones which did not get an allocation had to switch to other fuels. The oil industry on the other hand did not enjoy the benefits of the high price, for the difference between the cost of production and the selling price went to the government to be used - more than likely - to subsidize development of the coal and peat industries. The growth or decline of any branch of economy was conditioned not by the demand for its products from the consumers, indicating their preference for it compared to other alternative products available, but by the decision of the planners, based on the data of the preceding period or periods and on considerations of other, non-economic factors.

In the past the increase in the efficiency in a given industry was judged by the increase in the productivity of labour in it. As long as the expenditure of labour kept declining in consequence of investments more or less equal to those in other branches, all was considered to be well.

In the maze of inflationary pressures, shortages and disproportions, prices were changed from time to time, primarily to reduce subsidies or to increase government revenue. No comparison was made, or could be made, between branches of the economy because of the arbitrary price fixing.

This is why, as long as productivity of labour continued to increase in the coal and peat industries (and it was bound to do so with mechanization and introduction of modern methods) the planners were content.

A unified fuel and power balance pointed out clearly that, had the capital and labour employed in coal and peat industries been transferred to oil and gas, its output in terms of thermal units would have been increased and thus the economy would have benefited. The same can be said for other fields - for example railways and shipping, where it was possible to show that use of alternative sources of power would have resulted in a considerable saving.

In the fuel industry of the USSR the way to the most economic utilization was indicated through the use of a unified fuel balance, which made it possible to compute a universal standard for the fuel industry.

The universal standard for an economy as a whole is "value", which evolves as a result of the interaction of economic forces in a free economy. In an economy where factors are determined in an arbitrary manner, there can be no 'value' to serve as a medium with the aid of which projects in various fields could be reduced to a single standard for the purpose of comparison and evaluation.

One of the results of the recent structural changes in the fuel balance of the USSR appears to be a reduction in the importance that is being attached to the development of atomic power. This 'shelving' of the atomic power has been brought about by the reduction in power generation costs resulting from the wide-spread use of natural gas and fuel oil.

No final examination of the Soviet policy with regard to fuel and power can be made without first subjecting to closer examination the Soviet programme for the development of atomic power.(37)

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PART TWO: ATOMIC POWER

CHAPTER IV

THE PLACE OF NUCLEAR FUELS IN THE OVERALL FUEL BALANCE

Nuclear fuels are, after all, new types of fuel and as such their eventual place in the overall Balance of Fuel will be determined by their costs of production(1) and exploitation and consequently by relative costs of all types of fuel per unit of energy produced. This is true for the economies both of the West and of the USSR. But while in the free market economies costs determine the rates and directions of development, in the USSR this is not the case. There, the rates and directions of development are determined by the planners, who, by interfering with market forces, make proper calculations of costs impossible.

At the present stage of atomic power development the most efficient and least costly production techniques of atomic power are still unknown. It is the task of the scientists and engineers to improve these techniques and to pursue their investigations until the most efficient can be selected for future use. On the other hand application of atomic power depends also on prices of conventional fuels, and it is therefore countries with high costs of fuel which are the most interested in the new form of fuel and therefore have a greater material incentive to undertake research and to put to practical test these new forms of fuel.

This part of the study deals, accordingly, with those developments which are at present under way, the incentives involved in introducing these new developments and the shifts in fuel balances which may be expected as a result, first in the leading Western countries - U.S.A., United Kingdom and Canada - and then in the Soviet Union.

In each case a study is made of conventional reserves of fuels and of the demand for fuel and power. Then a survey is made of the atomic power development and research programmes, which made it possible to approach the problem of anticipated costs of atomic power. Finally, these costs of atomic power are compared with the costs of power from conventional fuels. Consideration of reserves of conventional fuels and their costs of extraction on one side and of probable future costs of atomic power on the other leads to a conclusion on the likely shifts in the future fuel balances.

In the case of the Soviet Union, this part deals mainly with nuclear atomic development. The question of fuel balance has been dealt with in Part I, while the detailed summary of the reserves of various forms of conventional fuels is given separately in appendices. As in the case of the Western countries an effort is made to outline the likely shifts in the future fuel balances.

Paucity of published data and uncertainty of future programmes have no doubt left a strong imprint on the following pages and rendered them overly descriptive. Still, the Soviet fuel balance of the future will be affected by atomic power and therefore even a cursory review of what is going on in this field seems to have a useful purpose.

R E F E R E N C E S

1. The costs of transportation in the case of nuclear fuels are so small that they can be disregarded altogether.

CHAPTER V

ATOMIC POWER DEVELOPMENT IN THE MAIN WESTERN COUNTRIES

1. The Experience of the United States

(i) The Abundance of Conventional Fuels.

The reserves of conventional fuels and of water power in the United States are plentiful. First of all, the United States are blessed with abundant reserves of coal - estimated at 524, 729 million short tons of bituminous coal, 186,467 million short tons of semibituminous, 231,678 million short tons of lignite and 6,996 million short tons of anthracite and semianthracite; a total of 949,870(1) million short tons, while the consumption is about half a billion tons a year at present, expected to increase to 750 million tons per year. Without the advent of atomic energy the figure would have reached 820 million tons by 1980, plus 100 million tons for export.(2)

Of the 950 billion tons of coal deposits found in the U.S.A. approximately 237 billion tons could be mined at or near 1954 prices, another 280 billion tons could be produced at prices 25 per cent above 1954 and the rest at prices ranging between one and a half to four times the 1954 prices.(3)

It is expected that in future the percentage of coal mined from open cast mines will increase. Open cast mining accounted for 10 per cent of output in 1940 and for 25 per cent by the end of the nineteen fifties. Productivity in the open cast mines is three times higher than in underground mines.[4]

Out of half a billion tons of coal mined annually, 140 million tons go for the production of electricity and another 140 million tons are taken by the iron and steel industry.

The U.S.A. coal reserves are geographically dispersed, are of good quality and are less than 1,000 feet below the surface. The reserves suitable for open cast mining are also considerable. From the purely physical standpoint of geological reserves there is no engineering basis for a "higher cost of coal recovery than it is now during the next two decades."[5]

Secondly, the proved reserves of oil in the U.S.A. are twelve to fifteen times the annual output. They have remained so since the nineteen twenties and one can deduce from this that the oil companies do not wish to engage in a thorough study of reserves which they are not likely to use within the next twelve to fifteen years. The fact that the oil companies are unwilling to devote more than 0.5 per cent of the value of crude oil production to solving the problem of secondary recovery, which would result in the recovery of some of the tremendous amount of oil left underground, shows that they are confident that they will find more oil when they need it.[6]

Besides the crude oil reserves, estimated at 272 billion barrels,[7] of which approximately 88 billion can be produced at present prices by present methods, the U.S.A. has deposits of Colorado shale, from which gasoline could be supplied in Los Angeles or on the Gulf Coast at a price only 10 per cent above the cost of gasoline from crude oil at local refineries. These deposits are estimated at no less than 900 billion barrels of liquid hydrocarbons in shale of a content 11 to 50 gallons per ton.(8) Synthetic fuel could also be obtained from tar sands and coal. Thus, as in the case of coal, there is little fear that the reserves of oil will be running out in the immediate future, although in the long run they are much smaller than those of coal. With oil, as with coal, there is no reason why prices should undergo any appreciable increase in the near future.

Finally, the ultimate gas reserves of the U.S.A. are estimated at 3000-6000 trillion cubic feet (c.f.) Proved reserves of natural gas as of December 31st 1955, were 223.7 trillion c.f., that is approximately twenty two times the annual production.(9)

Over the past decade, the ratio of proved reserves to production has declined steadily from 32.3 to 22.1 years, but this does not necessarily mean that reserves are growing harder to find. Until large trans-continental gas pipe lines were built after World War II, opening up major markets in the North and East, gas was a waste product consumed locally.

It can thus be seen from the above summary of the natural fuel resources of the U.S.A. that for the next twenty to twenty-five years there is no likelihood of a fuel crisis, or of considerable price increases. The prices of coal are not likely to rise, first, because of the abundant supply of easily mined coal and second, because of competition from oil and more recently from gas and nuclear energy also. The price of oil, on the other hand, is not likely to rise because of competition from Middle East oil, shale and to some extent from gas and coal, as well as from nuclear energy. The price of gas is likely to rise a little to come into line with other types of fuels when access has been gained to better markets through further long distance pipe line construction. The cost of transportation and the cost of production and prospecting once the easily available reserves are exhausted would result in the price of gas becoming stabilized as well.

The competitive prices of fuels in the U.S.A. are determined by the price of bituminous coal and cost of transportation. Coal is the predominant fuel in the boiler-fuel market except for certain areas, particularly in the Southwest and West coast, where oil and gas have locational advantages. In 1955 the boiler market consumed 250 million tons of bituminous coal, compared with nearly 100 million tons of coal-equivalent in fuel oil. The importance of gas in the boiler fuel market is small and is likely to decline still further. The boiler-fuel market includes most of the thermal power stations and much of the industrial energy consumption for process heat. To this may be added some high temperature heat requirements as for example, cement production.

The size and the limits of the respective areas where different fuels are used as boiler-fuel depend primarily on cost of transportation, which is relatively highest in the case of coal.

(ii) Atomic Power Development and Research.

In the United States the consumption of energy has been increasing at the rate of seven per cent per annum and of electric power, three per cent per annum.[10] Although the prices of conventional fuels are likely to remain stable for the next fifteen to twenty years, it is generally considered desirable to develop low cost nuclear power to be readily available when conventional fuel prices show a tendency to climb up. But even before then atomic power will find application in areas where the supplies of conventional fuel at low cost are absent or inadequate, as for example in New England, Florida, and California, where present energy resources are insufficient for expanding needs. In addition the U.S.A. is intent on retaining its position of leadership in the field of nuclear research. The present programme accordingly aims at achieving economically competitive nuclear power for the high cost areas of the U.S.A. and for export to other countries lacking cheap natural resources for power production. In the long run the aim is to develop nuclear power units which will be suitable for uses other than electric power production, such as providing process and space heat, as a means of propulsion for ships, aircraft, and land vehicles, and in general providing a cheap source of power that could be widely used to raise the standard of living.

The United States is in the happy position of not being pressed by a shortage of conventional fuels to make an early decision on the type of reactor to be developed on an industrial scale. The present programme is designed to embrace both the short and the long term needs and is being developed on a broad scale.

Atomic power stations are best utilized as base load power stations because of their high construction costs and low operating costs. They could be supplemented by thermal or hydro-electric power stations at peak periods. The economics of scale operate very strongly in atomic power station construction, thus the power station will have to be of a certain size to be competitive. An important item in the construction of atomic power stations is shielding, which does not increase proportionately with the increase in size of the power station. It can be said, therefore, that at present and for some time to come, nuclear power will have a relative advantage in situations where very large single power reactors, in stations of several, can be accepted on a utility system, e.g. reactors of 300,000 kw. to 700,000 kw. grouped together in stations of one to three million kilowatt capacity. Seen in this light all reactors constructed before 1958 have essentially been development prototypes for the very much larger units which will follow.

It is hoped that the research will lead to production of power at costs lower than can be attained with conventional fuels. For example, at present a pressurized water reactor is being installed on N.S. 'Savannah'. Although operation of this vessel is not expected to be competitive, compared with the existing methods of ship propulsion, it is hoped that further advance in nuclear study will make it possible to install competitive boiling-water reactors at first in tankers and later on in other types of vessels.

Low temperature process heat from atomic reactors will probably come first. It will be obtained from water-cooled reactors. Other types of reactors will have to be used for high-temperature process heat. The long-term programme also has in view the conservation of fossil fuels, and through research, of nuclear fuels also.

The reactors, such as pressurized water, boiling water, organic-cooled and gas-cooled, give promise of providing nuclear power at a rate that in the very near future would make it competitive in some areas where conventional power costs are high. The long-term project also includes work on reactors, such as fast-breeding reactors, homogeneous reactors, thermal-breeding reactors, and others, which, it is hoped, will be able to produce nuclear power and heat at substantially lower costs than can be achieved by using fossil fuels. The fast reactors of the future, being breeder reactors, will contribute to the conservation of nuclear fuels.

To this must be added the role of nuclear development in modern warfare. Nuclear power stations can be built to produce primarily plutonium, necessary for the manufacture of nuclear weapons. Finally, in the present East-West contest the U.S.A., as leader of the Western bloc, could not afford not to engage in research in the nuclear field on account of the possibility of new technological and technical developments which might give whichever bloc is the more successful in their exploitation an advantage over the other.

(iii) Anticipated costs of Atomic Power.

The main factor determining to what extent nuclear energy could replace conventional fuel in a given area is the cost of transportation of conventional fuels to that particular area. The cost of transporting nuclear fuels is so small that it can be disregarded. Transportation costs represent a substantial factor in costs of energy in most locations. Due to improvement in transportation and a shift to cheaper forms of transport the cost of transporting energy has tended to decline over the past quarter century and it is likely to continue doing so in the near future. In the coal industry the shift is away from rail transport and towards truck and barges as well as coal pipe-lines and conveyor belts. Improvements in long distance power transmission often permit energy to be carried cheaper in the form of electricity than if fuel had to be transported to the consumer and there burned to yield the required energy. The transportation of crude oil in large tankers and by pipe-lines had a similar effect in the oil industry. The possibility of transporting gas in liquid form by barges up the Mississippi to Chicago or by tanker to other destinations could make gas transportation cheaper where long distances are involved. Over short distances gas pipe-lines provide a cheap enough method of transport.

In the production of electric energy at competitive prices, the atomic industry will first enter with large central plants, working at 75-80 plant factor, built in areas where conventional fuel prices are swelled by high transportation costs. In estimates prepared in May, 1957, for nuclear power stations of this type, with fixed charges of 13 per cent, allowing for the by-product fuel value of recovered plutonium and including 25 per cent contingency factor, the total generating cost is shown for three different[11] types of "second generation" plants as follows: (in mills per kwh.)

Reactor type	Mills per kwh. 50% plant factor	80% plant factor
Pressurized Water (U.S.)	15.0 - 18.8	11.3 - 14.1
Boiling Water (U.S.)	13.7 - 17.1	10.5 - 13.1
Gas cooled Graphite moderated (U.K.)		
Constructed in U.S.A.	18.2 - 22.3	12.7 - 15.9
Constructed in U.K.	15.4 - 19.2	10.8 - 13.6

The above costs are based on the assumptions of present technology. It is generally believed, however, that with more experience these costs will be substantially reduced and will reach, at 50 per cent plant factor, 12 mills per kwh. by 1965.

Although it is not expected that small atomic power plants will be able to compete with the conventional ones for a long time to come, nevertheless they are of interest because of their special characteristics (the very small amount of fuel required once the station has been constructed.) They are considered as possible small power plants in remote areas, such as polar regions, where fuel delivery would be extremely costly, and as propulsion power suppliers on submarines and ships, where high costs are acceptable for special reasons.

In considering the economic aspects of nuclear energy it is necessary to bear in mind projects undertaken for military and prestige reasons. Although nuclear propulsion installed in submarines and experimental land vehicles will not lead to the business world following suit as long as costs are above those that are obtained by using conventional fuels, the experience gained in the course of operating such special-purpose units is likely to lead to a reduction in costs of nuclear propulsion through development of more economical models sooner than would otherwise be possible. The same is true of the small power plants, the so-called "package reactors". Where atomic power stations are used to produce electricity and plutonium - the latter for military purposes - and where the plant is geared to produce amounts of these products not in that proportion where marginal costs are equalized, but where economy in operation is sacrificed to obtain greater output of plutonium, then the difference between the maximum possible total return and the actual return may simply be considered as a primary subsidy and the difference between the total returns and costs of the same commodity on the market (i.e. electric current) may be considered a secondary subsidy. The same is true of experimental, research and special-purpose reactors where high costs per unit of output are accepted for special reasons. As time goes on and the amount of experience and information in the field of nuclear energy studies increases, the share of research and experimental plants in the total plant construction will decline. Similarly, as the production of plutonium increases and the reserves for military purposes are met, the industry will stand more and more on its own feet and the share of subsidies in the total capital investments in the nuclear development will also decline.

The table below gives estimates of nuclear costs for power generation in large and small reactors in 1965 and 1980:[12]

	Large Plant		Small Plant	
Cost Item	Short term (1965)	Long term (1980)	Short term (1965)	Long term (1980)
Plant per kw	$225	$150	$350	$190
Generating costs at 50% plant factor mills/kwh.				
Fixed charges	6.9	4.6	10.8	5.7
Operation & Maintenance	2.0	0.5	2.5	1.5
Fuel costs (incl.stocks)	3.0	0.8	4.7	2.5
	11.9	5.9	18.0	9.9

The long-term estimates take into account the introduction of high-temperature and breeder reactors, the arrival of which will result in extensive economies of fuel, a decrease in the size of plants and a higher rate of utilization.

Nuclear energy could compete with conventional fuels in some areas in low-temperature heat generation, but only in those fields where very large quantities of fuel are required, such as petroleum refining, pulp and paper production, food preparation and chemicals manufacturing. Although high-temperature heat generation is not feasible at present because of the various technical problems that must be overcome, it is generally believed that it will be possible to use it competitively before 1980. The prospect of using high-temperature heat in the iron and steel industry, and in cement, brick and glass manufacturing is likely to stimulate lively research in these fields. The large amount of heat required in blast furnaces and cement production, combined with the round-the-clock activity of these branches would make nuclear heat obtained from reactors particularly suitable.

In 1954 the average cost per million BTU of coke consumed at the blast furnaces was 60¢. At cement mills the cost of all fuels averaged 38¢. per million BTU, while the projected nuclear fuel cost in electric power generation shown in the table above, corresponds to 23¢. per million BTU in 1965 and 6¢. in 1980.[13] (3 mills per 1 kwh or 10,000 BTU, therefore 30¢. per 1,000,000 BTU, including stocks).

The use of nuclear propulsion in ships will be feasible at competitive cost after 1965, though it is already used in submarines and ship propulsion under conditions where costs are a minor consideration. With regard to the use of atomic power in the propulsion of land vehicles, this will probably come at a much later date because of the size of the unit involved and the possibility of collision.

The locations where nuclear energy will be introduced will be closely connected with the present and prospective prices of boiler-fuels. In the table overleaf are given:

A - projected growth of power generation 1975-80 prepared by the Fuel Power Commission according to the Power Supply Regions and the type of prime mover, and B - Electric Utility boiler-fuel costs in 1954 and projected to 1980 according to the same Fuel Power Commission Regions. From the table two things are obvious. One - that nuclear power will be introduced where the price of coal is already high and where a further increase in those prices is expected. Two - due to the influence of the new sources of energy and the use of cheaper means of transportation the difference in the price of coal from region to region will diminish from 20.2 dollars in 1954 to 13 dollars in 1980.

F.P.C.	Increase in Generation - 10^9 kwh					Coal Prices.(14)	
Region	Total	Nuclear	Steam	Hydro	Int.Comb.	1954	1980
1.	36.0	41.2	- 5.2	0	0	31.9	38.5
2.	45.5	40.1	5.3	0	0.1	22.5	27.9
3.	53.5	28.9	21.9	3	- 0.3	26.0	32.2
4.	39.3	38.1	1.4	0	- 0.2	25.6	28.7
5.	27.3	12.5	14.4	0.9	0.4	11.7	25.5
6.	5.1	2.5	1.0	1.9	- 0.3	24.7	29.7
7.	29.6	10.2	9.9	9.5	0	24.4	29.9
8.	35.7	34.4	1.3	0	0	24.3	31.5
	272.0	207.9	50.2	14.4	- 0.3	Average-24.4	30.8

In region 1, where coal prices are very high and are expected to increase still further, a decrease will actually occur in the amount of power generated from coal. In region 5, on the other hand, where the price of coal will remain relatively low, more than half of the future increase of power production will come from coal burners.

(iv) Conclusion - Anticipated shifts in the future fuel balance.

Because of the way it is produced, nuclear energy is likely to find its largest market in the generation of electric power (approximately 60 per cent in BTU in 1980),[15] and in process and furnace heat. To begin with nuclear energy will be utilized in areas with the highest furnace fuel prices, then, as the prices of nuclear power drop, it will move nearer and nearer to the sources of fossil fuels. The entry of nuclear energy will have a retarding effect on the growth of coal output and will also prevent any rise in coal prices. The combination of nuclear energy and coal fuel position will, to a certain degree, effect oil and gas industries.

It is estimated that by 1980 the total energy consumption in the U.S.A. will increase from 40.3×10^{15}BTU in 1955 to 80×10 BTU, that is - it will almost double. In the table overleaf are given energy consumption figures by primary sources in 1955 and 1980, the latter projected in column A - based on conventional sources only, and in column B - allowing for the introduction of nuclear energy. As can be seen from the table the share of nuclear energy by that time will amount to approximately 8.7 per cent of the total. It is estimated that nuclear energy will displace $3{,}025 \times 10^{12}$ BTU

TABLE VII

Energy Consumption by Primary Source in 1955 and 1980 (Projection Based on Conventional Sources Exclusively (A) and allowing for the development of nuclear energy (B))

Prime Energy Source	1955			A 1980			B 1980		
	Convent. Units	10^{15} BTU	% of Total	Convent. Units	10^{15} BTU	% of Total	Convent. Units	10^{15} BTU	% of Total
Bituminous Coal & Lignite (mil.t.)	423.4	11.1	27.5	826.0	21.6	27.0	710.0	18.6	23.0
Anthracite (mil.t.)	23.6	0.6	1.5	25.0	0.6	0.8	25.0	0.6	0.7
Liquid Petroleum products (bil. (1) bbls)	2.81	16.3	40.5	6.2	36.0	45.0	5.8	33.6	41.5
Wet Natural Gas (trillion c.f.)	10.1	10.9	27.0	18.0	19.3	24.1	17.4	18.7	23.1
Hydro (bil. kwh)	120.0	1.4	3.5	277.0	2.5	3.1	271.0	2.4	3.0
Nuclear Energy (10^{15} BTU)	-	-	-	-	-	-	-	7.0	8.7
TOTAL	-	40.3	100.0	-	80.0	100.0	-	80.9	100.0

(1) May include liquid hydrocarbons in 1980 from oil shale as well as from crude oil.

equivalent of coal, 2,459 x 10^{12} BTU equivalent of oil, 557 x 10^{12} BTU equivalent of gas and 51 x 10^{12} BTU equivalent of hydroelectric power. The heaviest losers to nuclear energy will be coal and oil, and their main losses will be in the areas far removed from the place of origin of the mineral fuels. One can say, therefore, that the deciding factor will be the cost of transport.

As can be seen from the foregoing table, it is estimated that due to the entry of nuclear energy the output of bituminous coal will expand by 116 million tons less than it would have done otherwise, and the share of coal in the fuel balance will decline to 23.7 per cent as against 27.8 per cent. The effect of nuclear energy on the output of liquid petroleum products will not be so great. Here the output in 1980 is expected to rise to the equivalent of 33.6 x 10^{15} BTU instead of 36 x 10^{15} BTU, and the share of oil in the fuel balance will be 41.5 per cent instead of 45 per cent. The effect of the introduction of nuclear energy on natural gas and hydroelectric power will be to reduce their share in the fuel balance by 1.0 and 0.1 per cent respectively.

2. The Experience of the United Kingdom.

(i) Imports of oil and the Growing Demand for Fuel and Power.

The United Kingdom depends on coal as its main source of energy. As can be seen from the table below, British reserves of fuel are rather one-sided.

Indigenous Energy Resources of the United Kingdom.(16)

Resource	Total estimated reserves, as coal equivalent, in millions of tons.	
Coal	21,950	mineable in 100 years
	130,900	total proved reserves
	43,000	additional probable reserves
	195,850	
	500	Coal suitable for underground gasification.
	2	per annum - Coal methane, mine upcasts
	1	per annum - /possibly/ - mine drainage
	5	per annum - Water power
	0.3	per annum - methane from fermentation
	2 - 5	per annum - Wind power, if all suitable sites were utilized
	23 -	Scotland only - Oil shale
	110 -	Cannel
	? -	Lignite
	1 -	per annum, tidal power from Severn Estuary
	negligible -	petroleum
	not known -	natural gas
	500 -	peat, in Scotland only.

United Kingdom coal reserves are extensive. However, "irrespective of the quantity of coal remaining in the ground the prospects of increasing production sufficiently to overtake the rapidly increasing demand are far from hopeful. In the last four years deep mined output has been barely maintained at around 215 million tons."(17) In 1956 the British Government approved an investment of £1,000 million in the coal industry in order to raise the level of output from 220 million tons per year to 250. Although the output of coal can be increased to some extent, the position of coal vis-a-vis other forms of power sources is likely to deteriorate.

> "During the period between 1950 and 1956 the average pithead price of coal in the United Kingdom has gone up by no less than two-thirds. The landed price of fuel oil has gone up by over a quarter. Thus, measured in terms of the price of oil, the price of coal in the United Kingdom has gone up by thirty per cent in six year"(18)

In the face of the difficulties in expanding coal output the United Kingdom has had to recourse more and more to imported oil and oil products.

Given below are the figures for the Petroleum trade of the United Kingdom in 1938, 1948 and 1954. (In million tons.)(19)

	Imports of:		Principal Sources of Imports.			Exports & Re-exports.
	Crude oil	Refined Products	Middle East	Caribbean	USA	
1938	2.3	9.5	2.8	4.8	2.0	0.6
1948	4.7	13.4	6.7	8.1	2.0	0.3
1954	28.4	7.0	25.2	4.5	1.5	7.8

In order to reduce the volume of imported fuel the United Kingdom tried to develop coal gasification, production of methane from coal mine ventilating upcasts and coal mine drainage and also from the fermentation of sewage. All these sources, however, can only provide such small amounts that they could not influence the overall situation in the fuel industry.

The increasing imports of oil and oil products constitute a heavy drain on the foreign exchange resources of the United Kingdom and it is the combination of these two factors plus the absence of any appreciable reserves of hydro-electric power that forced Britain to take decisive steps towards the rapid development of nuclear power. It is interesting to observe that before a definite decision to develop atomic energy was taken, a certain amount of attention was given to the possibility of using peat as a source of electric power. It was, however, decided that the construction of peat-fired power stations would be just as expensive as the construction of atomic stations. There was, in fact, a race between peat and nuclear energy and it may now be considered that peat has lost. Peat-fired power stations are likely to be constructed only within the schemes of land reclamation.

The decision to develop atomic energy was further affected by the threatening fuel bottleneck in British electric power production, as one of the leading consumers of fuel in the United Kingdom is the Electric Industry. In the table overleaf are given Electricity Industry statistics showing the fuel consumption in 1950-1954.

It is generally believed that the demand for energy in the United Kingdom will increase much more rapidly than the fuel industry (which in the case of the United Kingdom means mainly coal) could be expanded. It is estimated that by about 1975 the United Kingdom will need approximately three and a half times as much

TABLE VIII

<u>Fuel Consumption in the Electricity Industry During the Period 1950 - 1954 Period</u>.

Year:	Total Installed Capacity				Units sent out	Fuel Used - mil. tons.[20]		
	Steam	Hydro	Others	TOTAL	Mil. kwh	Coal	Coke	Oil
1950	14,436	542	105	15,083	51,911	32.2	0.893	0.073
1951	15,598	625	109	16,332	56,589	34.7	0.778	0.086
1952	17,049	649	125	17,823	58,802	35.1	0.852	0.065
1953	18,477	656	123	19,256	62,094	36.2	0.916	0.097
1954	19,816	704	124	20,644	62,042	39.1	1.124	0.178

electricity as was being produced when the atomic programme was planned in 1954, i.e. 223,000 million kwh. as against 69,000 million kwh. This means that at the present rate of consumption the country would need to set aside, for the use of power stations, 43 million tons of coal in 1954, 70 million tons in 1965, and 100 million tons in 1975. The present output of coal, including extra Saturday shifts and open cast mining, amounts to approximately 225 million tons per year without becoming involved in excessively heavy capital investments. Imports of coal and oil from abroad would involve huge expenditures of foreign exchange.

(ii) Atomic Power Development.

Faced with the situation where the demand for fuel and power was growing, while the expansion of coal output presented serious difficulties, the U.K. government was very interested in the use of atomic energy for the generation of electric power and as an alternative source of energy in general.

Early research carried out by the Atomic Energy Establishment indicated clearly the possibility of using atomic energy. In 1953 the government concluded that the growing importance of the industrial application of atomic energy, and the need for an organization akin to that of a large industrial undertaking, required that responsibility for atomic energy development should be transferred to a non-departmental organization. As a result the Atomic Energy Authority was created in 1954, and assumed responsibility for the Atomic Energy project on 1st August, 1954. Its powers embraced the production, use, disposal of, and all forms of research into atomic energy and radio-active substances, but not decisions with regard to the production of atomic weapons.

In 1955 the first U.K. plan for nuclear power production was prepared. It provided for the construction of:

2 power stations of 100,000 and 200,000 kw. capacity to be started in 1957 and completed in 1960/61.

2 power stations to be started in 1958/59 and completed in 1963.

4 power stations to be started in 1960 and completed in 1965.

4 power stations to be started in 1961/62 and completed in 1965.

The total investment was to amount to £300 million and the total capacity of the atomic power stations was to be equal to 1.5 to 2 million kw, increasing to 10-15 million kw. by 1975.(21)

This plan underwent two changes even before the date when construction was to be started on the first atomic power station. The first was caused by the entry of Scotland into the plan. The second resulted from the discovery that the thickness of steel that could be welded together could be increased from the previously estimated 2-2½" to 4". This made it possible to more than double the capacity of the power stations and the programme was increased to 4 million kw.

In 1955 British coal production fell short by 3 million tons and $200 million had to be spent abroad for the purchase of foreign coal. As a result of this, and the oil crisis resulting from the Suez Canal conflict in October 1956, the plan was changed once more. It was planned to increase the installed capacity to 6 million kw. in 1965, that is three times the original estimate. The third programme provided for the construction of:

8 power stations, work on which was to be started by 1960.

6 power stations to be started in 1960.

6 power stations to be started in 1962.(22)

The investment funds for the Atomic Industry were raised to £900 million.

The raised installed capacity was expected to be equal to about 15 per cent of the country's generating capacity and to supply about a quarter of the country's electricity. It was expected that by 1970 atomic power stations would provide approximately 40 per cent of the country's electricity and 10 per cent of all energy used. According to Sir John Cockroft, nuclear power would be doing the work of 150 to 200 million tons of coal by the year 2000.(23)

It was proposed to reduce gradually the construction of conventional power plants and to introduce atomic power stations. Given below is a table of new generating plant expected to come into operation in the years 1960-1964, the total output capacity at the end of each year and the share of nuclear plant generating capacity in it:

Year:	Conventional Plant built	Nuclear Plant built	Total Addition	Total Capacity	Per cent of Nuclear energy
1960	2263	-	2,263	27,130	-
1961	1978	575	2,553	29,359	2.0
1962	1846	250	2,096	31,143	2.6
1963	1569	500	2,069	32,799	4.0
1964	1877	500	2,377	34,833	5.2(24)
	9,533	1,825	11,358		

Listed in the following table are the atomic power stations under construction or planned, as of November 1959.

During 1964/65 nuclear energy was expected to constitute 8 per cent of all the electricity produced in the U.K., replacing 4-5 million tons of coal or its equivalent, out of the total 64 million tons required.(25) According to the plan for expanded atomic development the Commission was to have placed large orders for nuclear capacity during the early nineteen-sixties for completion before 1965.

On 20th June, 1960 the Minster of Power made a statement that:-

> "Since the 1957 programme was published it has been kept under continuous review, and what has now been decided is that the higher rate of ordering this year and the next, which the 1957 programme envisaged, is no longer justified because of the changes in the fuel supply position and in relative costs. In relation to the 1957 programme only this means a slowing down but the rate of ordering will be about the same as over the past five years. The resulting additions to capacity are expected to be greater because the output per station is expected to increase."(26)

According to the new programme, power stations at Berkeley, Bradwell, Hunterston, Hinkley Point, Trawsfynydd and Dungeness are to be completed as planned. The Sizewell power station, to be completed during 1965/1966 will have a capacity of 550,000 kw. This will bring the total installed capacity to 2,9250,000 kw.

The scaling down of the atomic programme was due to two causes. Since 1957 coal has become plentiful, and the oil supply prospects have also improved. The need for a sharp and sudden acceleration of atomic power development on fuel supply

TABLE IX

Atomic Power Stations Under Construction or Planned, as of November, 1959.

Stations	Number of Reactors	Total Output Capacity	Number of Turbo Al-ternators	Date Work Started	Anticipated 1st Reactor	Completion 2nd Reactor
Berkeley (Glos.)	2	275	4	Jan. 1957	Dec. 1960	July,1961
Bradwell (Essx.)	2	300	6	Jan. 1957	Dec. 1960	June,1961
Hunterston (Ayrsh.)	2	300	6	Oct. 1957	Aug. 1961	Sept.1962
Hinkley Pt. (Som.)	2	500	6	Dec. 1957	Mar. 1962	Dec. 1962
Trawsfynydd (N. Wales)	2	500	2	June, 1959	---	---

Planned:

Dungeness (Kent)	500,000 kw	- Ministerial consent obtained.
Sizewell (Suffolk)	650,000 kw	- Application for consent under consideration. (Note: output capacity subsequently reduced to 550,000 kw.)
Oldbury-on-Severn	1,000,000 kw	- Application to be made to the Minister of Power and Local Planning authorities. (Project shelved.)(27)

grounds has disappeared. The other contributing factor is the substantial drop which has taken place in the costs of conventional power from the new thermal power stations. The development of larger generating sets has reduced the capital costs of the new stations, the use of higher steam temperatures and pressures has increased their efficiency, and careful siting near to low-priced coal sources has reduced the delivery costs of coal to them. But it is noted that the nuclear costs are falling even faster. Although nuclear power costs are at present 25 per cent above those in conventional power stations it is expected that by 1970 nuclear generation for base load purposes is likely to become cheaper than conventional generation.[28]

Although the fuel crisis in the U.K. is at the moment under control this is only a temporary situation. By 1975 power stations will be consuming the equivalent of 125 million tons of coal and by 1980 the requirements are likely to reach 200 million tons.[29] Notwithstanding the fact that oil is likely to remain plentiful on the international market for many years, the U.K. cannot rely to such an extent on imports both for reasons of national safety and in view of the enormous drain on foreign exchange resources.

At present, thanks to the favourable fuel situation, Britain is able to postpone the planned atomic station construction by a few years and thus to make use of the lessons learned from the construction of the first power stations and to incorporate the new developments and improvements into later ones.

The 5,000,000 kw. level, planned originally to be achieved in 1965, will under the new programme, be achieved by 1968.

(iii) Atomic Research.

As it is at present envisaged, there will be at any time in the near future five or six atomic power stations in various stages of development, from design to commissioning. This should be sufficient to maintain the rate of development of nuclear technology and to sustain a nuclear plant industry capable of competing for overseas business, for the atomic industry is seriously considered in Britain as a branch of the economy that could provide a valuable contribution to the export trade.

The reactor development programme undertaken by the U.K. is not as wide as that of the U.S.A. This is for two reasons. First, England, being pressed for time by the situation in the coal industry and rising costs of oil imports had to embark on the nuclear energy programme as early as possible, hoping to achieve economies in the course of operation of the first power stations and improve upon them at a later date. Second, since England had no ready supply of heavy water and of enriched uranium, it concentrated on gas-cooled reactors, which, using natural uranium, are inherently safer and suit the congested conditions in Britain very much better, at least during the initial period.

Great Britain has undertaken the study of the following types of reactors:

a. Gas Cooled Graphite Reactor; using normal uranium, or U 235 enriched Uranium, U 233 or Plutonium in the form of rods or slugs contained in a graphite moderator. Carbon dioxide or some other suitable gas is circulated through the reactor under pressure to remove heat.

b. Fast Breeder Reactor; having an unmoderated core fuelled with plutonium or U 235, cooled with sodium or other liquid metal. The core is surrounded with a uranium blanket to utilize the neutrons which escape the core.

c. Liquid Metal Fuel Reactor; in which a fuel of U 235 or U 233 in molten bismuth circulates through a graphite moderator. The heat is removed from the liquid metal fuel solution and used to generate steam. A liquid blanket of uranium or thorium-bismuth slurry surrounds the reactor, and utilizes neutrons from the core to make fissionable material.

d. Pressurized Water Reactor; in which water or heavy water is circulated through a vessel or tubes containing solid fuel elements of slightly enriched or natural uranium. The water is then passed through a boiler in which steam is produced to drive a turbo-generator.

e. Sodium Graphite Reactor; using slightly enriched fuel; the moderator is graphite and the coolant is sodium, which can be used with high temperature.

(iv) Conclusion.

The United Kingdom atomic power station programme is based on the Calder Hall type reactor, which is cooled by carbon dioxide with graphite as a moderator and natural Uranium as fuel. "Under U.K. conditions a power station of this type, if optimised for power production, would generate electricity at a cost comparable with that of power from a modern coal-fired station."[30] Sir Christopher Hinton predicted that by 1970 power from gas-cooled reactors will fall in price to about 5.5 mills per kwh. and in the following decade to under 5 mills, as against 7 mills for conventional power.[31]

The present comparison of costs per unit sent out by nuclear and conventional power stations is as follows:- (mills per kwh.)

	Nuclear	Conventional
Interest and Depreciation	0.37	0.12
Initial fuel charge	0.06	--
Total capital charges	0.43	0.12
Fuel supply	0.24	0.44
Operating costs	0.06	0.06
Gross costs	0.73	0.62
Plutonium credit	0.07	--
Nett costs	0.66	0.62 [32]

As in the U.S.A., the U.K. Atomic Energy Authority conducts studies in other uses of atomic energy, such as ship and aircraft propulsion and others, and also as in the U.S.A. no immediate future prospects are seen in these fields so far as economically justifiable projects are concerned. In the most promising field - ship propulsion - it was estimated that "the cost of power delivered from a nuclear plant would be about 40 per cent higher than diesel power, and the ship's operating costs would be increased by at least 20 per cent."(33)

It must be noted finally that while in the U.S.A. the possibility of nuclear power stations is being considered only in connection with areas short of conventional fuel, in the U.K. the programme is being considered for the country as a whole and there is no evidence to show that the cost of coal transportation had a deciding influence on siting. This was decided on the basis of safety factors and of availability of the required amounts of water.

Also, unlike the U.S.A., the U.K. has no deposits of uranium at home and has to depend on imports from abroad. The situation, however, is different from that of oil. While oil is bulky and comes from the Middle East, where due to the political situation conditions can be expected to remain unsettled for a considerable time to come, Uranium can be imported in a pure form, particularly from Canada where conditions can be assumed to remain favourable to Britain.

3. The Experience of Canada.

The Present Fuel and Power Balance.

Energy consumed in Canada in 1954 came from the following sources: 33 per cent from coal (more than half of which came from imports from abroad), 7.8 per cent from wood, 39.4 per cent from petroleum, 5.3. per cent from natural gas and 9.5. per cent from electricity.(34) Let us review these conventional sources of energy more closely before proceeding to atomic power development in Canada.

(i) Coal.

The Canadian coal reserves were estimated in 1935 at:

2,158 million metric tons of Anthracite

284,161 million metric tons of bituminous coal

948,450 million metric tons of sub-bituminous and brown coal and lignite.

Total: 1,234,769 million metric tons.(35)

The output of coal reached 17,363,002 tons in 1950 and has since declined to 13,920,307 tons in 1954.(36) Although the reserves of coal in Canada are very rich the decline in requirements for coal does not offer much inducement for further exploration at the present time. The increasing competition from oil and gas for house heating and for industrial use combined with the conversion of railways to diesel have all resulted in a serious decline in the market. This change to other fuels has been particularly marked in Western Canada where the greatest proportion of Canadian coal reserves are located.

For geographical reasons, although abundantly supplied with coal reserves, Canada imported more than half of her coal requirements from the U.S.A. In 1954 imports amounted to 16,855,766 tons as against the dometic output of nearly 14 million tons;[37] but the volume of coal imports is also on the decline for the same reason that is causing the fall in home production.

In the past the demand for prime mover has been satisfied mainly from hydro-electric sources. As, however, these are utilized, it is likely that a greater demand will develop for coal as a prime mover and as industrial fuel in power stations and industry.

(ii) Oil.

In 1954 the Canadian consumption of oil was 33,458,000 kl. of which 15,392,000 kl. (46 per cent) came from Canadian wells.[38] Only four years earlier Canadian wells supplied only 22 per cent of home consumption. The volume of home production could have been as high as 24,000,000 kl. but was kept down by government regulations to fit in with the available refinery and distribution capacity.

The advance has been due to new discoveries of major oil fields in the Prairie regions of Western Canada. In 1945 proven reserves were approximately 11,060,000 kl., by 1950 the amount was increased to 191,000,000 kl., in 1952 it was 254,400,000 kl., and in 1954 385,000,000 kl., or twice the amount reported only four years previously and almost thirty five times the amount estimated ten years previously. It is reasonable to suppose that the reserves will continue to grow for some time to come.

In 1951, 1,500 oil wells were drilled in the country, in 1952 the number was 2,000. During the period of 1946-1951 $1,200 million was invested in the oil industry. In 1952 the amount was $300 million.

The potential oil reserves of Canada were estimated in 1952 at 800 to 8,000 million kl., to which must be added Alberta's McMurray's tar sands along the Athabaska River, estimated at 15-30,000 million kl.(39)

Prior to the discovery of oil in the prairies, refineries were concentrated in Ontario, which operated on oil both from the Ontario fields and imported from the U.S.A., and in the Montreal area of the St. Lawrence valley, processing oil from South America and the Middle East. Other refineries were located in Vancouver, taking oil from California and South America by sea. This distribution of oil refining capacity was not suited to handle the newly discovered Alberta oil, Following the discovery, a pipe line was built linking the Alberta oil source with the Vancouver refineries, which by 1954 operated entirely on home oil. A pipe line was also built from the Alberta fields to Sarnia and Toronto, which carried nearly 11 million kl. of oil in 1954 and satisfied nearly all the requirements of the refineries in the area. The projected increases in distributing and refining capacities will reduce and possibly eliminate altogether the demand for imported products, although the need for imported crude oil for the refineries on the Atlantic and St.

Lawrence will remain for some time to come.

(iii) Natural Gas.

The expanding programme of exploration for oil in Western Canada resulted in the discovery of gas reserves both associated with oil and independent from it. The output of gas was restricted by the smallness of markets, and the increase in production has been accompanied by a much greater increase in reserves. In 1946 the reserves were estimated at 153×10^{14} cubic metres. The annual increase in reserves is 4.2×10^{14} to 5.5×10^{14} cubic metres.(40)

The main problem has been how to find a market for this vast store of energy. Western Canada, where gas is abundant, has also abundant supplies of cheap coal, oil and relatively inexpensive hydro-electric power.

The large energy consuming areas of the Pacific Coast and Central Canada, as well as the adjoining areas in the United States, are the possible markets and pipe lines are being built to serve these markets.

The production of gas during 1950-1954 was as follows:-(41)

1950	$1,920,495 \times 10^3$ cubic metres
1951	$2,250,073 \times 10^3$ cubic metres
1952	$2,511,295 \times 10^3$ cubic metres
1953	$2,859,590 \times 10^3$ cubic metres
1954	$3,424,593 \times 10^3$ cubic metres

The 1954 output was sold to the following consumers:(42)

Domestic	1,050,550 x 10^3	cubic metres
Industrial	857,996 x 10^3	cubic metres
Commercial	560,671 x 10^3	cubic metres
Miscellaneous	8,495 x 10^3	cubic metres
Total	2,477,712 x 10^3	cubic metres

The remaining 946,481 x 10^3 is not accounted for in statistics and is probably largely distribution loss, and losses due to other causes.

(iv) Wood.

Although wood is used mainly in domestic heating, it is nevertheless an important source of heat. Statistics of wood consumption are largely incomplete as a great proportion of wood is cut and used by individuals. Given below are estimates made from census records of the wood consumption for the period 1945 to 1954. It is reasonable to assume that the fall in the consumption of wood as a fuel is continuing, particularly since natural gas became widely used for dometic heating.

Year	Cords of Wood	Bil. BTU. (at 20 mil. BTU/cord)	Bil. kcal. (at 5,040 kcal/cord)
1945	11,220,000	224,400	56,548
1946	11,000,000	220,000	55,440
1947	10,780,000	215,600	54,331
1948	10,560,000	211,200	53,222
1949	10,340,000	206,800	52,114
1950	10,120,000	202,400	51,005
1951	9,876,000	197,512	49,773
1952	9,520,000	190,400	47,981
1953	9,170,000	183,400	46,217
1954	8,820,000	176,400	44,453 (43)

TABLE X

Province	Available Gross Capacity (100% efficiency) At Q95	At Q50	Developed Capacity Turbine shaft.
British Columbia	6,549	12,101	1,676.2
Alberta	474	1,384	193.0
Saskatchewan	513	1,232	81.9
Manitoba	3,108	6,120	564.6
Ontario	5,042	7,990	3,614.7
Quebec	10,160	22,497	5,799.3
New Brunswick	115	368	122.4
Nova Scotia	24	172	127.5
Prince Edward Island	-	3	1.4
Newfoundland	894	3,030	241.1
Yukon and N.W. Territ.	357	895	24.2
TOTAL	127,236	55,792	12,446.3

(v) Electric Power.

Although there has been a considerable increase in the primary production of electricity from fuel-powered plants, and there is a trend in Ontario towards auxillary steam plants for peak loads, water power remains the principla source of electricity for central power stations which produce power for sale in Canada or for export to the U.S.A. In 1954, 95 per cent of central stations power was generated from water power and the total hydraulic production amounted to 65,846 million kwh., an increase of 52 per cent since 1948.(44) Total potential and developed sources of water power in Canada, as of the end of 1954 are shown in the table following (in thousand kilowatts.)(45) In 1954 Canada was exceeded only by the United States in total water power installation and only by Norway in average installation per capita - the Canadian rate being 0.82 kw. per head of population.(46)

(vi) Atomic Power: Development and Research.

As these observations indicate, Canada will not suffer any fuel shortages for many generations to come. However, there are areas where, due to transport costs, fuel prices are very high. A very good example of this is the Far North. In such areas atomic power stations could be economically built and operated. These will have to be small power stations, easy to put up, capable of satisfying the needs of small communities. The other possibility for atomic power stations is in areas requiring large quantities of electric power, which are far from sources of conventional fuel. Atomic power stations in such areas are likely to be the same size as those being built in the U.S.A., the U.K. and, as we will presently see, also in the USSR.

I. Reserves.

Canada is fortunate in that it has large natural resources of nuclear as well as conventional fuels.

The main Uranium Deposits are:

Ia) Beaverlodge Lake area, discovered in 1948, located on the North shore of Lake Athabaska, known as Ace ore-body, producing 2000 tons per day since 1957.

Ib) Gunnar Deposits, Saskatchewan. Discovered in 1952. Situated at Crackingstone Peninsula; jutting into Lake Athabaska S.W. of Beaverlodge, it produced 1,250 tons per day.

Ic) Blind River area, discovered in 1953. Situated in the province of Ontario on the Northern shore of Lake Huron, it includes Mines Pront (commissioned in 1955) Algom and Consolidated Denison (1956). Total output for the area to-day amounts to 25-30,000 tons per day.

Id) Great Bear Lake, discovered in 1930 and owned by Eldorado Gold Mines Limited, it was taken over by the Canadian Government in 1942.[47]

The Canadian ores are refined at Port Hope on Lake Ontario, and the final concentrate goes to the United States to be converted into Uranium metal.

II. Power Production.

At the present time these atomic energy resources are being utilized in Canada by the following four projects.

The first is Canada's first Atomic Power Station, the Nulcear Power Demonstration located at the power station of the Hydro-Electric Power Commission of Ontario at Ralphton near the village of Des Joachims on the Ottawa river, approximately 150 miles N.W. of Ottawa. Essentially this is a pilot plant generating 10-20,000 kw. It was scheduled to be completed at the end of 1960 and to start operating early in 1961. It will use natural uranium for fuel, possibly slightly enriched with plutonium, and heavy water as moderator. The fuel will be in the form of natural uranium oxide rods sheathed in zirconium and numbering about two hundred. The project is under the Nuclear Power Plant Division and will be used for studying the requirements for large base load stations.

The second is CANDU. This project is also under the Nuclear Power Plant Division, and has also been set up for studying requirements of large base load stations. CANDU has a capacity of 200,000 kw. It is filled with natural uranium and moderated with heavy water. At 80 per cent load factor it could produce electricity at 6 mills per kwh. The fuel elements will not be re-processed but stored away as they are, being considered of no value. The cost of the power generated therefore, will not depend on the value assigned to plutonium contained in spent fuel.

The third is the OCDRE dual role reactor, considered to be the best alternative of natural uranium fuelled reactors to be used in small power stations, or in stations of up to

100,000 kw. This project is also under the Nuclear Power Plant Division. A study is being made of a plant of approximately 40,000 kw. It will use natural uranium as fuel, and organic liquid as coolant. It will have high reliability of operation. Designed to provide steam suitable for the turbines and heating system of a conventional power station, it is considered mainly for possible use in the Far North.

The fourth is the study of small plants using enriched uranium fuel; this project is under the Reactor Research and Development Division at Chalk River. Under this project a study is being made of small power stations provided with a pressurized light water or boiling light water reactor, using enriched uranium fuels. These reactors are expected to be more economical than the ones using natural uranium as fuel and moderated by heavy water, and they are intended for use in the Far North.

As in the U.S.A. the location and the extent of utilization of the atomic energy in Canada will be determined primarily by the cost of transport for conventional fuels.

III Research.

Canada's research and development activities in the atomic industry are concentrated at Chalk River. During the war this was a joint U.K. - Canada undertaking, but in 1947 the Canadian National Research Council (CNRC) assumed responsibility for it. In 1952 a Crown company - Atomic Energy of Canada Limited, took over from the CNRC. In June, 1954 the name of the Crown company was changed to Nuclear Research Limited, and a holding company - Atomic Energy of Canada Limited - was formed to hold the stock of the Nuclear Research Limited, and of Eldorado Mining and Refining Limited. The latter, among other things, buys all Uranium ores and concentrates produced by private companies in Canada.

Canadian Atomic Energy Establishment is engaged in four main activities:-

a) Development of economic atomic power

b) Fundamental research

c) Operation of nuclear reactors and separation of nuclear fuels (Plutonium and Uranium 233.)

d) Production of Radioactive Isotopes and associated equipment, such as therapy units for cancer treatment.

Canada has at Chalk River:-

1) The ZEEP Reactor, which went into operation in 1945. It has a power of 10 watts. It is a research reactor, using uranium as fuel and heavy water as moderator.

2) The NRX Reactor, which went into operation in 1947. It has a power capacity of 40,000 kw. This is a research reactor, uranium fuelled, using heavy water as moderator. In reactors of this type, when the fuel is in the form of natural uranium rods, the coolant used is ordinary water.

3) The NRU Research Reactor of 200,000 kw. This reactor uses natural uranium in rod form as fuel. Heavy water is used as a moderator and as the coolant. It is circulated through eight 17-ton exchangers outside the reactor.

It must be noted that Canada's considerable achievements in the atomic field are to a great extent due to historical causes. Because it was far removed from the war area, Canada was chosen as a base for the Commonwealth Research Centre. At the end of the war it found itself with a very large research establishment and first-hand appreciation of the possibilities of nuclear development. Canada seized the opportunity to continue with the research, but while in the U.S.A. and especially the U.K., the main emphasis was on atomic power stations, Canada concentrated on other aspects, particularly the medical application of atomic industry products. So far as the atomic power stations are concerned, Canada is interested in this field from the long-term point of view rather than the immediate future.

(vii) Conclusion.

The role which nuclear power is likely to play eventually in the Canadian economy has been summarized as follows by the President of Atomic Energy of Canada Limited:-

> "The growth in power demand over the next twenty five years is likely to continue at the rate of about 5 per cent a year. On this basis, the total installed capacity in 1981 will be approximately 48 million kw. as compared with the present capacity of 16 million kw. Since Canada has large untapped hydro resources and an abundance of cheap conventional fuels in some regions, a substantial part of the future power demand will be supplied by new hydro stations or thermal stations using conventional fuels. To be more precise, it is estimated that out of the 48 million kw. total installed capacity in 1981, 33 million will be supplied from hydro stations, between 8 and 11 million from conventional thermal stations and between 4 and 7 million from nuclear stations. This forecast is based on the assumption that it will be possible to produce nuclear power at a cost not higher than the cost of producing power in a conventional thermal station using coal at $8.00 a ton. To the extent that the cost of nuclear power is less than this there will be a corresponding increase in the percentage of new power, which will be supplied by nuclear stations."(48)

Consequently, nuclear power might be used to satisfy the needs for electric power in Canada under the following conditions:-

1) Where there is a demand for large blocks of base load power and where no source of conventional power is close at hand to meet the demand.

2) Where there is a growing demand for power that justifies construction of a medium size power station and where conventional fuel costs are high.

3) In the Far North where there is a demand for small size power units, but where due to high cost of transport, conventional power could not compete with that coming from nuclear power stations.

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CHAPTER VI

ATOMIC DEVELOPMENT IN THE USSR.

1. Soviet Attitude to Atomic Power.

In the USSR the change in the attitude towards various types of fuel brought about by the consideration of the opportunity costs, following the preparation of a unified fuel and power balance, appears to have been extended to the atomic industry as well. Although no clear statement on the present attitude of the Soviet Authorities to atomic power is available, from various things that have been said and written it can be gathered that up to about the introduction of the 7 Year Plan they were prepared to back the construction of atomic power stations. The sixth Five Year Plan (1955-1960) provided for the construction of atomic power stations with a total capacity of 2-2.5 million kw. by 1960. The programme included construction of five large power stations of 400 to 600,000 kw. each, to be brought into commission starting from 1958. The aims of the programme were to supply power to areas short of conventional fuel and to select the most convenient and economic reactor for further development.(1)

However, after the preparation of the fuel and power balance a statement was made in a book published by the Gosplanizdat (Gosplan Publishing Office) that "during the coming fifteen years the electric power from the atomic power stations will probably not play a significant role in the fuel and power balance of the country."[2] Other writers dealing with the future prospects of fuel and power supply for the country do not include atomic power within the scope of their calculations.[3][4] No new projects for the construction of atomic power stations have been announced during the last 2-3 years.

When the special commission prepared the fuel and power balance they must have considered the economic aspects of the atomic power production side by side with the calculations for the production of power from fossil fuels. The available date of their research can be summed up as follows:-

	Coal	Oil	Uranium
Fuel electric equivalent kwh/kg [5]	8.0	12.0	22,850,000
Labour input per ton	0.7	0.3	?

Since the commission strongly advocated development of oil and gas and since it is stated in a Gosplan publication that the atomic power will probably not play a significant role in the fuel and power balance of the country for the next fifteen years, it must be assumed that in spite of such a very high electrical equivalent, uranium as a source of power compares unfavourably with the others under the present technological conditions, and that the present difference is wide enough for a negative forecast to be made for such a long period of time ahead. It must also be pointed out that in the light of the present knowledge the comparative costs of the atomic power are expected to remain considerably higher than of conventional types, for a long time as it is planned that even after 1965, 10 million tons of low quality coal will be brought to Urals from Eastern Siberia to be used for the production of electric power in thermal power stations.[6]

Some of the possible reasons for this state of affairs could be:-

a) That the uranium raw material is either unavailable or that it is of a poor quality, and therefore costs of production of uranium are high. There are reasons to believe that indeed this is one of the contributing factors.

b) That due to the nature of Uranium raw material, or insufficient mastery of techniques the extraction of Uranium from raw material is costly or low.

c) That losses in the course of the preparation of fuel elements and in the course of testing prior to use in power stations are high.

d) That the burn up of fuel elements is low, or that the amount of heat that can be gainfully obtained from the fuel burn up is low due to inefficient operation of heat exchangers.

e) That the production of equipment and construction of plants is too costly compared with the conventional power stations.

Since the Soviet Authorities do not publish information which would indicate which of the above reasons is valid, no definite conclusion can be drawn at the present time. Nevertheless it can be pointed out that costs of construction of the power stations do not appear to differ much from those in Western countries, and that types of reactors reflect closely the types that have been developed abroad. It is reasonable to assume, therefore, that the costs which compare so unfavourably with those in the West are in the field of gathering, preparing and utilizing nuclear fuels. The special interest which the Soviets show in the development of breeding reactors points in this direction, though the problem of these reactors is of such an importance that almost any amount of interest in it is justifiable.

It must be borne in mind that under Soviet conditions there are two other factors which might be contributing to the reluctance to give high priority to the atomic power. First stems from the inherent reluctance on the part of the planners to take risks and to base a section of their programme on something as unpredictable as atomic power is at the present stage of development, and consequently, a reluctance by the individuals and groups to take the responsibility of advocating such an undertaking, and secondly - lack of incentive to take risks in developing the new forms of fuel, since abundant supplies of conventional fuels are available. The second the USSR shares with the U.S.A. and Canada.

The unfavourable situation in which Great Britain finds itself with regards to the conventional fuel supply is a very strong incentive to try out new sources of energy - and among others the nuclear energy. Once before Britain has been in a similar situation during the second half of the 18th century, when finding itself with inadequate reserves of charcoal for iron and steel production, the British industry switched to the use of coal in smelting. The new form of fuel turned out to be more efficient and placed the British in an advantageous position. On the other hand, the iron and steel industry of Russia, which before that had the highest output in the world entered the period of stagnation.

> "An important cause of this stagnation was the fact that the iron and steel industry of the Urals continued to develop in the pre-reform period of the XIX century mainly based on compulsary labour of the serfs assigned to the iron works and the alloted land grants. (In the eighteenth century every newly constructed iron producing plant in the Urals was granted all the land within the radius of 64 km.[7] As a result of these grants almost the entire huge Urals area became the property of several undertakings. The metallurgy worked on charcoal and the size of the forests belonging to the plants also determined their production.
>
> The plants were provided with cheap labour, cheap raw materials and fuel from the forests assigned to them. At the same time competition from abroad was absent on the Russian market. Metals imported from abroad were dear, since they were subject to prohibitative duties. Being able to maintain high prices due to the absence of competition the Urals manufacturers made large profits even with the very low state of technical and organizational structure."[8]

Similarly to-day, being well supplied with conventional fuels Russia does not have the same strong incentive to try out new forms of fuels as England must.

Although the authorities in the Soviet Union are not prepared to commit themselves to a large scale development of atomic power, they nevertheless continue to give high priority to scientific study and research development in the field.

Similarly as in the U.S.A. the reasons for supporting the research are prestige, political and to insure the availability of atomic when it becomes competitive with that from conventional power stations.

It would appear, however, that even by comparison with the U.S.A. and Canada the Russian readiness to experiment with the new power lags behind, although greater opportunities for using atomic power seem to exist there because of climatic conditions and the existence of large industrialized and unindustrialized regions lacking in conventional fuel resources.

2. Historical Outline.

The beginning of nuclear research in the Soviet Union dates back to the early days after the revolution. From the formation of the Soviet state to approximately 1929, nuclear research was carried out by individuals such as P.L. Kapitsa, a lecturer at Leningrad Polytechnical Institute, (for a time he collaborated in 1921-22 with Lord Rutherford at the Cavendish Laboratories in Cambridge). Another Russian scientist interested in nuclear research was V.I. Vernadski, founder of the State Radium Institute in Leningrad in 1922. He stayed in Paris in 1923 to do some experimental work at Mme. Curie's Radium Institute. Among others in this field were Dimitri V. Skobeltsin and Vitalii G. Khlopkin.

In May 1930, Abram F. Ioffe succeeded in interesting the Chairman of the Supreme Council of National Economy, Serge Ordzhonikidze, in the problem, with the result that substantial funds were granted for nuclear research and the field was placed under the administrative care of the People's Commissariat of Heavy Industry, where it remained until after the great purges of 1936-38. It was then transferred to the Soviet Academy of Sciences which - after years of non-co-operation with the regime - by the end of the purges was finally brought completely under government control.

In 1938 the Leningrad Physics-Technical Institute, the Leningrad Radium Institute, the Leningrad State Optical Institute and the Physics-Technical Institute in Kharkov were doing serious research in nuclear physics. Working in this field at Leningrad Physics-Technical Institute at this time were Igor Kurchatov, A.I. Alikhanov, A.L. Artsimovich, D. Skobeltsin and others whose names to-day stand for nuclear research in the USSR.

> h "By the end of the thirties, the USSR had a full complement of well-equipped and well staffed nuclear laboratories, comparable with those of any other major country."(9)

In November 1939 a conference on the Physics of the Atomic Nucleus was held in Kharkov, the published results of which show that new developments in nuclear research taking place outside the Soviet Union were well appreciated by the Russians and that translations of the literature published in the West were available to Russian scientists.

In 1939 the Commission for Isotopes of the USSR Academy of Sciences was formed under the Chairmanship of V.I. Vernadsky. This initiated practical work on the production of heavy water and the separation of uranium isotopes. In the spring of 1940, under no less a body than the Presidium of the Academy of Sciences of the USSR, a special committee for the Problems of Uranium was formed; this committee included some of the foremost men of science of the Soviet Union. Its composition was:- Chairman of the Committee: V.G. Khlopkin; members: Academicians V.I. Vernadsky, A.F. Ioffe, A.Y. Fersman (a geologist), S.I.Vavilov, P.I. Lazarev, A.N. Frumkin, L.J. Mandelstam, G.M. Krzhizhanovsky, P.L. Kapitsa and Professors: I.V. Kurchatov, D.I. Shcherbakov, A.P. Vinogradov and Y.B. Khariton.

The task of the Committee was to:-

1. Prepare a scientific research programme for the study of uranium and to assign parts of it to the various institutes of the Academy of Sciences.

2. Organize the development of methods for separating the fissionable uranium isotopes, and pursue research on controlling the process of radioactive disintegration (i.e. controlling a chain reaction).

3. Co-ordinate and generally supervise scientific research projects of the Academy of Sciences on the problem of Uranium.

The Presidium of the Academy of Sciences recognized "the necessity of using powerful cyclotrons for work on the problems of Uranium" and ordered that:-

1. The Radium Institute Cyclotron, which was put into limited operation in 1937, be brought up to full capacity by the end of 1940.

2. That the construction of a cyclotron for the Physics-Technical Institute be completed "not later than the first quarter of 1941".

3. That the Lebedev Physics Institute in Moscow prepare by October, 1940 the plans for the design and construction of a "new, powerful cyclotron in Moscow" to be included in the Academy budget for the capital construction plan for 1941.[10]

A special expedition was sent to Central Asia to look for Uranium deposits. Plans were discussed for producing heavy water at Chirchik in Central Asia at the rate of 15 kg.

per year. At the Radium Institute, methods were developed for separation of isotopes by linear acceleration of uranium ions. The main efforts were thus directed towards discovering methods for quantity production of the fissionable material and moderator.

> "In general, therefore, it would appear that the Soviet Union and the United States were progressing towards important achievements in nuclear physics at about the same pace".(11)

When Germany attacked the USSR, Russian research in the nuclear field stopped for over two years. Only towards the end of 1943 were the Moscow workers of the Academy of Sciences able to return from temporary posts in the Eastern part of the country. Kurchatow, although he was a Leningrad man, was then made a full member of the Academy of Sciences and returned with them.

In the pre-war years Soviet scientists published freely the results of their work in the field of nuclear research, and they continued to do so during the early war years, when information in this field was already classified in the U.S.A., the U.K. and Canada.

During the first three years of the war, the Russians were able to do very little compared to what was being achieved in the U.S.A. Most of the nuclear research establishments were situated in the European part of the country and had to be evacuated. Scientists were put to work on projects immediately concerned with the waging of war. As a result, by the end of 1943, Russia was a long way behind the U.S.A. At about this time the military implications of nuclear power were probably appreciated in the USSR and the attitude of the government towards the new science changed. In September 1943, at the General Meeting of the Academy of Sciences of the USSR, A. Baikov inaugurated a policy of secrecy on the subject of atomic research in the USSR,[12] which was only partly removed at Geneva in 1955. It can be assumed that by 1955 military requirements were already satisfied and the question of the peaceful utilization of the new sources of energy came to the forefront. It must not be forgotten that the First Geneva Conference on the Peaceful Uses of Atomic Energy took place almost two years after hydrogen bombs had been exploded by both the U.S.A. and the USSR.

Atomic Reactor Development in the USSR.

It is useless to speculate how much Russian scientists were assisted by Soviet Intelligence organizations in their efforts to catch up with the Western Powers. The first Russian Reactor PSR, which went into operation at about the beginning of 1947 was fuelled by natural uranium moderated by graphite and cooled by water. The unit bears a striking resemblance to the Hanford Reactor 305, built in the USA before March, 1944. Given below are comparative figures:-

	Hanford 305	PSR
Power	10 watts	10 watts
Diameter	18-20 ft.	19 feet
Lattice spacing	8½ inches	8 inches
Loading	27 tons of Uranium	25-50 tons of Uranium
Rod diameter	1.448 inches	1.2-1.6 inches

The delay in construction is not difficult to explain. Even if the Russians had obtained details of the reactor design as soon as it was built in the U.S.A. their industry required some time to manufacture the necessary graphite of required purity and produce the necessary amount of Uranium. Judging from statements by Russian scientists, the industry did not find either task easy.

From this pile the Plutonium Research Reactor and its successors were probably developed. Form it was also developed, in about 1952, the plutonium breeder power reactor, the RFT, an enriched uranium-graphite, water-moderated reactor for physical experiments and for fuel elements testing, which in turn was the precursor of the first Soviet Atomic Power Station of the USSR Academy of Sciences built under the direction of D.I. Blokhintsev. The next step after the Atomic Power Station is likely to be a Uranium Graphite power reactor in which water coolant will be replaced by sodium.

The first Uranium Graphite pile also served as a starting point for the study of water-cooled, water-moderated reactors (Water-water reactors VVR) developed by Kurchatov's Institute, which will lead to the construction of large water-cooled, water-moderated power plants during the next few years. An experimental boiling reactor, sponsored by Kurchatov, will be a further development of this system. The reactor of the atomic ice-breaker Lenin is also of this type.

During 1956-57, the Soviet Union sold seven Water-water reactors to the satellite countries and Egypt, for installation at their research institutes.

The first Soviet heavy-water reactor was designed in 1947 and commissioned in April, 1949. This was the experimental reactor of the Academy of Science of the USSR. It uses heavy water both as a moderator and as a coolant. The fuel used is 2 per cent enriched Uranium.

The reactor was designed under A.I. Alikhanov and V.V. Vladimirski. In conception it is close to the Canadian NRX and the Chicago CPS, which suggests that the Russian scientists may have used material provided for them by the intelligence network.

On the basis of experience gained from this reactor in future large heavy-water power stations will be built. One such power station is being built by Soviet experts in Czechoslovakia.

Another power reactor to be developed from the heavy water prototype will be a homogeneous thorium-breeding pilot power reactor.

The Soviet Union sold to China and Yugoslavia experimental reactors moderated and cooled by heavy water, using as fuel 2 per cent U-235 enriched uranium rods.

Given below is the diagram of Soviet reactors (see Appendix A).

In addition to the above the Russians have recently developed a high-neutron "impulse" or "pulsed" reactor. The reactor was developed in the Joint Institute of Nucllear Research at the end of 1958. It is said to be compact and economical.

Though its average capacity is not great at the moment of impulse, it produces a tremendous flux of neutrons and during this period it develops the power of tens of millions of kilowatts. The design of this reactor is being further elaborated and there are indications that it may be developed as a power unit. The reactor uses enriched uranium fuel and ordinary water.

Soviet Reactor Programme.

Late in 1949 the Russians started work on a power demonstration reactor, which came into operation on 27th June, 1954. This was the first reactor to contribute electricity for general public consumption. The Russians brought a model of this power station with them to the First Geneva Conference on the Peaceful Uses of Atomic Energy. The station was developed by D.I. Blokhintsev, N.A. Dollezhal, A.K. Krasin and V.A. Malikh, who were awarded Lenin prizes in 1957 for their work on it.

This station is located approximately seventy miles South-west of Moscow at a place called Obninsk. The capacity of the station is 5000 kw. Because of its size the unit is really more of a testing pilot plant than a power station. It uses 550 kg. of Uranium metal enriched 5 per cent with Uranium 235. Only 15 per cent of U 235 is burnt up and there is relatively little production of plutonium. Graphite is used as a moderator and pressurized water as a coolant. Heat is delivered through a heat exchanger to a secondary water circuit, which takes it to the turbo-generator. The reactor is rated at 30,000 kw. thermal, but at a pressure of 1500 lb.p.s.i. the operating temperature is only 550°F (300°C) and consequently efficiency is low. The shield is a graphite reflector, three foot of water and ten feet of cement. The station uses less than 5kg. of U 235 to produce 20 million kwh. of electricity a year, at a cost considerably in excess of the average in large coal burning stations (which in 1953 was 10 kopecks per kwh.) but comparable to that of coal burning plants of the same size.

In June 1955 A. Malenkov told Western journalists that another power reactor was under construction at the time in Russia, and that it would be completed before the completion of reactors in England. Two months later D.I. Blokhintsev confirmed Malenkov's statement and said that the reactor was to be completed in about the middle of 1956. He avoided giving any details as to the type of the reactor. In the autumn of the same year V.V. Vladimerovsky, speaking at the industrial conference in New York described the reactor as 100,000 kw. carbon dioxide cooled, heavy water moderated, using natural uranium as fuel. Work on the construction of this reactor was also confirmed by the Finance Minister Zverev in Pravda on the 27th December 1955. The completion of this reactor was never announced and it was either abandoned in favour of a more advanced version, or completed for military purposes and kept secret for this reason.

The 6th Five Year Plan (1655-60) provided for the construction of Atomic power stations of a total capacity of between 2-2.5 mil. kw. In the field of reactor development the programme mentioned construction of ten types of atomic power reactors ranging from 50,000 to 200,000 kw. Some of them were to be designed for use in desert and polar regions.[14] The plan provided for the construction of five large atomic power stations of 400,000 - 600,000 kw. capacity each, which were to be brought into commission starting from 1958. The construction of these large power stations had a dual purpose; to improve the supply of electric power to some regions - in the first instance to those that lacked conventional resources of their own - and to make possible to select the most convenient and economic reactor for further development of atomic power stations in succeeding Five Year Plans.[15] As well as the construction of large power stations the plan provided for several experimental atomic plants of an electrical capacity of 50,000 - 70,000 kw.

The five Power stations to be constructed were probably:- (for detailed description of projects see end of Ch.VI)

Power Station I	to be constructed near Moscow, of 400,000 kw.
Power Station II	one of the two power stations to be constructed in the Urals; it is located near Sverdlovsk, at Byeloretsk. For details see Appendix IIA.
Power Station III	second power station to be constructed in the Urals; its location is unknown. The joint capacity of the Ural atomic power stations was planned to be one million kw.
Power Station IV	located at Voronyezh, on the river Don.
Power Station V	the proposed location of this type of power station in the USSR is not known, but a station of this type is under construction at Banska Bystrica in Czechoslovakia.

Projects other than Atomic Power Production

Apart from their interest in atomic energy as a source of electric power, the Soviets are also interested in it as an explosive force in the engineering industry for large scale excavation projects, as a means of propelling ships, submarines, land vehicles, locomotives, aircraft, and other machinery, as well as utilizing it as a source of isotopes for use in industry, medicine and scientific research.[42]

Uranium reserves

The Russians have not disclosed the size nor the whereabouts of their uranium reserves. Since the war, however, intensive search by volunteers and by scientific expeditions has continued throughout the Soviet Union. The Russians have made extensive use of AN-2 type planes equipped with aeroradiometers, flying at 360 feet above ground. In charge of the aeroradiometrical research is Vladimir Il'ich Baranov.[43]

It is unlikely that the Russians succeeded in locating satisfactory deposits until recently (end of 1959) since they continue to use uranium ores mined in the satellite countries - East Germany, Czechoslovakia, Hungary, Poland and Roumania. Apart from the cost of transportation, the Russians must be aware of the fact that since these countries are developing their own atomic industries, they begrudge the ores leaving for the USSR. This is particularly true of Poland, where reserves are both scarce and of low grade. Another indication that the Russians are short of uranium ore is their serious consideration of a project to extract uranium from Lake Miass in the Chelyabinsk area, considered to be a very expensive way of obtaining it.

In Russia itself there are known deposits in the Fergana Valley in Kirgiz and Tajik SSR. In pre-war days, uranium bearing ores were mined here at Tyuya-Muyuan and Tabashar for their radium content.

In Eastern Germany the main uranium mining region is in Saxony. The exploitation of these reserves was started immediately after World War II. The programme was expanded under the code name Wismut A.G. in 1946, when Major General Nikolai Motrfanovich Maltsev was appointed head of it. On the 17th July, 1947 the East German corporation "Wismut" was officially established.

The Czech deposits are in the Joachimsthal in Western Czechoslovakia. The mines here are 600 years old and have been exploited as sources of lead and silver. After radium was discovered the mines became a source of radium.

The other reserves in Czechoslovakia are found in the Pribram region of central Bohemia.

Heavy Water.

Russians have padi serious attention to the production of heavy water, and according to Academician Kurchatov, several methods are used to produce it.

Before the war, plans were made for the production of heavy water at Chirchik in Central Asia. It was proposed to obtain heavy water by the process of electrolysis.

Heavy water was also obtained in small quantities, for experimental purposes, at Dnyepropetrovsk. The Russians started research on low temperature distillation as early as 1946.

The production of heavy water is a very heavy drain on electric power. To produce one ton of heavy water up to 100 mill. kwh. is necessary. It is possible that one of the reasons for the construction of large size hydro-electric and thermal power stations in Siberia, where the demand for such quantities of electricity will not arise for a number of years, is the need to satisfy the demand of the heavy water producing plants, as well as other requirements of the atomic industry research laboratories.

The Russians plan to build more ice-breakers of the "Lenin" type. Apart from ice-breakers they are also interested in the construction of atomic tankers and cargo ships. It is generally agreed that atomic propulsion could only be used under present conditions on large size tankers (over 20,000 tons) or on cargo ships of over 15,000 tons intended for long runs - as, for example, to China or Vladivostok via the Northern route. (?) The Russians point out that the distance from Vladisvostok to Odessa is 17,400 km. and to cover it requires 3,200 tons of oil. The same voyage could be made on 2.4 kg. of U 235. By using atomic propulsion, calling at Northern ports for refuelling could be avoided and thus both the time and the length of the voyage considerably shortened. The same is true for units of the whaling fleet and for factory ships of the fishing industry.

Floating atomic power stations are considered for Polar regions, to supply power for new projects under development in their initial stages.

Because of the Northernly location, atomic submarines are of greater significance to the USSR than they are to the U.S.A., for strategic reasons, and because of the possibility of their use for regular under-icepack travel to Eastern ports.

The use of atomic power in aircraft is also being considered. The long distances that their aircraft have to fly to reach foreign targets or distant airfields inside their own country make the Russians consider seriously the possibility of an aircraft that could fly for several thousand miles without interrupting its flight for refuelling.

In Russia the bulk of goods is transported by rail. Some of the haulage is done over very long distances, as for example on the Trans-Siberian railway, and atomic locomotives for heavy duty freight trains are being considered. Such locomotives could also be used to supply electric power to new towns and projects under construction.

It is possible that atomic power could be utilized for driving the large size mining equipment used in open cast ore mining locations far removed from cheap sources of fuel.

The Russians are also considering small, mobile atomic power units mounted on caterpillar trucks or wheels to be used in a manner similar to the U.S. Army Package power reactor. Use for them could be found in the Far North, in the newly developed territories, in virgin soil lands, and desert areas.

Isotopes.

Russians claim that they have made a very extensive use of isotopes, thus affecting enormous savings to their economy. In 1955 they claim to have shipped 1,500 packages per month (as against 900 per month by the AEC in the U.S.A.) By the first quarter of 1957 the Russian monthly average had crept up to 2,250 packages.

The overall technical aspect of the Soviet Isotope programme is supervised by the Chief Directorate for the Utilization of Atomic Energy, which is a body in the Council of Ministers of the USSR. But day-by-day distribution is handled by the All-Union Trust of the Ministry of Chemical Industry - Soyuzreaktiv.

The Russians tend to stress the use of isotopes in industry rather than in medicine as is done in the West. Industry, and in particular heavy industry, is considered to be the most important sector of the Russian economy and as can be expected, isotopes have been widely used in metallurgy, engineering and control of technical processes. Isotopes are used in determining the rate of wear of furnaces, machine tools, measuring temperatures in blast furnaces, controlling hearth operations and sorting metal strips.

In the engineering and building industries, defectoscopes produced in great numbers and varieties must be used in accordance with the state inspection rules to check all welded boilers, ship hulls, bridges, gas pipes, and other seams. Isotopes are also used for gauging the thickness of coating, for recording the level of liquids in sealed vessels, such as storage tanks and other types of containers.

Isotopes are also used to provide a very small amount of current to drive special electronic apparatus. Because of the long life of isotopes, these could be used for illuminating marker bouys in Northern waters, and for driving batteries in missiles.

According to data of the Institute of Economics of the Academy of Sciences of the USSR, the use of radio-active control equipment and automatization of the Industrial enterprises in the USSR had even by 1958 saved the Soviet economy approximately 500 million roubles. It has been estimated that wider application of the radio-active equipment already developed would alone save the country as much as four billion roubles a year.(44)

Controlled Fusion Research.

The controlled fusion research can be said to be to a great extent a bye-product of the arms race. Both in the U.S.A. and in the USSR the development of thermo-nuclear weapons was soon followed by efforts to harness for peaceful uses the enormous power released in the fusion of light element particles. It would appear that the British research in the controlled fusion was inaugurated even before the country embarked seriously on the production of a hydrogen bomb.

From the time the first hydrogen bomb was set off by the Americans in September, 1952 and by the Russians in August, 1953, both countries worked in secrecy on fusion control. Although the existence of the research ceased to be a secret after 1955, when the three major atomic powers, the U.S.A., the U.K., and the USSR admitted that they were engaged in controlled fusion research, the desire on the part of each to reap the benefits of being the first to enjoy the advantage of having an almost unlimited amount of cheap power, keeps their efforts apart.

At Geneva, and in particular during Kurchatov's visit to Harwell in 1956, the Russians demonstrated that they have had considerable success in this field, and that working with plasma they have attained temperatures of over a million degrees centigrade, which they claim was the highest attained under laboratory conditions at the time. Russian research was done at the I.V. Kurchatov Institute. In charge of work was L.A. Artsimovich, and M.A. Leontovich was in charge of the theoretical questions.[45]

The difficulty with the thermo-nuclear reaction is how to sustain and exploit the high temperature attained. For a while there was in evidence a degree of optimism on this account, but as difficulties became more apparent a search was started for alternative ways for utilizing fusion. Thus from work with plasma attention was switched to "stationary" processes, such as obtaining thermo-nuclear reactions through the use of periodically recurring shock-waves caused by a small controlled explosion or by accelerators. Another method is to cause an electric explosion in a wire. In the U.S.A. a study is being made of Dr. Alvarez's "cold" reaction, involving the use of mu-meson bombarding hydrogen. The Russians claim that Academician Zheldovich had some success in this field as early as 1954, i.e. nearly two years before Dr. Alvarez came out with his idea.

Although nothing definite has been achieved in controlled fusion so far, the possibilities here are so enormous that the amount of attention given to this field is not likely to decline in the near future.

Nuclear Power and Experimental Plants.

Power Plant Type I. - Graphite Moderated Water Cooled Reactor.

This power station was planned to be of the same type as Obninsk one, i.e. graphite moderated and water and steam cooled. The steam in the secondary circuit, heated to 480-500°C, under pressure of 90 atmospheres will feed turbines of 200,000 kw. each.[16] (In February 1958 N.Nikolayev, Deputy Head of the Main Administration for the Utilization of Atomic Power, attached to the Council of Ministers of the USSR, stated that the turbines will be of 100,000 kw. capacity). Superheating will be done within the reactor itself and consequently there will be no need for a heat exchanger, which is the most costly part.[17]

Because high parameters of steam can be used, the efficiency of this atomic power station can be fairly high - more than 35 per cent. This is more or less the same as the efficiency of large modern thermal power stations working on high and super high steam parameters.[18]

It was planned ultimately to have a power station with a thermal capacity of 1,150,000 kw. and gross electrical capacity of 400,000 kw. of which 25,000 kw. would go to satisfy the requirements of the power station itself. To begin with this power station was to have been constructed at Obninsk, where it was to have been joined to the already existing 5000 kw. station. However, at present a plant of this type is under construction at the village of Byeloretsk, 56 km. East of Sverdlovsk. This site was visited in July 1959 by

US Vice President and his party. They were told that by 1961 the first part of the power station - 200,000 kw. - would be ready for operation. After Kurchatov's death this station was named after him. Its full name in future will be "Kurchatov Beloyarsk Atomic Power Station"/Beloyarskaya Atomnaya Elektrostantsia Imeni Kurchatova/.

Power Plant Type II - Water-Water Reactor (VVR).

Atomic Power Stations referred to in the Soviet press as Number Two and Three will use ordinary water as moderator and also as a coolant.[20] Double circuit will be installed; the first being water under pressure and the second, water changed into superheated steam in the steam generators, and the condenser of the turbine. The steam producing plant will be made up of several separate blocks of 210,000 kw., each consisting of a reactor and three coolant loops with their own steam generators, circulating pumps, of primary circuit, and 3 turbo generators of 70,000 kw. each. Approximately 10,000 cubic metres of water at 275°C under pressure of 100 atmospheres will flow from each reactor into each of the three steam generators. On entering the steam generator the water will impart its heat to the secondary circuit, cooling in the process to 250°C and will be pumped back into the reactor. The feed pumps of the secondary circuit will send water into the steam generator, from which saturated steam under pressure of 30 atmospheres will enter the turbines.

The design makes it possible to shut off any one of the steam generating loops without stopping the reactor, therefore the reactor will be able to operate at a reduced output. This increases the safety of the power station during the operation and facilitates its maintenance and inspection of the components of the primary circuit.[21]

The reactor will use slightly enriched uranium, in the form of Uranium dioxide, contained in zirconium alloy casings.[22]

The advantages of this reactor are - possibility of extensive burn-up of uranium and simplicity of construction. Estimated costs of producing electricity in atomic power station of this type are comparable to those in thermal stations.[23]

An Atomic Power station of Type II is to be constructed at the village of Novovoronezhskaya, near the town of Voronezh on the river Don in the Ukrain. The capacity of this power station will be 420,000 kw., that is two reactor blocks of the type described above.[24]

A similar power station is to be constructed near Leningrad, though no further details have as yet been released.[25]

Atomic Power Station Type III - Heavy Water Moderated Gas Cooled Reactor.

The third type of power station will be a heavy water reactor, working on thermal neutrons, and using heavy water as moderator. According to information given out in 1956 carbon dioxide circulating at 500°C, producing steam at 30 atmospheric pressures, will be used as coolant in this reactor. The temperature of water in the secondary circuit will be 400°C. The secondary circuit will activate turbines of 200,000 kw.[26] Two years later, in Tekhnika Molodyezhi, it was stated that the turbines would be of a medium pressure and of 50-100,000 kw. capacity.[27]

Natural uranium will be used as fuel. This is much cheaper than using enriched uranium, which is the main advantage of this type of reactor.

This reactor has been developed by the Thermonuclear Laboratory working under the direction of A.I.Alikhanov.

There is no definite information to date that such a power station will be built in the USSR itself, although there is one being constructed by Soviet experts in Czechoslovakia. The station will be a 150,000 kw. unit located on the river Hron, near Banska Bystrica.[28]

The reactor is a steel cylinder 4 m. in diameter, 19 metres high. The active zone is contained in an aluminium tank filled with heavy water. Gas is circulated through the reactor under pressure of 60 atmospheres in an enclosed circuit, pumped in by gas blowers. The heavy water is kept under the same pressure.

The active zone consists of fuel elements assemblies, made up of uranium rods 4 m. long and 4 mm. in diameter, covered with a protective layer of magnesium alloy. The power arrangement is similar to that in conventional power station.[29]

Atomic Power Station - Type IV; Graphite Moderated Water Cooled.

This power station has a reactor which is graphite moderated, cooled with ordinary water, heated to very low temperature only. The efficiency of conversion of heat to electricity is very low. The fuel is natural uranium. The plant appears to be similar to a dual purpose plutonium and electric current producing plant authorised by the US 85th Congress at the Hanford Plutonium Plant, to be constructed by October 1962. The capacity of the power station is to be 600,000 kw. It will produce over 1 ton of plutonium per year. The location of the plant has not been disclosed but it is very likely placed on the site of some Russian atomic weapons production centre.[30]

The first part of this power station, a unit of 100,000 kw. was put in commission in September 1958.

Experimental Reactor Plant I - Boiling Water Reactor On the Volga near Ul'yanovsk.

Experimental Reactor Plant I (planned capacity 70,000 kw) will work on thermal neutrons. A boiling water reactor, it will use ordinary water as moderator and coolant and make it operate generators. This means that the secondary circuit will be eliminated. Saturated steam obtained in the reactor will be directed into turbines at a 29 atmospheres pressure. Since the steam will be radio-active it will be necessary to operate the entire plant, including turbines, by remote control. On the other hand the elimination of the secondary circuit will considerably reduce costs.

This type of reactor arrangement could be used in mobile power stations and to propel ships.

The Experimental Reactor Plant I will be used to study the stability of operation and control characteristics of this type of reactors and to investigate the problems involved in operating a turbine on radio-active steam.(32)

Experimental Reactor Plant IA - Block Type.

Another type of boiling reactor is the one where the active zone is placed in a container under pressure. Moderator and coolant is ordinary water. In such a reactor in order to obtain a high capacity, steam separators are placed in special drum-separators outside the reactor and induced circulation of water in the active zone is arranged for with the pre-set steam porosity, that is the frequency and the size of bubbles are pre-arranged. A change in the size of bubbles is accompanied by a change in the effectiveness of the water moderator. The initial activity, permissable for the capacity of regulating rods is to a considerable degree compensated by the negative steam activity. The limits of the 'boiling' area in the active zone of the reactor change in accordance with the nature and amount of cooling water circulating through the reactor. For this reason a certain amount of variation can be observed.

In the USSR, in the Ulyanovsk area a boiling water reactor of block type of electric capacity of 50,000 kw. is under construction. It will be used to study operational data of this type of reactors in general and also in the study of the problems connected with the stability of the reactor.[33]

Experimental Reactor Plant IB - Channel Type.

This reactor, also referred to as Urals reactor, has two groups of channels with fuel elements of enriched uranium, similar in construction to those used in the first atomic power station in the USSR. In one group of working channels, numbering 730, the water circulating under pressure of 160 atmospheres is heated and partly converted into steam. The steam-water mixture enters the drum of the separator, where steam is separated from the water and enters the vaporizer where it converts the water of the secondary circuit into steam.

From the vaporizer the steam of the secondary circuit, under pressure of 100 atmospheres enters the group of steam heating channels, numbering 268, in the active zone, where it is superheated to 450-500°C and then directed to the steam turbine. The condensed water from the vaporizer mingles with the water from the drum separator and moves to the circulating pumps and then into the reactor.

The problems connected with the formation of a two phase state of liquid in the working channels (instability resulting from possible pulsation in the liquid expenditure through channels and the process of steam heating in the active zone) have been sufficiently studied in the reactor of the First Atomic Power Station at Obninsk. Pulsations and distortions in the expenditure of water through the channels constitute a great danger, as unequal removal of heat might result in the burning out of the casings of the fuel elements.

Practice has shown, however, that the uniformity of work of the reactor in the state of boiling can be attained through the installation of throttle washers in the entry zone of the channels.

In the "Block Reactors" of this type the formation of steam takes place not in channels, but in the space of the active zone, which is provided with an evaporation mirror /zyerkolo isparenia/, an increase in the general capacity requires an increase in the diameter of the block, which brings in serious technological difficulties. The channel reactor described here avoids these difficulties.

The active zone of this reactor with a thermal capacity of 285,000 kw, has the diameter of 7.2 m., height 6 m. and it is surrounded by a graphite reflector 0.8 m. thick. The whole graphite assembly, contained in a steel muff, is 9 m. high and 9.6 m. in diameter. The efficiency of an atomic power station with the uranium-graphite reactor is expected to be approximately 36 per cent. In this design of a boiling water reactor technological difficulties are not likely to crop up even if the capacity of it is increased one and half to two times.

It is reasonable to expect that the reactor assembly "reactor block - steam generator" described above could equal in capacity a coal burning power station with a steam generating capacity of 900 - 1000 tons of steam per hour. Steam boilers of such capacity are still to be produced.

The danger in this type of atomic power station is from radiation and contamination of the surrounding area. The extent to which these can be overcome will determine the applicability of the reactor to power production.

The novel design of the channels in the active zone of this reactor deserves attention from the point of view of safety. The channels are constructed in such a way that in case of breakage in the channel the fissionable material enters the graphite assembly, but does not enter water or steam system. Water or steam, which in a case of an accident might enter the graphite assembly cannot do noticeable damage because in such a case a special valve automatically reduces the flow of heat carrier almost to nothing.

According to experimental data, on leaving the reactor, the oxygen activity of the superheated steam in the uranium graphite reactor amounts to 6.8×10^{-4} curies/kg. The radio activity caused by the contained in the steam sodium, calcium, manganese and other admixtures, which bring the salt content of the superheated steam to 0.1 mg/kg. is only 3×10^{-8} curies/kg. The radioactivity of the superheated steam will, therefore, be determined by the activity of oxygen.

The nuclear-physical qualities of the Uranium-graphite reactor with the steam heater is not better than the boiling water reactor of the block type, where ordinary water acts both as moderator and coolant, and where casing for the fuel elements is made of zirconium. But the possibilities of improving the nuclear-physical characteristics of the Uranium-graphite reactor with superheated steam are not yet exhausted. The idea contained in the construction of the uranium-graphite reactor, where steam is superheated in the active zone, has met with the approval of specialists.(34)

According to Western experts two things about this reactor are significant. First, that it produces steam which is superheated in the reactor, and the second, that it can operate on an enrichement of only 1.8 per cent.(35)

Experimental Reactor Plant II - Sodium Graphite Reactor (near Ulyanovsk).

Experimental Reactor Plant II will also work on slow (thermal) neutrons. It will have a capacity of 50,000 kw. The reactor will use liquid sodium (which solidifies at 98°C) as coolant. Graphite will be used as moderator, as it reacts only slightly with sodium, and is also relatively cheap.

The reactor will be cooled by four primary liquid sodium circuits, with intermediate heat exchangers and pumps, two secondary sodium circuits with steam generators and pumps and a turbogenerator, condenser and water feed pumps. Using liquid sodium it will be possible to operate with high temperatures at low pressure in the primary and secondary circuits, thus obtaining high parameter steam in the steam generator, which will mean a high rate of exploitation.

The temperature of the sodium liquid on leaving the reactor will be 560°C and in the secondary circuit 540°C, which would make it possible to obtain superheated steam of 500°C at 90 atmospheric pressures.[36]

It is necessary to use in this case a three circuit system of heat removal from the reactor since perforation of the tubes in the sodium -to-water heat exchanger might give rise to a vigorous reaction between water and radio-active sodium, resulting in the formation of highly radioactive steam. Use of an intermediate non-radioactive circuit also facilitates maintenance of the steam generator.

The reactor consists of a cylindrical graphite stack pierced by vertical holes into which are inserted the fuel elements assemblies. The fuel elements consist of slightly enriched uranium clad in stainless steel.

Development of this station will provide a considerable amount of experience in operating reactor plants with sodium coolant. It will also indicate the possibility of developing stations of a higher power with reactors of this type.[37]

Experimental Reactor Plant III - Fast Breeder Sodium Cooled Reactor near Ulyanovsk (Soviet Code BR-50).

This is a fast breeder reactor working on fast neutrons without a moderator/Rasshiryennoye Vosproizvodstvo/. Its precursors were:

a) BR-1

The first Russian physical reactor on fast neutrons (BR-1) was commissioned in April 1955. It reached a capacity of several dozen watts. It was used for the study of neutron spectra and for research work on the fat neutron system. The reactor was located on the site of the First Atomic Power Station at the Institute of Physics of Glavatom at Obninsk.

The active zone of the reactor BR-1, 130 mm. high and 100 mm. in diameter, consists of plutonium rods, contained in stainless steel casings and of rods of uranium alloy /obednyennogo urana/. These plutonium rods and uranium alloy rods are assembled in a cylinder which is surrounded by a reflector. The reactor is provided with a regulating system. There is no special protecting screen around it. No provision is made for heat extraction.

b) BR-2

To follow BR-1, BR-2 (a reactor for research in the field of nuclear physics and material study) was constructed in 1956.

Its thermal capacity is up to 100 kw. with a flow of fast neutrons of 10^{14} x H/cm^2 per second. The active zone of this reactor consists of plutonium rods of the same size as in BR-1. Apart from plutonium rods there are also uranium alloy rods. Mercury is circulated in the area between the rods, taking heat out of the reactor. The reflector has a mobile section, of uranium rods, which serves as a regulator and can be used to stop the reactor in case of accident, and an external mobile section in the form of a cylinder-shaped screen 700 mm. high and of the same diameter. Outside the external screen is placed a layer of copper 150 mm. thick.

c) BR-5

As an intermediary stage between reactor BR-2 and the reactor for atomic power stations which would work on fast neutrons, a prototype reactor BR-5 of 5000 kw thermal capacity was constructed and commissioned in July 1958. This reactor has a neutron flow of 10^{15} x H/ cm^2 per second.(38)(39)

This reactor somewhat resembles the US reactor (using enriched uranium) which came into operation in 1951.

Atomic Power Propelled Ice-breaker "LENIN".

The work on the construction of "LENIN" was started on 17.7.1956. On 5.12.1957 the ice-breaker was launched and the period of fitting out was started. On 20.12.1958 tests in berth were carried out next to the construction plant. On 19.9.1959 the ice-breaker received power from the atomic reactors for the first time. The length of the vessel is 440 ft, beam 90 ft and displacement 16,000 tons. The construction of the vessel lasted three years and two months.[40]

The "LENIN" is powered by three pressurized water reactors, which give to the main generators the maximum capacity of 44,000 hp. The steam from the reactors is also expelled forward under pressure to melt ice. It will be able to ply icy northern seas for periods of about one year without refuelling. Normally the ice-breaker will operate on two reactors, the third one being used only when the heaviest conditions are encountered.

The vessel has a double hull; the space between is used as a storage space for drinking water. It carries two helicopters for air conditions and ice field reconnaissance.

The pressurized reactors on the "LENIN" are almost the same as those powering the US submarine "NAUTILUS".[41]

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CHAPTER VII

CONCLUSION

The comparison of fuel economies of the USSR, U.S.A., U.K., and Canada leads to an overall conclusion that so far technological changes in types of fuels have been better utilized by the free market economies than by the planned economy. Whereas the free market economies have been shifting over to more economic types of fuels, the USSR has been saddled with an uneconomic type of fuel - coal - for a very long time, namely until the preparation of the unified fuel and power balance, for it was only then that a conscious decision has been taken to effect the shift to more economic forms.

The avowed aim of a free economic system and of a centrally controlled one is to satisfy the needs and wants of the people. In a free economic system those needs are manifested through the people's demand. Under controlled economy the needs and wants of the people are determined by the government, which, apart from any other considerations can only determine priority mix for various products in accordance with its own point of view. Planning of this kind propels the economy along predetermined lines, and is often blind to technological changes brought about by progress. Under such conditions priority mix, enforced by bureaucratic machine, disregards relative costs under specific conditions and often prevents effective exploitation of innovations. Since the production targets are fixed and the bulk of profit goes to the state, the industries and individual enterprises with low costs (as for example oil and gas in the past) are not able to make use of their advantageous position. The change in output is dictated not by a spontaneous change in demand but by government decision based on its own considerations. Low costs lead primarily to a government revenue and not to an expansion of the given industry, the size of which is determined beforehand by the plan. If the new shift comes about, it will come as a result of a belated government decision to alter the order of priority with regard to this sector.

In an economy where basic variables are determined in such an arbitrary manner, there can be no value to serve as a medium with the aid of which projects in various fields could be reduced to a single standard for the purpose of comparison and evaluation. Writing in 1920, when the centrally controlled economy was being established in the USSR, Professor Ludvig von Mises said:-

> "In the Soviet Commonwealth every economic change becomes an undertaking whose success can be neither appraised in advance nor later retrospectively determined. There is only groping in the dark" ...... "for where there is no free market, there is no pricing mechanism, without a pricing mechanism there is no economic calculation."(1)

This analysis is as true to-day as it was then. In planning rigidly ahead without the benefit of the free market to point out relations of costs in various industries and to adjust them when technological progress requires it, the Soviet planners are called upon to perform an impossible task - to prepare a plan based on the "correctly guessed" relative cost structure in various industries and at the same time to allow for the flexibility necessary for the progressive development of the economy. Failure to do that involved the Soviet economy between 1928 and 1960 in great losses.

After the preparation of the unified fuel and power balance it is clear that compared with gas and oil coal is less economic as a source of heat and as a result a shift took place, which aims at replacing coal with oil and gas wherever their costs of production and transportation are lower than those of coal.

From 1960, the time of preparation of the Fuel and Power Balance for the entire Soviet economy the story of the past seems about to repeat itself. Now it is the relative uncertainty of the long term unit costs of oil and gas as well as coal on the one hand, and atomic power on the other, which the Soviet planners must somehow translate into the long term plans of the fuel and power industry, and it cannot without risking extensive misallocation of resources.

In the West, this transition will be determined by relative market prices of all fuels. In U.K. atomic power is an alternative to high price coal or imported oil, while in U.S.A. and Canada atomic power must compete with abundant reserves of fossil fuels, the production of which can be increased substantially without any appreciable increase in the costs of extraction.

The factor that makes application of atomic energy attractive in these countries is the cost of transport, which is nearly zero so far as atomic fuels are concerned. Transport costs at power stations fuelled with conventional fuels are small when these are located directly at the mines, but mount rapidly with the increase in distance between the mines, oil wells or gas holes and the power stations. Because of the high cost of construction and very effective economies of scale atomic power stations can be best utilized as base load power stations.

Assuming technical level and the availability of raw materials equal to those found in the Western countries there are reasons to believe that in the Soviet Union atomic power could be utilized economically in many areas where conventional fuel resources are located far from consumption centres. In the course of the survey it was noted that the Urals, the Western and the Central regions and the North West of the European part of the country all have to import fuel from other parts of Russia and that even in the areas of the East, containing 80 per cent of Russia's coal, there are places where coal prices are very high because of the distance over which it has to be transported to isolated development areas.

The study of the Soviet attitude to gas and oil leads one to the conclusion that the country has embarked upon the period of "Gas priority" which is replacing "coal priority". The preparation of the fuel and power balance will probably prevent the development of a situation as out of hand as existed during the "coal priority" period, which caused such huge losses to the economy. But at present the problem arises - How to reconcile nuclear power on the one hand and oil and gas on the other?

The Soviet Union is building at present an oil pipeline from Kubishev area past Moscow, across Poland to Germany and Czechoslovakia, a distance of over 3,000 km. Can such a line be an economic undertaking? And under what conditions? According to Soviet sources natural gas compared with Donbass coal is 7.3 times cheaper at the place of extraction and only 1.8 times cheaper when delivered to a consumer 1,200 km. away. Taking the cost of natural gas at 10 Roubles and Donbass coal at 73 Roubles per conventional ton of fuel the following table can be compiled.[2]

Cost of fuel at place of Extraction	Cost of fuel at place of use	Cost of transport over 1200 km.	Cost of Transp. over 100 km.
10	58.53	48.53	4.04
73	98.55	25.55	2.13

It must be added that in the case of coal, costs per km. decline with the increase in distance, as the handling charges are the same whatever the distance of transportation. In the case of gas, on the other hand, the initial advantage due to the fact that gas is found underground under pressure, is lost with the distance and with the period of time during which gas reserves are used. It is likely, that with the increased use of gas the costs of both production and transportation are likely to increase. And how to fit into this table the atomic power, the unit costs of which are as yet uncertain?

The fuel balance has shown the errors of the past. It remains to be seen, whether it will lead to the avoidance of errors in the future as well.

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A P P E N D I C E S

APPENDIX A

FUEL RESOURCES OF THE USSR.

The Russians claim that by 1956 deposits of hard fuels, oil, natural gas and hydroelectric power discovered within the USSR borders, when converted into conventional fuel units, amounted to 1,590 billion tons, compared with 1,550 billion tons for U.S.A. and 730 billion tons for Europe (without USSR.). They also point out that the natural resources of the USSR have not been investigated as thoroughly as in the U.S.A. or Western Europe.(1)

The total water power resources of the USSR are estimated at 340 mill. kw. or 2978 billion kwh. per year. The theoretically probable gross water power potential of the USSR was determined at 420 mill. kw. or 3680 billion kwh. per year. More than half of the water power resources of the USSR belong to the Arctic ocean (including Berents Sea, Kara Sea, Laptyev and East Siberian Sea), while lakes without outlets, which include the Caspian and the Aral seas, account for 26.7 per cent. In the USSR there are fifty rivers with a potential power capacity of more than 10 billion kwh., and twenty-one rivers with a potential power capacity of more than 20 billion kwh. It is estimated on the basis of surveys, however, that only half of the water power potential is exploitable, the rest must be lost for technological and other reasons.(2)

In spite of the extensive hydraulic resources the bulk of power in the USSR is obtained from thermal power stations using coal or peat; in 1955 22,707,00 kw. installed capacity out of 37,230,000 kw. used these fuels.(1)

According to estimates made by the academician G.M. Krzhizhanovsky in 1937, known deposits of coal in Russia constituted 21.0 per cent of world reserves and were the second largest after the U.S.A. Russian deposits of oil constituted 58.8 per cent of known world resources, of peat 60 per cent, of water power 28 per cent. Dr. Voznesensky, on the other hand, gives the latest figures for the USSR as comprising 11.4 per cent of world reserves of coal, compared with 6.4 for Europe, 35.7 per cent for Asia, 18.7 per cent for Africa, 18.7 per cent for North America, 16 per cent for South America and 4.5 per cent for Australia.(2) A.F. Zasyadko gives Russian coal reserves at 7765.3 billion tons of which half are at a depth of less than 600 metres.(3)

The size and the composition of the natural resources of fuel and power in the USSR are given in the table overleaf.

TABLE XI

Fuel and Power Resources of the USSR.[1]

Sources of Power	Unit of Measure	1913	1937	in %
Anthracite and coal	bil. t.	230,000	1,443	94.7
Brown coal	" "		211	
Oil	bil. t.	0.9	6.4	0.7
Natural Gas	bil. m^3	-	986	0.1
Oil Shale	bil. t.	-	55	0.9
Peat	bil. m^3	-	145	3.4
Wood	bil. m^3	-	24	0.2
Total in bil. tons of conventional fuel			1,427.4	100.0

Water power Resources mill. kw. Minimum estimate 58

Maximum estimate 280 revised to 300[2]

and to 340[3]

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APPENDIX B

Coal.

The principal coal deposits of the USSR are:-

Donbass - amounting to 90 billion tons, situated in the Donetz ridge. Historically this is the most important coal basin. The calorific value of the deposits is said to be 6,800 calories per kg. Although it does supply a certain amount of coal to Moscow and the Moscow region, the distance that separates it from the capital is 800 miles, which has an appreciable effect on the cost at the place of consumption. The Donetz basin coal deposits are being depleted and costs of production are high. In the case of 10.5 per cent of the mines the costs are two to three times higher than the average for the industry, and it has been urged that the exploitation of these mines should be discontinued.(1)

Kuznetsk Basin. The Kuzbass reserves are estimated at 450 billion tons of high grade coal, of calorific value of 7,000 calories per kg. The basin is located in the Kuznetsk between the Ala-Tau range and the Solair Range, along the river Tom. The basin was developed rapidly after 1931 as a part of the scheme to develop the metallurgical industry of the Urals based on Magnitogorsk iron ore and Kuznetsk coal. The distance between these two sources of raw material is 1,200 miles.

Karaganda Deposits are estimated at 53 billion tons. The coal here is not as good as in the Kuznetsk basin, as its calorific value is only about 6,000 calories per kg. but the basin is nearer to the Ural iron and steel centres. Karaganda coal has replaced Kuznetsk coal in Magnitogorsk, but not in the central Urals, where Nizhni Tagil and Chelyabinsk continue to use Kutznetsk coal.(1)

Ural Deposits, which include the coal deposits of Kizyl, Bogoslavsky (Ugolny) Yegorishno, Chelyabinsk (Lignites), Bredy (Anthracite) Dombrovsky and others. The coals here have the calorific content of only 5,200 calories per kg., and some of the deposits are near exhaustion.

Moscow Basin, the reserves of which are estimated at 12 billion tons, consists mostly of lignites. These are of poor quality, with calorific content of approximately 4,000 calories per kg. Moscow basin coal is used as domestic fuel and as furnace fuel in power stations in the Moscow area. The cost of production of Moscow coal is 222.2 per cent higher than the average cost of production for the USSR. The coal is three times dearer than coal from Donetz basin.(2)

Tungus Basin in Siberia, estimated at 440 billion tons, situated in the basin of the Upper, Middle and Lower Tunguska rivers. Especially important here are the rich coal deposits of Cheremkhovo Basin, near Irkutsk, estimated at 80 billion tons, suitable for metallurgy, gasification and extraction of liquid fuels.

Apart from the above there are also found in Siberia large deposits of lignite in the Lena and Chulymo-Yenisei basins, estimated at 203 and 43 billion tons respectively. Coal is also found in Minusinsk (20 billion tons), and Kansk (42 billion tons).

In the Transbaikal area of Siberia are located the coal deposits of Bukachacha, Gusinoye Ozero and Chernovskie Kopii. Altogether, Siberian coal deposits are estimated at 800 billion tons, which is approximately 50 per cent of total Soviet reserves.

In the Far East, coal is found in Sakhalin, Kamchatka, the Bureya Basin (estimated at 26 billion tons), the Kivda-Raichikhinsk, the Suchan and the Suifun basins, which in 1955 together contributed over 4 per cent of coal mined in the USSR.

Pechora Basin, situated in the European North approximates Donbass reserves in size. Opened during the second FYP (1933-1937) its output in 1955 was over 14 million tons.

Tkrarcheli and Tkibuli deposits in Georgia, estimated at 200 million tons, are of local importance only.

In Central Asia there are a number of coal basins estimated jointly at 18 billion tons. The richest among them are the Fergana Valley deposits of Sulyukta, Kyzyl-Kiya, Shurab, and Kok-Yangak.

Ekibastuz basin in Kazakhstan, contains approximately 7 per cent of all Russian reserves. Here, from open cast mines the coal is loaded directly onto the railway wagons by enormous excavators at the rate of one trainload every 10 minutes.

The principal users of coal are railways, metallurgical industries and electric power stations, which together consume two-thirds of the total output. The consumption of coal in iron and steel industry and in transport was as follows (in million tons):-

	1932	1940	1950
Railway and river transport	25	49	65
Iron and steel industry	12	39	60

The Soviet government attached a great deal of importance to the mechanization of the coal industry. By 1940, 95 per cent of cutting and hewing, 90 per cent of conveying, and 60 per cent of underground haulage was done by mechanical means. Due to mechanization, organization and the use of incentives, output per worker increased from 11.8 tons in 1927/28 to 14.1 tons in 1932, 23.7 tons in 1936 and 30.6 tons in 1940.[1]

See Table overleaf, (Estimation of Coal by Areas).

TABLE XII

Extraction of Coal by Areas (1)

	1913		1928		1932		1937		1940	
Total	29,117	100	35,510	100	64,360	100	127,968	100	165,923	100
1. Donetz Basin	25,288	86.9	27,330	77.0	44,716	69.5	77,466	60.5	94,319	56.8
2. Kusnetsk Basin	774	2.7	2,618	7.4	7,255	11.3	17,813	13.9	22,487	13.6
3. Ural Basin	1,217	4.2	1,989	5.6	3,166	4.9	8,085	6.3	11,956	7.2
4. Moscow Basin	300	1.0	1,135	3.2	2,613	4.1	7,506	5.9	10,093	6.1
5. Karanganda Basin	-	-	-	-	722	1.1	3,937	3.1	6,298	3.8
6. E.Siberian Output	847	2.9	1,009	2.8	2,456	3.8	5,800	4.5	9,229	5.6
7. Far East	373	1.3	1,073	3.0	2,261	3.5	4,845	3.8	7,217	4.3
8. Pechora Basin	-	-	-	-	9	0.0	120	0.1	273	0.2
9. Central Asia	158	0.5	234	0.7	743	1.2	914	0.7	1,685	1.0
10. Georgian SSR	70	0.2	85	0.2	205	0.3	400	0.3	625	0.4
11. Ekibastuz										

Source:-
(1) Promishlennost' SSR. Gostatisdat Moscow. 1957 p. 142 - 143.

continued/

Extraction of Coal by Areas[1](Continued)

	1945		1950		1955		1958	1965
Total	149,333	100	261,089	100	391,259	100	495.8	600-612 (Plan)
1.	38,403	25.7	94,645	36.3	140,958	36.0	181.7	
2.	30,027	20.1	38,526	14.8	58,539	15.0	75.3	
3.	25,667	17.2	32,487	12.4	47,058	12.0	61.0	
4.	20,253	13.6	30,881	11.8	39,494	10.1	47.2	
5.	11,340	7.6	16,440	6.3	24,710	6.3	24.3	
6.	9,206	6.2	17,523	6.7	26,631	6.8	36.1	
7.	7,858	5.3	13,140	5.0	17,355	4.4	20.0	
8.	3,349	2.2	8,688	3.3	14,153	3.6	16.8	
9.	1,413	0.9	3,777	1.4	5,870	1.5	7.7	
10.	661	0.4	1,725	0.7	2,712	0.7	3.0	
11.					2,282	0.6	6.15	

R E F E R E N C E S

P.171. 1. A.F.Zasyadko. Fuel and Power Industry of the USSR /Toplivno Energeticheskaya Promishlennost' SSSR/. Gosplanizdat. 1959. Review of the book by N.Melnikov in Planovoye Khozyaistvo.1960.III. p.85

P.172. 1. Stefan Lament. Soviet Fuel and Power. Soviet Studies. 1952/53. Vol.IV. p. 1-14.

2. A.F.Zasyadko. Fuel and Power Industry of the USSR /Toplino Energeticheskaya Promishlennost' SSSR/. Gosplanizdat. 1959. Review of the book by N.Melnikov in Planovoye Khozyaistvo. 1960.III. p.85.

P.174. 1. Stefan Lament. Soviet Fuel and Power. Soviet Studies. 1952/53. Vol.IV. p.6.

APPENDIX C

Oil

By 1972 the output of oil, which in 1959 was 144 million tons and constituted 35.4 per cent of the national fuel balance will increase to between 350-400 million tons, and its share in the balance will rise to 37.5 per cent as against 32 per cent for coal and 23.5 per cent for gas.

The most important oil centre of the USSR in the past was the Caucasus, including the area situated on the Apsheron Peninsula on the south west shore of the Caspian sea adjoining the city of Baku. In 1941 Azerbaijan produced 71.5 per cent of oil in Russia. The output was reduced by half during the war and, partly due to the fact that the deposits are being depleted and partly because other oil bearing areas have been developed, by 1955 the importance of Azerbaijan had declined to 21.6 per cent. Other important oil bearing centres belonging to this group are Grozny and Maikop.

Second Baku is a name generally applied to the Perm (Molotov), Syzran (Kuibishev), Boguruslan (Chkalov) areas of the Middle Volga Region and the Ishimbai and Tuimaza districts of the Bashkir ASSR. It is becoming an increasingly important supplier of Russian oil. The oil was discovered here in the middle of the thirties and the industry developed rapidly due to the war-time shift to the East.

The Emba oil bearing area is located principally in

W. Kazakhstan. It yields oil of especially high quality. The most important oil deposits in this area are Dossor, Makat, Iskine, Koschagil and Baichunas.

The industrial oil regions of Central Asia are located in the Fergana Valley and the basin of the upper Amu-Darya. The Fergana oil region includes the Andizhan and Namangan deposits as well as newly discovered deposits in the South West, the Novaya Bukhara (Kagan) near the city of Bukhara. In the basin of the upper Amu-Darya, oil reserves are in the Khandak and Uch-Kyzyl regions of the Uzbek SSR. There are two large oil-bearing areas in Turkmen SSR, the Western and the Eastern. The first includes the important Nebit-Dag oil bearing region and the second includes the basin of the lower Amu-Darya, the Karakum sands, the borderland of the eastern Kopet Dag and the Paropamiz.

Oil deposits are also found in Sakhalin, Kamchatka, and at the foot of the Carpathian mountains.

On April 30th 1960 Pravda carried an article stating that at the Tyumen forest North of Novosibirsk, 350 km. North of Tyemen and 200 km. East of Ivdel station, a Russian drilling team struck oil at a depth of 1428-1436 m. The output of the well was given as 25-30 tons per day. In June 1960 a second well was sunk, producing 350 tons per 24 hours, and the third one, opened since then, has an output of 60 tons per 24 hours, in addition to which it provides 5,000 m^3 of natural gas.(1) The oil content of the new wells is 0.831 of oil. Sulphur content is 0.4 per cent, which puts it in the category of high-grade oil of the type found in the areas of Bashkiria and Checheno-Inguish. The size of this Siberian oil-bearing area is believed to be equal to the oil area of Bashkiria. Should this prove to be the case the present oil situation in Siberia would be radically changed.

Changes in location of oil extraction in USSR are given in table below.

	1913	1940	1955	1956	1957
Caucasus	97.0	87.1	56.7	30.0	27.0
Volga-Ural	-	6.0	29.0	58.0	62.8
Central Asia and Kazakhstan	2.9	4.8	11.8	8.0	7.1[1]

During the 1951-57 period the share of various regions in the growth of the oil industry was as follows: Tartar SSR - 37 per cent, Bashkir - 27 per cent, Kuibishev - 14 per cent, Stalingrad - 6 per cent, Saratov - 4 per cent. The table below gives the places occupied by the more important centres in the USSR oil production:[2]

	1940	1950	1956	1957
Azerbaijan	1	3	3	3
Tartar SSR	-	2	2	1
Bashkir	4	1	1	2
Kuibishev district	7	4	4	4
Stalingrad "	-	7	7	7
Saratov	-	8	8	8

The level of expenditure per one ton of oil (including its heat producing capacity) is on the average three times lower than the cost of one ton of coal. In the future this important economic superiority of oil extraction will increase since the level of costs per ton of oil in the Volga-Ural region, whose share in the total oil extraction is steadily growing, is approximately three times lower than the average for the oil industry as a whole. Oil compares favourably with coal in expenditure of labour to prepare the reserves for exploitation and in conditions of work. Productivity of labour in the oil industry (calculated in terms of conventional fuel) is four times higher than in the extraction of coal.(1)

The table below gives the average 1946-54 share of the various regions in capital investments in oil extracting areas and their contribution to the increase in oil extraction.(2)

	Capital investments in oil extraction	Share in the increase in oil extraction
Caucasus	47.2	20.4
Volga-Ural	30.3	69.1
Central Asia	13.1	8.6
Far East	5.7	0.3
Ukrain	2.5	0.8

By the beginning of 1957 the oil industry of the USSR had 31 pipe-lines of the aggregate length of 11,500 km. of these 6 product-pipe-lines had the length of 4,000 km. Of the

11,500 km. 5,000 km. were constructed during the 1950-55 period. (Compared with 180,000 km. of pipelines including 50,000 km. of product-pipe-lines in the U.S.A.[1] The 6th FYP and the Seven Year Plan, which superseded it, also provide for the construction of long pipe-lines. The main lines planned are:[2]

Tuymazy - Omsk (Second Line) - Completed by 1957
Omsk - Irkutsk
Al'metyevsk - Gorki - Completed by 1957
Al'metyevsk - Perm / Molotov / - Completed by 1957
Gorki - Ryazan - Moscow
Gorki - Yaroslavl
Ishimbai - Orsk
Omsk - Novosibirsk
Ufa - Omsk - Novosibirsk - Irkutsk
Kuibishev - Bryansk / Products pipe-line/
Ufa - Omsk - Novosibirsk /Products line /

An international oil pipe-line is to be built to link up the USSR with Czechoslovakia, Hungary, Poland and German Democratic Republic. The line will start near Kuibishev, on the left bank of the Volga. It will be one metre in diameter and will first run to Mozir (in the Ukrain) a distance of 1,600 km. long, from where one line will run to Ushgorod and from there across Czechoslovakia to Hungary. The second line will cross the Russian-Polish frontier near Brest Litovsk, run across Poland a distance of 675 km. and enter the German Democratic Republic on the latitude slightly North of Berlin. The line is to be completed by 1962.[1]

TABLE XIII

Extraction of Oil Shale (in thousands of tons).[1]

	1928	1932	1937	1940	1945	1950	1955
USSR	0.6	318.2	515.0	1682.9	1387.1	4716.2	10,793.2
R.S.F.S.R.	0.6	318.2	515.0	734.1	514.0	1156.4	3,782.5
N.W. Region	-	73.0	254.0	403.5	-	347.3	2,068.2
Central Region	-	-	2.0	23.0	-	-	-
Volga Region	0.6	245.2	259.0	306.8	514.0	809.1	1,714.3
Ural Region	-	-	-	0.8	-	-	-
Kazakh SSR	-	-	-	1.8	12.1	16.8	1.0
Estonian SSR	-	-	-	947.0	861.0	3543.0	7,009.7

(1) Promishlennost' SSR. Gospolitizdat. Moscow, 1957. p. 166.

TABLE XIV

Output of Oil - by Union Republics. (000 t.)[2]

	1913[1]		1928		1932		1937		1940		1945	
USSR	10,281	100	11,625	100	21,414	100	28,501	100	31,121	100	19,436	100
RSFSR	1,295	12.6	3,682		8,841		5,746		7,039	22.6	5,657	
Ukranian SSR	1,047	10.2	-		-		0.7		353	1.1	250	
Uzbed SSR	13	0.1	17		44		362		119	0.4	478	
Kazakh SSR	118	1.1	250		247		490		697	2.2	788	
Georgian SSR	-	-	-		3		9		41	0.1	36	
Azerbaijan SSR	7,669	74.6	7,657		12,228		21,414		22,231	71.5	11,541	
Kirgiz SSR	-	-	-		-		0.8		24	0.1	19	
Tajik SSR	10	0.1	11		17		27		30	0.1	20	
Turkmen SSR	129	1.3	8		34		452		587	1.9	629	

Source: (1) Within present frontiers.

(2) Promishlennost' SSSR. p. 155.

(continued).

Output of Oil - by Union Republics (000 t.)[2] (continued).

	1950		1955	
USSR	37,879	100	70,793	100
RSFSR	18,231	48.2	49,263	69.6
Ukranian SSR	293	0.8	531	0.7
Uzbek SSR	1,342	3.5	996	1.4
Kazakh SSR	1,059	2.8	1,397	2.0
Georgian SSR	43	0.1	43	0.1
Azerbaijan SSR	14,822	39.1	15,305	21.6
Kirgiz SSR	47	0.1	115	0.2
Tajik SSR	20	0.1	17	0.02
Turkmen SSR	2,021	5.3	3,126	4.4

R E F E R E N C E S

P.179. 1. Pravda. 14.9.1960.

P.180. 1. M.Brenner. Problems of the Oil Industry in the Perspective of the Development of National Economy of the USSR /Problemy Nefti v Perspektive Razvitia Narodnogo Khozyaistva SSSR/.Voprosy Ekonomiki. 1958.II.p.21.

2. Ibid., p.21.

P.181. 1. Ibid., p.16.

2. Ibid., p.28.

P.182. 1. K.V.Dolgopolov, A.V.Sokolov and E.F.Fyodorova. Oil and Gas in the USSR /Neft i Gazy SSSR/. Uchpedgiz. Moscow. 1960.

2. Ibid.,

P.183. 1. Pravda. 27.7.1960.

APPENDIX D

Natural Gas

Russian latest estimates of potential reserves of natural gas are stated at 50-60 trillion cubic metres. Estimated reserves are stated to be 19-20 trillion cubic metres, and the present industrial reserves - as of 1959- 1.5 trillion cubic metres. In 1940 the reserves were estimated at 15 billion cubic metres, by 1953 the figure was raised to 389 billion cubic metres, by 1956 it was nearly half a trillion. In 1958 alone were discovered 17 major gas reserves and the increase in the industrial reserves during that year amounted to 300 billion. In 1959 the increase was 500 billion, and the total industrial reserves reached one and a half trillion cubic metres.(1)

The main gas reserves of the USSR are:

a) Stavropol Krai reserves and the Krasnodar Krai reserves in the North Caucasus, which will probably be made into a single unified gas producing area.

b) Kalmik ASSR reserves.

c) Gazli reserve in Bukhara-Khivinsk region in Uzbekistan, estimated at over 400 billion cubic metres.

d) Shebelinsk deposits in the Ukrain, estimated at 400 billion cubic metres.

e) Beryozovo-Tyumen Oblast deposits.

f) Yakutia deposits.

g) Saratov Oblast deposits.

h) Stepnovskoye Reserves in Trans-Volga.[1]

During the present 7-year plan in the European part of the USSR the output of gas is to be increased 3.8 times, compared with twofold increase for oil and 7 per cent increase in the production of coal. In 1965 there will be extracted 150 billion cubic metres of gas of which 100 billion shall be used up in the European part of the USSR. In 1965 the share of gas in the balance of the fuel economy shall be 27 per cent, and by 1972 - 23.5 per cent.

Introduction of natural gas as industrial and non-industrial fuel in the USSR was started during the war when were constructed Yelshanka-Saratov and Boguruslan-Kuibishev gas pipe-lines. Though a short line from Izberbash to Mahachkala of 65 km. was constructed prior to that in 1940. During the Fourth FYP (1945 - 1950) was constructed gas pipe-line Saratov-Moscow, 843 km. long, which resulted in an annual saving of 1 million cubic metres of wood, 650,000 tons of Moscow Basin coal, approximately 150,000 tons of Kerosine, and more than 100,000 t. of crude oil. The pipe-line is of a small diametre. It has 6 compressor stations. The cost of transporting gas along it equals approximately 50 Roubles for 1000 m^3 of gas conveyed.[2] [3]

During the same period was constructed gas pipe-line Dashava-Kiev of 513 km. made up of 36 m. segments, which was later extended to Moscow. The third important line was Kohtla-Yarve to Leningrad, of 203 km. In 1957 was commissioned

Shebelinka-Dnepropetrovsk line and Shebelinka-Kharkov. The cost of transporting as over these two lines is only 3-4 Roubles per 1000 m^3. This is due to the fact that the gas found here is under high pressure, which eliminates the use of compressor stations.

The current Seven Year Plan provided for the construction of 26,000 km. of gas pipe-lines, including:

Stavropol - Moscow (second line) of 1,300 k. - now completed.

Stavropol - Nevinnomissk - Mineralnie Vody - Drozny.

Serpukhov - Leningrad - now completed.

Al'matyevsk - Kazan - Gorki - - completed by 1957.

Under construction at present are:

Krasnodarsky Krai - Rostov-on-Don - Serpukhov - Kalinin - Leningrad pipe-line of 1,020 mm. in diametre.

Shebelinka - Dnepropetrovsk - Odessa - Kishinev line.

Shebelinka - Kharkov - Kursk - Orel - Bryansk.

Saratov - Ivanovo - Cherepovetz.

Kazan - Gorki.

Dashava - Minsk - Vilnius - Riga.

Karadag - Akstafa - Tbilisi.

Akstafa - Erevan.

Gozli - Urals (a double line of 1,020 mm. in diametre).

Minsk - Leningrad.

Tashkent - Chikment - Dzhambul - Frunze - Alma-Ata.

Beryozovo - Sverdlovsk.

Grozny - Tbilisi.

Generally the thickness of the pipes is 720 - 820 mm.

in diametre, except where stated otherwise.

Under construction near Moscow is the first seasonal gas storage space.

It is estimated that by 1965 approximately one quarter of the population shall use gas coming from gas networks or in compressed form in gas-tanks.

In 1957 the total length of gas lines in the USSR amounted to 6,600 km. of which 77 per cent (5,000 km.) were used for transporting natural gas and 23 per cent - for synthetic gas.

The largest gas pipes in the USSR are 3-4 times smaller than in the U.S.A. The largest Russian pipe-lines are of up to 5 mill. cubic metres, while those in the U.S.A. are 14.3 mill. cubic metres (Texas - N.Y.) or even 20.9 mill. cubic metres (Texas - Pennsylvania - New York).

According to the current Seven Year Plan the application of gas in 1965 is to be as follows:

10 per cent for consumers' needs.

6 per cent - raw material for chemical industry.

34 per cent - for use at power stations and as boiler fuel.

43 per cent for technological purposes in cement, iron and steel and machine building industries.

7 per cent for the use in gas industry itself.(1)

TABLE XV

Extraction of Natural Gas.[1] (mil. cub. m).[2]

	1928	1932	1937	1940	1945	1950	1955	1960
USSR	304.0	1049.0	2178.9	3219.1	3278.0	5760.9	8980.9	53 bil. m^3 (Plan)
RSFSR	126.9	519.8	180.0	209.9	1494.8	2867.3	4291.0	
North Region	-	-	-	-	447.0	1076.4	1075.9	
Volga Region	-	-	-	-	728.3	964.7	1627.2	
N. Caucasus	126.9	519.8	156.3	195.0	120.2	322.2	595.3	
Ural	-	-	27.3	14.9	130.9	418.9	799.8	1965
Far East	-	-	-	-	68.4	85.1	192.8	150,000 (Plan)
Ukranian SSR	-	-	-	495.1	776.9	1536.5	2927.6	
Uzbek SSR	-	3.0	1.0	0.7	8.9	52.2	103.0	
Kazakh SSR	1.3	2.3	3.7	3.9	4.9	7.4	24.7	
Azerbaijan SSR	175.5	522.0	1991.0	2498.1	976.7	1232.8	1493.8	1972
Kirgiz SSR	-	-	-	-	0.1	-	-	280-320 (Plan)
Tajik SSR	0.3	1.9	3.2	2.2	0.8	0.2	-	
Turkmen SSR	-	-	-	9.2	14.9	64.5	140.8	
								1975 400-425 bil. m^3 [3]

Source:

(1) Including by-product gas.

(2) Promishlennost' SSR. p. 156.

(3) Maslakov D.I. Fuel Balance of the USSR. Gosplanisdat. 1960.

TABLE XVI

Extraction of Gases in USSR (in million cubic metres).[1]

Republics and Regions	Natural Gases				Coal and Shale Gases			
	1928	1940	1945	1955	1928	1940	1945	1955
RSFSR - Incl.	126.9	209.9	1494.8	4291.0	26.8	167.0	129.0	961.0
Volga Region	-	-	728.3	1627.2	-	-	-	-
North "	-	-	447.0	1075.9	-	-	-	-
Ural "	-	14.9	130.0	799.8	-	-	-	-
N.Caucasus Region	126.9	195.0	120.2	595.3	-	-	-	-
Far East Region	-	-	68.4	192.8	-	-	-	-
Central Region	-	-	-	-	26.8	118.8	129.0	578.0
N.W. Region	-	-	-	-	-	48.2	-	383.0
Ukranian SSR	-	495.1	776.9	2927.6	-	0.03	0.3	9.6
Azerbaijan SSR	175.5	2498.1	976.7	1493.8	-	-	-	-
Turkmen SSR	-	9.2	14.9	140.8	-	-	-	-
Uzbek SSR	-	0.7	8.9	103.0	-	-	-	-
Kozakh SSR	1.3	3.9	4.9	24.7	-	-	-	-
Tadjik SSR	0.3	2.2	0.8	-	-	-	-	-
Kingiz SSR	-	-	0.1	-	-	-	-	-
Estonia SSR	-	-	-	-	-	0.9	1.0	387.9
Latvia SSR	-	-	-	-	-	4.7	2.5	16.7
Total	304.0	3219.1	3278.0	8980.9	26.8	172.63	133.3	1375.2

Source: (1) Dolgopolov K.V., Sokolov A.V. and Fyeodorova E.F. Oil and Gas in the USSR. Uchpedgiz. Moscow. 1960.

Extraction of Gases in USSR (in million cubic metres).[1] (continued).

Republics and Regions	All - Gases			
	1928	1940	1945	1955
RSFSR - Incl.	153.7	376.9	1624.3	5252.0
Volga Region	-	-	728.3	1627.2
North Region	-	-	447.0	1075.9
Ural Region	-	14.9	130.9	799.8
N. Caucasus Region	126.9	195.0	120.2	595.3
Far East Region	-	-	68.4	192.8
Central Region	26.8	118.8	129.5	578.0
N.W. Region	-	48.2	-	383.0
Ukranian SSR	-	495.13	777.2	2937.2
Azerbaijan SSR	175.5	2498.1	976.7	1493.8
Turkmen SSR	-	9.2	14.9	140.8
Uzbek SSR	-	0.7	8.9	103.0
Kozakh SSR	1.3	3.9	4.9	24.7
Tadjik SSR	0.3	2.2	0.8	-
Kingiz SSR	-	-	0.1	-
Estonia SSR	-	0.9	1.0	387.9
Latvia SSR	-	4.7	2.5	16.7
Total	330.8	3391.73	3411.3	10356.1

R E F E R E N C E S

P. 188. 1. A.F. Zasyadko. Fuel and Power Industry of the USSR /Toplivno-energeticheskaya Promishlennost' SSSR/. Gosplanizdat. 1959. Review of the book by N.Melnikov in Planovoye Khozyaistvo. 1960.III.p.85.

P. 189. 1. Ibid., p.85.

2. 1000 m^3 of gas is equal to approximately 3 tons of coal.

3. K.V.Dolgopolov, A.V.Sokolov and E.F.Fyedorova. Oil and Gas in the USSR /Neft in Gazy SSSR/. Uchpedgiz. Moscow. 1960.

P. 191. 1. Ibid.

APPENDIX E

Oil Shale

The most important of developed Russian deposits of Oil shale are in the Estonian SSR, which in 1955 accounted for 65 per cent of all shale extraction in the USSR. Besides these, three are rich deposits in the Southern part of the Timan ridge, along the Ukhta river, along the right bank of the Volga near Ulyanovsk, near Syzran, and in the region of Obshchy Sirt.

Utilization of shale is of particular importance to regions that are poor in other types of fuel (Estonian SSR, Leningrad district, and others). The combustible shale mass contains 70 - 80 per cent of volatile substances, which makes it ideal fuel for gasification and for distillation of liquid fuel. During the Fifth FYP a gas pipe-line, Kohtla-Yarve - Tallin, was constructed.

The Sixth FYP 1955 - 1960 provided for an increase of 67 per cent in the output of shale. (1)

1. Promishlennost' SSSR. Statesticheski Sbornik. Gospolitizdat. Moscow, 1957. p.304.

APPENDIX F

Peat

As can be seen from the general outline in Chapter I the Soviet Government attached a great deal of importance to the development of the peat industry. In many parts of Russia Peat is the only local fuel available. In 1938 reserves of peat were estimated at 150,600 mill. tons. Peat is used extensively in the Central and north west part of Russia.

In 1955 thermal power stations of aggregate power capacity of 2,234,000 kw. used peat as fuel to produce 12,422 billion kwh. of electricity. (Compared with 15,290 billion kwh. produced in power stations burning oil).

Peat extraction in 1958 amounted to 52.8 mill. tons. Although the Soviet experts take a much more critical attitude to peat now, this is a very recent innovation, as can be seen from the following statement:-

> "The extraction of peat in the USSR by 1956 has grown 30 times compared with 1913. Yet the share of peat in the fuel balance of the country (6 per cent in 1940, 5 per cent in 1950, 4.2 per cent in 1955) does not correspond to the colossal reserves, to the high power qualities of peat, nor to its particular importance as a widely spread local fuel. For a number of areas and republics (Byelorussian SSR, Lithuanian SSR, Latvian SSR, Korelo-Finish SSR (since lost its status as the Socialist Republic), Mordvin ASSR, Chuvash ASSR, Kalinin, Vologda, Ivanovo, Vladimir, Novgorod, Pskov regions and others) peat is the only local mineral fuel.(1)

The Sixth FYP provided for an increase of 44 per cent in the output of peat in general and of 73 per cent in milling (frezerni) peat.

Electric Power Produced from Peat and other local fuels[1]

	1932	1937	1940	1950
Total production of electric energy in billion kwh.	13.5	36.4	48.3	90.3
Per cent produced from local fuels	55.6	-	72.0[x]	
Of which peat	20.9	26.0	20.0[x]	

x - Ministry of Electric Power only.

The seven year plan provides for an output of peat in 1965 of 71 million tons, of which 55 million tons will be milling peat. Capital investments per 1 t. of production capacity is at present equal to 200 Roubles but can probably be reduced to 140 Roubles by 1965. Cost of peat in 1965 is expected to be 11.7 Roubles per ton as against 20 Roubles per ton in 1958.[2]

TABLE XVII

Peat Extraction according to Union Republics and Economic Regions of RSFSR.[1]

	1940	1950	1955	1958 mil.t.	1965 mil.6.
USSR	33229.4	35998.7	50776.9	52.4	71
RSFSR	25569.2	27490.1	36069.3	35.6	
North Region	57.5	274.1	399.7		
N.W. Region	3372.6	3571.1	4425.0	3.6	
Central Region	19275.0	20546.3	27943.9	27.5	
Volga Region	616.4	408.7	245.7		
N.Caucasus	2.9	4.0	-		
Ural	2086.0	2582.9	3008.1	3.5	
W.Siberia	158.0	97.8	46.7		
E.Siberia	-	0.7	-		
Far East Region	-	4.5	0.2		
Ukranian SSR	3544.0	2927.9	4119.2	4.1	
Byelorus SSR	3361.0	3912.3	7190.8	8.7	
Uzbek SSR	4.7	-	-		
Kazakh SSR	97.8	4.0	1.1		
Georgian SSR	-	-	1.8		
Lithuanian SSR	102.1	505.4	1594.5	1.9	
Latvian SSR	212.9	623.4	1265.8	1.7	
Kirgiz SSR	42.7	31.9	12.5		
Tajik SSR	4.1	-	0.1		
Armenian SSR	8.0	34.0	19.3		
Estonian	282.9	469.7	502.5	0.4	

Peat Extraction 1913-1965

1913	1.7	1938	26.5
1914	1.9	1939	29.9
1915	1.7	1940	33.2
1916	1.6	1941	
1917	1.4	1942	
1918	1.1	1943	
1919	1.2	1944	
1920	1.4	1945	22.4
1921	2.0	1946	27.3
1922	2.2	1947	30.6
1923	2.4	1948	34.4
1924	2.9	1949	36.0
1925	2.7	1950	36.0
1926	3.6	1951	39.8
1927	4.9	1952	37.2
1928	5.3	1953	38.6
1929	6.9	1954	45.0
1930	8.1	1955	50.8
1931	12.4	1956	
1932	13.5	1957	
1933	13.8	1958	52.8
1934	18.3	1959	
1935	18.5	1960	
1936	22.5	:	
1937	24.0	1965	71.0 Plan

Source: (1) Promishlennost' SSR. Gospolitisdat. Moscow. 1957.

R E F E R E N C E S

P. 197. 1. Economics of Industry of the USSR /Ekonomika Promishlennosti SSSR/. Gospolitizdat. Moscow. 1958. p.308.

P. 198. 1. Stefan Lament. Soviet Fuel and Power. Soviet Studies. 1952/53. Vol.IV. p.12.

2. D.I.Maslakov. Fuel Balance of the USSR /Toplivni Balans SSSR/. Gosplanizdat. 1960. p.105.

APPENDIX G

Wood.

In the Western world wood as a fuel is largely a relic of past economy, but in Russia it still occupies an important position. In 1955 wood constituted 6.7 per cent of the Russian fuel balance, as against 2.4 per cent for gas. In 1958 the share of wood declined to 5.2 per cent, (while that of gas increased to 5.4). According to the present Seven Year Plan in 1965 wood will still account for 3 per cent of the Russian fuel balance. (See Table: Fuel Balance of the USSR).

In 1955 industrial thermal power stations of total capacity of 528,000 kw. (compare that with 591,000 kw. run on natural gas) used firewood to produce 1,091 billion kwh. of electricity. In the rural area there were 2,443 electric power stations of joint capacity amounting to 100,200 kw. burning wood to produce 89 million kwh. of electricity.(1) (See Table: Power Stations of USSR grouped according to fuel used - for 1955).

Charcoal is still used in Urals for making very high grades of iron. Large numbers of lorries and tractors use products of wood distillation as fuel. But apart from industrial uses wood serves to supplement solid fuels for heating purposes in towns and is almost the universal fuel of the countryside. In 1935 it was estimated by experts that the consumption in the rural areas amounted to 220 mill. cubic metres, which was twice as much as used by industry and by the town population.(2)

The total reserves of firewood in the USSR are estimated at 24.2 billion cubic metres, which corresponds to approximately 10 billion tons of conventional fuel. About $\frac{3}{4}$ of the total reserves of firewood of the country are concentrated in the regions of Western and Eastern Siberia and the Far East, yet these regions yield only approximately 16 per cent of firewood. The regions of the Centre North West and Volga, though possessing only 5.4 of all the wood reserves of the country produce and ship annually 42 per cent of all the firewood of the USSR. The Central Industrial region alone while accounting only for 2 per cent of the national reserves, produces and ships more than 20 per cent of the total. The European North produces a great deal of firewood which is mainly transported to the centre, while the Urals use the greater part of their firewood for the charcoal metallurgy.

R E F E R E N C E S

P. 201. 1. Promishlennost' SSSR. Statisticheski Sbornik. Gospolitizdat. Moscow. 1957. p.195.

2. Stefan Lament. Soviet Fuel and Power. Soviet Studies. 1952/53. Vol.IV. p.9.

APPENDIX H

ELECTRIC POWER GENERATING CAPACITY OF THE USSR

Water Power

The water power resources of the USSR were recently estimated by the Russians to be 300 mill. kw. compared with 82 mill. kw. in the U.S.A.[1] Since coming to power the present government has consistently attached a great deal of importance to electrification and, in particular, to the development of hydroelectric power resources.

Within USSR there are 108,500 named and mapped rivers. The hydroelectric capacity of just the fifteen hundred largest was estimated at the above quoted figure of 300 mill. kw., capable of producing 2,000 billion kwh. of electricity per annum, while the probable total reserves are estimated at 3,700 billion kwh. a year.[2] Various planning bodies have put forward schemes for construction on the rivers of the USSR of approximately 1,800 hydroelectric power stations with a total installed capacity of 100 million kw. At some future date these power stations should be able to produce 700 billion kwh. of power and thus save the country 700 mill. tons of natural fuel every year. Apart from these it is proposed to build up to 20,000 hydroelectric power stations for agriculture.[3]

During the period of reconstruction after the First World War, the Revolution and the Civil War, hydroelectric power stations of joint installed capacity of 100,000 kw. were constructed. These included Volkhov hydroelectric power station of 58,000 kw. near Leningrad, completed in 1926. This was the first large hydroelectric power station HEPS completed under the Soviets. After that the Zemo-Avchalskaya HEPS. in Tbilisi, The Bezuiskaya in Tashkent, the Yerevan on the Razdan and the Kontopazhskaya on Kontopaga were put in commission.

During the first Five Year Plan (FYP) 1928-1932, construction was started on the largest HEPS in Europe - the Dnepr HEPS of 500,000 kw. In addition the Nizhne Svirskaya, Rionskaya, Gizeldonskaya and other power stations were started. The total newly installed capacity was approximately 350,000 kw.

In the course of the 2nd FYP (1932-1937) Nizhne Svirskaya, Niva II, Ivanovskaya (the first on the Volga). Gizeldonskaya and other less important HEPS were commissioned. A total of 578,000 kw. was installed during this period.

The Third FYP (1937-1940) saw the commission of Uglicheskaya HEPS on the Volga, Konsomolskaya in Tashkent and a few smaller ones. By 1940 the total installed capacity of the hydroelectric power stations of the USSR amounted to 1,587,000 kw.

The Second World War cost the Russians almost one million kw. of installed capacity in hydroelectric power stations. But at the same time construction was started on 40 smaller power stations in the Eastern part of the country. Nevertheless the installed capacity in 1946 amounted to only 1,427,000 kw. i.e. 160,000 kw. below the 1940 level.

In the Fourth FYP (1945-1950) six large HEPS were reconstructed and thirty new ones built, including Khramskaya, Ozyernaya, Farkhandskaya, Shcherbakovskaya and others. In Dneproges, destroyed by the Germans, the old turbines, each of 91,000 hp. were replaced by others of 108,000 hp. and the installed capacity of the station thus raised to 650,000 kw.

The Fifth FYP (1950-1955) saw the introduction of an ambitious plan of hydroelectric power construction, with the Kuibishev HEPS as the main project. Placed in commission during the FYP period were the Tsimlanskaya HEPS of 164,000 kw., Gyumushskaya of 224,000 kw., Verkhne-Svirskaya of 160,000 kw. and Mingechaurskaya of 357,000 kw. Work was started on the construction of Stalingrad, Novosibirsk, Bukhtarma, Votkinsk, Angara and other HEPS projects. By 1955 the share of hydroelectric power stations in the electric balance of the USSR amounted to 13.6 per cent.

During the first 10 years after the Second World War the capacity of hydroelectric power stations increased from 1,427,000 kw. to 5,986,000 kw. By 1955 there existed in the USSR 390 large power stations of which 90 were hydroelectric. In addition in 1955 there was a further 140 power stations under construction.

The Sixth FYP (1955-1960), which was discontinued in 1957, provided that the total capacity of the thermal power stations would increase 2.2 times (from 37,236,000 kw. in 1955 to 81,919,000 kw. in 1960) and of hydroelectric 2.7 times (from 5,986,000 kw. to 16,162,000 kw.). The total output of electric power was to be increased from 170, billion kwh. to 320 billion kwh. of which 18.5 per cent (59 billion kwh.) was to be produced in HEPSs.

The following important large scale projects were included in the Sixth FYP:-

In the European Part of the RSFSR

Complete the Kuibishev HEPS (2,100,000 kw.), Stalingrad HEPS (planned originally at 1,700,000 and re-planned at 2,310,000 kw.) and Votkinsk HEPS (540,000 kw. Subsequently raised to 1,000,000 kw.)[1] Start the construction of the Saratov HEPS (1,000,000 kw.), the Nizhne-Kamskaya HEPS (approx.900,000 kw.) and of the Cheboksarayskaya HEPS (approx. 800,000 kw.).

In the Ukranian SSSR.

Complete the construction of Khakhovka hydroelectric power centre (planned at 2,500,000 kw. and re-planned at 3,360,000 kw.)

Construct Kremenchug HEPS (450,000 kw., subsequently raised to 625,000 kw.),[2] Dneprodzershinsk HEPS (250,000 kw.), Nevskaya III (Nevskaya II was built in 1934) and Knyazhegubskaya HEPS. The last two in the Northern Part of European Russia. Start construction of the Kanyevskaya HEPS in the Ukrain and Vetibeskaya HEPS. in Byelorussia.

In Georgian SSR.

Bring into commission the Landazhurskaya, Khramskaya, Tkibulskaya and Gumatskaya HEPS, as well as start construction of Daryalskaya HEPS on the Terek. Also start construction of another HEPS on the Rioni.

In Azerbaijan SSSR

Start the construction of another HEPS on the Kura.

In Moldavia SSSR

Start the construction of the Kamenskaya HEPS on the Dnester.

In the Baltic States

Bring into commission the Kaunas HEPS on the Nemen and start on the construction of the Plavinskaya HEPS (120,000 kw.).

In Kirghiz SSSR

Start the construction of the Uch-Kurganskaya HEPS on the Naryn (112,000 kw.).

Start the construction of another Paarikhanskaya HEPS; and of two HEPS on the Chiski canal.

In the Tajik SSSR

Complete the construction of the Kara-Kum HEPS on the Syr Darya and of the Perepadnaya HEPS on the Vakhshski canal on the Vakhsh.

In the Armenia SSSR

Complete the construction of the Seven Razdan cascade HEPSs and start construction of the Tatyevskaya HEPS of 100,000 kw.

In the Karelo-Finnish Autonomous Area

Bring into commission the Ondskaya HEPS (80,000 kw.) and the Kumskaya HEPS. Bring into commission the Vigostrovskaya and the Paliesandalskaya HEPS. Start the construction of the Iovskaya HEPS (80,000 kw.).

In connection with the decision by the Party to develop the Eastern regions, power development in the Eastern part of the USSR is gaining increasingly greater momentum. On the Irtish, the "Dneproges of Kazakhstan" - the Ust-Kamenogorsk HEPS - has already been brought into commission, while the following projects were to be undertaken:-[1]

Start the construction of the Shulbinskaya and the Kapchagaiskaya HEPS and bring into commission the hydroelectric centre of the Ob' of 400,000 kw.

Start on the construction of Kamenskaya HEPS on the Ob' (500,000 kw.). The above two projects are to be the beginning of the powerful HEPS on the Ob'.

Start the construction of the Krasnoyarsk HEPS on the Yenisei (3,200,000 kw. Subsequently raised to 4,200,000 kw.)(1) This is to be the first of the HEPS utilizing the power resources of this river.

Bring into commission the Irkutskaya HEPS on the Angara (660,000 kw.) and bring into commission the first stage of the Bratsk HEPS on the Angara. Bratsk capacity was to have been 3,200,000 kw. It was raised to 3,600,000 kw.(2) and later to 4,500,000 kw.(3)

In spite of the large scale construction planned for hydroelectric power stations their share in the total volume of electricity produced was to remain small.

> "However high may be the tempo of construction of hydroelectric projects, in 1960 81.5 per cent of electricity will be produced in thermal power stations, and this percentage will decline very slowly in subsequent years. The directives of the XX Congress of the CPSU indicate a huge program of construction of thermal power stations. These will be constructed in the European part of the USSR though the largest individual projects will be in the Asiatic part. For use in thermal power stations there are in Siberia coal deposits of world magnitude as well as colossal reserves of natural gas. There, on the coal deposits spread in colossal massifs from the Ural mountains to the Pacific Ocean, the largest power stations can be constructed.(4)

To be completed during the Sixth FYP was the first stage of a single power system for European USSR. This was to consist of:

a) The Central Volga section - covering the Moscow, Upper Volga, Kazan, Kuibishev, Saratov, Stalingrad, Astrakhan regions and the Central Chernozyom areas of Voronezh, Lipetsk, Tambov, Kursk, Oryol.

b) The Southern Section - covering the Donetz basin, Rostov, Dnepr area, Kiev and Odessa systems.

c) The Urals Section - covering the Molotov, Sverdlovsk, Chelyabinsk, Chkalov regions as well as the oil producing region of Bashkir and Tartar SSSRs.

The system was expected to cover an area of 2.2 million square miles and to be the largest in Europe. Subsequently it would include the North West Section embracing the systems of Leningrad, Lithuanian SSSR, Latvian SSSR, Estonian SSSR, Byelorussian SSSR, Karelo-Finnish area, Murmansk district and also the Caucasian section, covering Armenian SSSR, Azerbaijan SSSR, Georgian SSSR, and the North Caucasian system. The system was to be interconnected by means of high tension lines.

It was also planned at a later date to link the European system with the Siberian, consisting of the Krasnoyarsk-Bratsk-Irkutsk power system.

In this connection it should be noted that in 1956 a high tension line of 400 km. from Volga HEPS to Moscow was constructed, and in 1958 a transmission line of 500 km. was constructed from the Volga HEPS to the Urals. The high tension line linking Stalingrad HEPS with Moscow, also 500 km. long, has been completed as well. This brings to realization the first stage of the formation of the European Power System (Evropeiskaya Energeticheskaya Sistema - E.E.S.).

When the Sixth FYP was abandoned and the Seven Year Plan introduced instead (1958-1965) the new targets did not depart in principle from the old ones. While addressing the Special 21st Congress of the CPSU in January 1959 N.S. Khrushchev said:-

> "Towards the close of the coming Seven year period the output of electric power must rise to 500-520,000 million kwh. a year, while the rated capacity of the power station will be doubled. With an 80 per cent rise in industrial output, power consumption in industry will increase 120 per cent and electric power per worker will nearly double."(1)

To win time and to use capital investments most efficiently the Seven Year Plan calls for the priority construction of thermal power stations operating on natural gas, crude oil and low grade coals. Parallel with putting the thermal power stations into operation provision is being made for the construction of hydroelectric power stations such as Bratsk, Krasnoyarsk, Kremenchug, Bukhtarma (of 525,000 kw.), Votkinsk, and others.

Construction of Thermal Power Stations

In 1955, out of 170,225 million kwh. of electricity produced in the USSR 147,060 million kwh. was produced in thermal power stations of various types. Besides electricity, many of these thermal power stations also supplied steam or hot water to be used for heating purposes - this the Russians call "tyeplifikatsia" which can be translated as "thermification".

This secondary use of by-product heat resulted in a higher utilization of fuel, which in the thermification power stations is 2 to 2.5 times higher than in ordinary thermal power stations.

The movement for mass thermification was started in the USSR in the early 30ies. Since then all major new enterprises have their energy and heat from the thermification stations. All motor works (Moscow, Gorky, Yaroslavl'),tractor plants (Kharkov, Stalingrad, Altai), the main heavy machine-building works (Ural, Donbass, Siberia),paper combines (Balakhinsky, Marrsky, Syassky) the majority of textile and metallurgical combines - all have their own thermification stations.

The number of thermification stations in 1930 was only 14, and their aggregate capacity was 125,000 kw. By 1940 the number grew to 100 with 2.5 million kw. and by 1955 to 200 with 8 mill. kw. Annual supply of heat by thermification stations amounted in 1955/56 to approximately 50 mill. mega-calories or equal to 3 million tons of conventional fuel.[1] Another source gave annual heat supplied as 100 million mega-calories and an annual saving of fuel equal to 16.7 million tons of fuel.[2]

In the majority of thermal power stations steam from turbines at a pressure of 1.2 to 2.5 atmospheres is used for space heating, while steam extracted at high pressure of 8 - 15 atmospheres is used for technological purposes.

In Moscow the length of the heat distributing network exceeds 300 km. while in smaller towns it varies from 100 to 150 km. The radius of districts supplied with heat from the stations varies from 6 - 8 km. and in some cases it is even greater. For example in Kharkov the radius is 12 km.[1]

Thus while thermal power stations convert only 30 per cent of fuel into electric energy, thermification stations utilize 60 - 70 per cent.

From the time of the establishment of Communism in Russia until a few months ago the official policy was:

a) to utilize local fuels

b) wherever possible, to use low quality fuels in power stations.

The first arose from the dislocation in transport during the earlier years and consequent shortage of fuel in the areas away from the fuel resources, the second was a deliberate policy pursued by the leaders.

"Our planned economy used high quality fuels with utmost care. Liquid fuels go to aviation, motor transport, chemical industry. Good quality coal is used in coking plants, in chemical industry and in metallurgy. Coal of inferior quality, rejects from coal industry, peat, oil shale, etc. are used in power stations. Such major thermal power stations as Kashirskaya, Cherepetskaya near Moscow, Chelyabinskaya, Sverdlovskaya, and others burn local brown coal, while Shaturskaya, Gorkovskaya, Ivanovskaya, Leningradskaya (Krasny Oktyabr), Dubrovskaya and others burn peat. How rational this is can be seen from the fact that Kashirskaya power stations by using Moscow Basin brown coal, over the period of its existence has refrained from using more than a million wagons of fuel from the Donetz basin."[2]

In order to make use of these low quality fuels -

"Our engineers succeeded in designing boiler-aggregates which utilized very well such fuels that have been rejected by almost all other branches of the national economy - fuels

> with a moisture content of 50 - 60 per cent (Ukranian lignites, milling peat (frezernii torf) and anthracite dust). At present a solution is being found to the problem of burning the colossal deposits of coal that often come to the very surface with a moisture content of 50 per cent and ash content of 25 per cent - containing only up to ¼ of combustible substance."(1)

Already in 1940, 72 per cent of the entire output of the major power stations was obtained from local, low quality fuels. Twenty per cent of this was obtained from peat. The policy of utilizing low quality fuels remained in force after the war. The Fifth FYP saw the construction in Donbass of the Mironov power station of 400,000 kw., working on by-products of coal processing plants and anthracite dust, giving the cheapest power in Donbass. It was followed by the Slavyanskaya regional power station of 200,000 kw. Commissioned in the South Kuzbass area was the South Kuzbass regional power station of 400,000 kw. operating on the by-products of the coal enriching plants. Near Moscow the large Cherepetskaya Regional Power Station of 600,000 kw. was constructed.

By the end of the Fifty FYP the largest installed capacity of any thermal power station did not exceed 600,000 kw. The XX Congress of the CPSU held on 14 - 25 February 1956 indicated that increases in the capacity of regional power stations should be attained through construction of large power stations and installation of aggregates of 100, 150 and 200,000 kw. and that such power stations should be placed in the regions where the fuel is extracted.

The Seven Year Plan places even greater emphasis on the development of thermal power stations of large capacity with turbine capacity of up to 600,000 kw. each. By installing large size turbines it is expected to gain large scale economies in capital investments and a reduction in fuel and labour expenditures.

It has been suggested that four typical models should be used in the construction of thermal power stations. The best one is considered to be a thermal power station of 2,400,000 kw. consisting of eight aggregates of 300,000 kw. each. The characteristic of this power station is that the preparation of the coal dust to be burnt in the power station can be undertaken outside the power station. The prepared dust is pumped into bunkers and thence into the furnace. The boiler is not built but assembled from prefabricated reinforced concrete components, which reduces the cost of construction.

The second model is of 1,200,000 kw. capacity with six aggregates of 200,000 kw. each; the third type, particularly suitable for the southern regions of the country is of 600,000 kw. consisting of four aggregates of 150,000 kw. each, mounted in the open air under awnings. The fourth model is a completely assembled thermal power station of 400,000 kw.

Preliminary calculations show that the cost of construction of such power stations should not exceed 800 Roubles per kw. and that the period of construction could be halved compared to present rates. (1) Another source states that the costs of construction in the first type of power station could be reduced to 620 Roubles per kw. (See table below - Capital

Investments in Various Size Power Stations).

In the construction of large size thermal power stations the Russians are at present following the American example, though on a larger scale, of building block systems consisting of a boiler, turbine, generator and transformer, which makes the production of electric power both cheaper and simpler.

A clear indication of the improvement in the work of thermal power stations is the systematic reduction in the amount of fuel used to produce one kwh. In 1913 this amounted to 1.06 kg. By 1954 it was more than halved, amounting to 497 gramms (as against 432 gramms in the U.S.A.). (See Table below for the data on the reduction of fuel consumption in Electric Power Stations in the USSR).

The directives of XX Congress of the CPSU set precise tasks for the Sixth FYP, which were later incorporated in the present Seven Year Plan.

> "In order to continue the increase in the efficiency of operation of the power stations and to reduce costs, it is essential to use at the large size thermal power stations equipment for a steam pressure of 130 atmospheres at a temperature of 565 C°, with an intermediary superheating of steam boiler-turbines; to master the method of industrial use of turbine blocks of 200,000 kw. for the steam pressure of 220 atmospheres at 600 C°; to introduce turbine-blocks of 300,000 kw. for steam pressure of 300 atmospheres at a temperature of 650 C° as well as a number of experimental and industrial gas turbine power stations."(1)

In addition the XX Congress also advocated the introduction of automation. It was stated that the thermal power stations working directly on open cast coal mines can produce electricity at 3-4 kopecks per kwh.[1] The latest policy is to build power stations of 600,000 to 2,400,000 kw. at the coal mines. It is estimated now that electricity could be produced in Siberia in such large power stations at 1-2 kopecks per kwh., and that the cost of electricity even when transmitted to the Urals would not exceed 3 kopecks.[2]

In connection with the formation of power systems, transmission lines linking large size power stations will be constructed. The table below gives the planned length of transmission lines and the length per 1,000 kw.

	1958	1965	1970	1975	1980[3]
Length of transmission lines in thousands of km.	88.4	296	516	1000	1500
Ratio length (KM/1000 kw.)	1.7	2.6	2.7	3.1	3.2

The 1959-65 Plan provides for the construction of approximately 200,000 km. of transmission lines, of which[4]

7,000 km. of 400,000 - 500,000v.
3,700 km. of 330,000 v.
32,000 km. of 220,000 v.
77,000 km. of 154 - 110,000 v.
35,000 km. of 35,000 v.

In the future can be expected a shift from lines of 400,000 - 500,000 v. of transmitting capacity of 1 mill. kw. and

1,000 km. long to transmission lines of alternating current of 600,000 v. and direct current of 800 - 1,200,000 v. of transmitting capacity of several million kw. and 2 - 3,000 km. long.(1)

The data given above refer to the socialized sector only, and consequently do not include agriculture, for which separate figures are given below.

Electric Energy in Agriculture

Up to the present time all Soviet programs of electrification have been mainly concerned with industry. In 1940 all the Kolkhozes, Sovkhozes and MTSs consumed 425 mill. kwh. of electricity, which was less than one per cent of the total.(2) In 1955 agriculture used two per cent of the total supply of electricity (3.5 billion kwh. out of 170,225). In 1954 the installed capacity of the agricultural power stations amounted to 1.5 mill. kw. and agriculture consumed 1.5 billion kwh. In 1954 only 20 per cent of Kolkhozes in the USSR had electricity. At that time 10 per cent of Sovkhozes and 5 per cent of MTS, which enjoyed special government support, still had no electricity. It is estimated that only for electrification of stationary agriculture will be required 20 billion kwh.

Electric power for Kolhozes comes from their own small power stations and the cost of power to Kolkhozes reaches 1 Rouble per kwh., compared with 10 kopecks per kwh. in regional thermal power stations and less than 1 kopeck in the latest type hydroelectric power stations.

In 1956 of 21,000 kolkhozes using electric power for production purposes only 25 per cent used electric power for mechanization of processes on farms.[1] Although more attention is being paid to supplying agriculture with the necessary electric power capacity the lag, accumulated over the entire period of the Soviet rule, will take a long time to make up.

TABLE XVIII

Fuel Consumption in Thermal Power Stations if the USSR.
in grammes per kwh.

1913	1060(1)
1932	761(2)
1935	700(1)
1940	596(2)
1941	580(1)
1944/45	572(1)
1950	539(2)
1954	497(1)
1960 (planned)	420(1)

1. A.V. Vinter and Markin, A.B. Elektrifikatsia Nashei Strani pages 39, 67.

2. Soviet Studies, Volume IV, 1952-1953.

TABLE XIX

Data on the Water Power Potential of European and Asiatic Territories of the USSR[1]

Method of Estimate	Territory	10 kw.	10 kwh	%	Thous.kwh. per sq.km.
Theoretical probable gross potential (Approximate estimate)	USSR	420	3680	-	-
Theoretical gross potential (taking into account 1477 rivers)	USSR	340	2978	100	133.7
	Europe & the Caucasus	60	528	17.7	104.6
	Asia	280	2450	82.3	143.0

1. Source: Dr. A.N. Voznesensky, Water Power Resources of the USSR and Their Exploitation. Fifth World Power Conference, 1956. Vienna. Volume 13. p.4693

Twenty-one Largest Rivers of the USSR -
Potential Water Power Resources

River	Basin	10^6kw.	10^9kwh.
Lena	Laptev Sea	18358	161
Enysei	Kara Sea	18213	160
Angara	Yenisei	9879	86
Amur	Sea of Okhotsk	6432	56
Indigirka	Eastern Siberia	6199	54
Volga	Caspian Sea	6196	54
Narin	Syr Darya	5944	52
Pyrandj	Amu Darya	5822	51
Ob	Kara Sea	5735	50
Aldan	Lena	5510	48
Vitim	Lena	5425	48
Kolima	Eastern Siberian Sea	5248	46
Lower Tungu	Enisei	4146	36
Hatanga	Laptev Sea	4106	36
Vakhsh	Amu Darya	4072	36
Olekma	Lena	4007	35
Amu Darya	Aral Sea	3834	34
Katun	Ob	3753	33
Irtish	Ob	3177	28
Bartang	Amu Darya	2429	21
Vilui	Lena	2425	21 (1)

TABLE XXI.

Capacity of Power Stations and Output of Electric Power 1913 - 1960[3]

	All Power Stations		Hydro-elec.Power St.	
Year	000 kw.	mil.kwh.	000 kw.	mil.kwh.
1913[1]	1,141	2,039	16	35
1913[2]	1,098	1,945	16	35
1916	1,192	2,575	16	37
1917				
1918				
1919				
1920				
1921	1,228	520	18	10
1922	1,247	775	19	12
1923	1,279	1,146	21	20
1924	1,308	1,562	23	30
1925	1,397	2,925	26	40
1926	1,586	3,508	89	50
1927	1,698	4,205	103	256
1928	1,905	5,007	121	430
1929	2,296	6,224	126	462
1930	2,875	8,368	128	555
1931	3,972	10,686	130	592
1932	4,677	13,540	504	812
1933	5,583	16,357	740	1,250
1934	6,315	21,011	840	2,376
1935	6,923	26,288	896	3,676
1936	7,529	32,837	956	4,013
1937	8,235	36,173	1,044	4,184
1938	8,941	39,366	1,173	5,084
1939	9,894	43,203	1,295	4,705
1940	11,193	48,309	1,587	5,133
1941				
1942				
1943				
1944				
1945				
1946	12,338	48,571	1,427	6,046[4]
1947	13,677	56,491	1,857	7,283
1948	15,157	66,341	2,191	9,369
1949	17,149	78,257	2,798	11,512
1950	19,614	91,226	3,218	12,691
1951	22,117	104,002	3,338	13,722
1952	25,250	119,116	3,814	14,908
1953	28,602	134,325	4,520	19,201
1954	32,815	150,695	5,135	18,561
1955	37,236	170,225	5,986	23,165

(continued)

Capacity of Power Stations and Output of Electric Power 1913 - 1960(3) (continued).

	All Power Stations		Hydro-elec.Power St.	
Year	000 kw.	mil.kwh.	000 kw.	mil.kwh.
1956				
1957				
1958	53,000(6)	233,000		46,500(7)
1959				
1960	81,919	320,000(9)	16,162	(6P) 59,000(5)
1961				
1962				
1963				
1964				
1965		500-520(6) [550](10)		91,600(7)
1966				
1967				
1968				
1969				
1970		1000(900)(8)(940)(11)		
1975		1500(8)		
1980		2300(8)(2400)(11)		
1990				
2000		10-15000 kwh = 40 - 50000 kwh per inhabitant		

Source: (1) Within present frontiers.

(2) Within frontiers prior to Sept. 1917.

(3) Promishlennost' SSSR. Gospolitizdat. Moscow 1957.

(4) Promishlennost' SSSR. Statisticheski Sbornik. Gospolitizdat. 1957. Moscow.

(5) Compiled on the basis of information given in Promishlennost' SSSR, p. 171 and in Elektrifikatsia Nashei Strani - p. 171.

(6) Yageman D. Economic Problems of Power Projects Construction. Voprosy Ekonomiki 1960. II. p. 96.

(7) Probst A. Problems of Development of the Fuel Economy of the USSR. Voprosy Ekonomiki 1960. III. p. 23.

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(8) Neporozhni P. The Problems of Power Industry Constructions. Planovoye Khozyaistvo. 1960. III.

(9) The Plan of Development of the National Economy of the USSR for 1960. Planovoye Khozyaistvo 1959. XI. p. 14.

(10) Neporozhni P.S. Speaking at Bratsk on 24.8.1960. Pravda 25.8.1960.

(11) Pospelov P.N. V.I. Lenin and the Building of Communism in the USSR. Vestnik Akademii Nauk. June. 1960. pp. 7-21.

TABLE XXII

Power Stations of USSR grouped according to fuel used - in 1955.(1)

No. of power stations. 107.805	Capacity 000.kw.	Output of El. power bil.kwh.
All power stations stationary and mobile: of which -	37,236	170,225
Hydroelectric power	5,986	23,165
Oil fuel	6,233	15,290
Coal	20,473	109,139
Peat	2,234	12,422
Shale	274	1,314
Firewood	528	1,091
Natural Gas	591	3,066
Gas generator	67	77
Other gas fuels	541	3,748
Other sources of power	309	913
Mobile power stations	1,318	2,273
of which		
Oil fuel	1,021	1,341
Coal	205	730
Wood	49	45
Natural gas	29	132
Generator Gas	11	8
Other sources of power	3	17

(continued)

Source: (1) Promishlennost' SSSR. Gospolitizdat. Moscow 1957. pp. 178, 186.

Power Stations of USSR grouped according to fuel used - in 1955.[1] (continued).

Rural Power Stations

	No. of power stations	Capacity	Output of Electric power mil. kwh.
Total of which	40,843	1905.1	2626.0
Hydro Electric	5,818	410.4	686.3
Oil burning	31,082	1306.0	1749.5
Wood	2,443	100.2	89.0
Coal	791	55.1	73.5
Peat	250	12.6	10.4
Shale	5	0.3	0.3
Natural Gas	12	0.5	0.9
Generator Gas	390	18.2	14.1
Wind-drive	5	0.2	0.1
Other sources	47	1.6	1.9

TABLE XXIII

Capital Investments in Various Size Power Stations.[1]

Capacity of the Station in thous. kw.	No. of Turbines	Turbine Capacity in 100 kw.	Cpt. invest. in R. per kw.installed	Fuel expend. (in gr/kwh of current Fuel).	Labour Co-eff.(workers) per 1000 kw. capacity
100	2	50	1,408	450	5.40
300	3	100	1,170	372	2.06
600	3	200	925	361	0.85
1,200	4	300	850	331	0.48
1,800	3	600	655	324	0.36
2,400	4	600	620	324	0.30

Source: (1) Vilensky M. Some Problems of the Overall Electrification of the USSR. Voprosy Ekonomiki. 1960. VIII. pp. 53 and 54.

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P.213. 1. Ibid., p. 2954.

2. A.V.Vinter and A.B.Markin. Electrification of our Country. Gosenergoizdat. Leningrad, 1956. p.62.

P.214. 1. Ibid., p.62.

P.215. 1. P.Neporozhni. The Problems of Power Industry Construction /Voprosy Energeticheskogo Stroitel'stva/ Planovoye Khozyaistvo. 1960.III.

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P.217. 1. Ibid.

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3. Ibid., p.8.

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