THE SOVIET HYDROELECTRICITY INDUSTRY

by

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Date September 17, 1965
Hydroelectric power has traditionally been the object of much publicity in the Soviet Union, yet few facts are available regarding the significance of hydro to the electricity industry on a national, and especially on a regional, basis. This thesis seeks to clarify the situation in determining the significance of Soviet hydro potential as well as existing hydro capacity on both national and regional levels. In so doing a system of regions based on power networks has been used and for these regions total installed generating capacities have been calculated so as to provide a basis for quantitative ranking. This study is not concerned simply with the generation of electricity, but with estimating absolute size and type of regional installed capacity and generation, together with the heretofore neglected aspect of consumption. A different approach to evaluating the importance of consumers of electricity is advocated, one in which load factor plays an important role and required KW capacity to meet a particular demand constitutes the prime criterion. The result has been to emphasize the spatial variations in complementary aspects of the Soviet electricity industry.

It was found that the concepts most frequently used in assessing Soviet hydro potential have certain limitations, the most important being a neglect of relative distribution. By considering the distribution of remaining prospective dam sites in
terms of "economically accessibility," it has been possible to reduce the figure for Soviet hydro potential by almost one-half. While it has been shown that there has been a movement eastward and therefore greater correlation between hydro capacity and hydro potential at present, including hydro capacity currently being installed, almost a third of the "economically accessible" hydro potential is now utilized.

For many years there has been concern over meeting system peak load demand economically and in this context hydro capacity in many regions has assumed the function of meeting peak load demand, especially during the winter months.

The Central Siberian region has not as yet realized the full benefit of the large scale projects, both hydro and thermal, thus far undertaken and at present is not characterized by low cost electricity. A decreasing average cost can be expected during the next few years. While traditionally viewed as a source region of electricity it has been determined that a possible export of 15-20 percent of total regional generation would have only a limited impact if exported to European Russia. It can be expected that this region will prove to be attractive in the location of electricity intensive industry. It is the consensus here also that large scale hydro construction will continue, but at a slower pace.

The demand for electricity in Central Siberia is not yet characterized by any particular industry or sector. In the
future aluminum production will constitute an important share of total demand for electricity in this region.

The one feature common to the four regions of European Russia is a dependence to a greater or lesser degree on external sources of energy for the generation of electricity. While emphasis has been placed on the utilization of local energy resources, insofar as hydro is concerned, little can be expected as over 80 percent of potential has now been utilized.

To date the Urals and Center-Volga have experienced the most serious power shortages, due primarily to the high degree of industrialization and heavy concentration of urban population respectively. The South in contrast does not appear to be in the same situation, the result both of its broader energy resource base and a more diversified demand. The Northwest region while scheduled to be interconnected with the Unified European Power Network, lacks any distinguishing feature in its electricity industry and will remain of peripheral importance.

Within what have been referred to as the Peripheral Regions there exists considerable "economically accessible" hydro potential. However, much of this is likely to remain undeveloped for many years to come, especially in the Far East. In the Caucasus and Central Asia, while hydro has traditionally provided the bulk of electricity, in recent years gas-fired thermal stations have made striking inroads. In the Caucasus limited gas reserves will of necessity force the region to look to external sources if this
trend is to continue. This is not a problem in Central Asia where there exists extensive gas reserves. Of the remaining regions, Northeast Kazakhstan and Murmansk, only the former is scheduled to assume significance on the national level.
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The author wishes to acknowledge the advice given by Dr. D.J.M. Hooson and Dr. J.D. Chapman. The assistance provided by the staff of the Institute for the Study of the U.S.S.R., Munich, is also gratefully acknowledged.
The energy industry in the U.S.S.R. is currently in the throes of extensive internal reorganization. Oil and gas are rapidly increasing their relative shares of the fuel mix, reflecting a comparatively late move away from an earlier predominance of coal. The positive correlation between energy consumption, and the level of economic development, has long been recognized in the Soviet Union and much of the impetus for recent changes stems from this recognition.\(^1\) Growth of the electricity industry has always been actively promoted, but it is only recently that the spatial pattern of production and consumption has altered significantly.

Much publicity is derived from accomplishments in the power industry, especially in the fields of hydroelectric development and the extra-high voltage (EHV) transmission of power. Because of their characteristic large scale, the construction of hydro plants is frequently eulogized as symbolic of the technical achievements possible under a Socialist system.\(^2\)

To appreciate the scale and characteristics of the Soviet electricity industry a few general comparisons can profitably be made with the North American situation.

Figure I depicts the rapid increase in total Soviet installed capacity since 1920. While it is obvious that the rate
FIGURE 1

INSTALLED GENERATING CAPACITIES,
SOVIET UNION, UNITED STATES, CANADA
of growth has been significant, it should be noted that the total capacity has always been much less than that of the United States. In both countries the relative shares of hydro and thermal capacity are about the same. On the other hand the U.S.S.R. currently has about four times the generating capacity of Canada, and in this instance absolute installed hydro capacities are equivalent. In contrast to the U.S. and Canada, however, a standard function has generally been ascribed to Soviet hydro capacity—that of meeting peak demand.

The Pacific Northwest is in many ways analogous with the Central Siberian region of the Soviet Union in that both represent areas of active hydro development at approximately the same distance from their potential markets, California and European Russia respectively. These markets are at present energy deficient and must look to external sources in order to meet basic requirements. The import of electricity facilitated by a unified power network of comparable areal extent (i.e., 1,500 to 2,000 miles) is planned in each case. Similarities in the size of plant and function exist between British Columbia and Central Siberia. In both regions power generation is the keynote, with flood control and irrigation being minor considerations, and construction is currently underway on what are the largest scale projects to date.

Insofar as American and Soviet thermal power generation is concerned, general trends are similar, in that increased emphasis
is being accorded the use of high calorific fuels such as gas and oil facilitated by evolving networks of pipelines. Greater significance, however, has traditionally been attached to the utilization of local energy resources in the U.S.S.R. In both cases electricity generated by nuclear power plants is still relatively unimportant.  

Consumption of electricity in the U.S. clearly is dominated, in both relative and absolute terms, by the domestic sector, as Table I reveals. It is only in the transportation sector that Soviet requirements are absolutely greater than American. This is the result of the emphasis the U.S.S.R. has put on electric traction, something which has yet to gain favour in North America.

With the broad comparative picture of the Soviet electricity industry outlined, the purpose of this study should be made explicit.

THE SCOPE OF THE STUDY

In conjunction with the considerable verbal attention given the electricity industry, much has been said regarding the Soviet Union's hydro potential, particularly in the eastern regions. As past statements have tended to be of a eulogistic nature, an objective consideration is long overdue. Both the concepts used to measure hydro potential and the distribution of prospective dam sites have been analysed in detail and it is hoped that a more realistic picture is the result.
### TABLE I

**CONSUMPTION OF ELECTRICITY**
**SOVIET UNION—UNITED STATES**<sup>a,b</sup>

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<th>Soviet Union</th>
<th>United States</th>
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<tr>
<td></td>
<td>BKWH</td>
<td>Percent of Total</td>
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<td>Domestic and Allied</td>
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<td></td>
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<tr>
<td>Consumption</td>
<td>45.4</td>
<td>15.8</td>
</tr>
<tr>
<td>Industry</td>
<td>222.1</td>
<td>77.6</td>
</tr>
<tr>
<td>Transportation</td>
<td>18.6</td>
<td>6.6</td>
</tr>
<tr>
<td>Total Consumption</td>
<td>286.1</td>
<td>100.0</td>
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<sup>b</sup> Line loss and station consumption have not been separated.
There is a dearth of regional studies on the Soviet electricity industry and because of the characteristic macro-coverage significant regional variations in the position of hydroelectricity relative to thermal electricity have been clouded over and ignored. There exists, therefore, the problem of giving some comparative, quantitative rank, in terms of installed generating capacities, to a system of regions.

While spatial variations in the generation of electricity have tended to be dealt with cursorily, the consumption of electricity is a subject to which no attention has been directed. In the past it has not been possible either to rank industries in terms of electric power requirements, or to obtain any sort of regional comparison of industrial or sector needs (i.e., domestic).

Thus attention accorded the consumption of electricity in European Russia and the Central Siberian region in this study constitutes a pioneer effort. Although the calculations of necessity have used different base years, it is now possible to obtain some idea as to both the relative and absolute importance of the various consumers on an intra- and inter-regional basis.

Central Siberia has been treated in greatest detail since it is generally looked upon as the future storehouse of electric power. In order to test the validity of this statement, present as well as future regional requirements for electric power have been estimated.

As a result of this analysis one fact became clearly
apparent—that recognition of the difference in load factors between types of consumer has been absent in other discussions of electricity consumption. Generally, the absolute number of kilowatt hours (KWH) consumed by a particular industry or sector of the economy is used as the basic criterion in determining relative importance. Yet as will be pointed out, load factor is responsible for the perhaps unexpected importance of certain sectors of the Soviet economy. Thus, it is here given full recognition and kilowatt (KW) capacity required to meet specific demands is used as a measure of relative importance.

In summary, the concern here is in estimating the absolute size and type of regional installed capacity and generation, together with consumption. Soviet generation and consumption of electricity has not been analysed on a regional basis before, as far as is known. Thus, this study attempts to present an analysis of the spatial pattern of complementary aspects of the electricity industry. It is intended to fill in part what is considered to be a void in the literature on the Soviet power industry.

FUNCTIONAL REGIONS

The regions used in this study are based on the areal extent of the several grid systems which are now a functional and fundamental part of the Soviet power scene. Grid systems, from a geographic point of view, represent a highly functional and meaningful unit. Thus far, however, there have been few geographic
studies which utilize them as a basis for regionalization. This is somewhat surprising as there has been considerable literature on electric power industries. Doubtless, Martha Church's paper is the pioneer in this field, although the purpose of her utilization of grid systems differs from that here. The principal guide in delimiting the regions for this study has been the Soviet map, Elektrifikatsii SSSR, 1:8,000,000, but in addition extensive use has been made of the Soviet technical literature in order to keep abreast of recent interties.

One might argue that the distribution of installed capacity would constitute a better basis for regionalization, however, it is felt that in a regional study of the electricity industry such an approach could lead to difficulties. For example, in the case of Central Siberia an examination of the distribution of installed capacity on Figure 5, page 35 might lead one to expect that the Ust-Kamenogorsk industrial area would be included within a Central Siberian region. However, no interconnection exists between the Kuznetsk basin and the area referred to, nor is one planned (see Figure 8, page 61). Consequently, Ust-Kamenogorsk in this study is not included in Central Siberia.

The regions dealt with are depicted on Figure 2. Greatest attention will be accorded those of European Russia (Center-Volga, Ural, South, and Northwest) and Central Siberia, since they account for roughly two-thirds of total Soviet installed capacity and slightly more of total generation of electricity. Finally,
what are referred to as the Peripheral Regions (Caucasus, Central Asia, Northeast Kazakhstan, Far East and Murmansk) are considered, but in less detail.

In the concluding chapter some attention is given to the prospects of hydro development in the Soviet Union, especially in Central Siberia. Additionally, its purpose is to summarize the spatial variations in the production and consumption of electricity in the Soviet Union.

SOURCE MATERIAL

There exists considerable literature in Russian on the Soviet electric power industry. However, with the rapid advance being made by Soviet engineers particularly in the fields of hydraulic construction and EHV long distance transmission of power, increasing amounts of material are becoming available in English. The material generally falls into two categories; that of a technical nature (in Russian, English and German) and that which is principally descriptive. When by Soviet authors, the latter is very often of a eulogistic nature and although frequently containing useful information, considerable care must be taken in evaluation. In this study the technical literature has been utilized wherever possible. Of the journals pertinent to the subject, the following have been found most useful: Elektricheskiye Stantsii, Energetika and Gidrotekhnicheskoye Stroitel'stvo.
In order to appreciate fully Soviet power development, it is necessary now to consider in some detail certain technical considerations which differentiate the situation in the Soviet Union from that of other areas.
REFERENCES: CHAPTER I


2. For a typical example see, Pobeda Stroiteley Bratskoy GES, (Triumphant Construction of Bratsk Hydro Station), Trud, January 16, 1964, p. 1.


5. A discussion follows in Chapter II.

6. In the Soviet Union there have been political-economic factors associated with hydro development as the conservation of non-renewable energy resources has played an important role in theory. See, Von Gottfried Vogel, Die Elektrizitätswirtschaft, UdSSR: Unser Wissen über die Sowjetunion, (ed. K. Krüger), Berlin, 1957, p. 35.


10. Martha Church, The Spatial Organization of Electric Power Territories in Massachusetts, University of Chicago, Department of Geography Research Paper No. 69, Chicago, September, 1960.

REFERENCES: FIGURES


Figure 2. Primary reference for this Figure, Elektrifikatsiya SSSR, (1:8,000,000), Glavnogeodezii i Kartografii, Gosudarstvennogo Geologicheskogo Komiteta SSSR, Moskva, 1963; additionally, the following sources have been used, E.A. Trofimovskaya, Edinaya Energeticheskaya, (Single Energy System), Izdatel'stvo Znaniye, Moskva, 1963, pp. 20-21; M.I. Galintskiy, S.K. Danilov, A.I. Korneev, Ekonomicheskaya Geografiya Transporta SSSR, (Economic Geography of Transport in the U.S.S.R.), Izdatel'stvo Transporta, Moskva, 1965, p. 57.
CHAPTER II

HYDRO POWER IN THE SOVIET UNION

In view of the fact that the focus of this study is on hydro power development, it is necessary that several technical aspects be clarified before proceeding with an analysis of the distribution and characteristics of the electricity industry. While Soviet engineers are further advanced than their Western counterparts in certain phases of hydraulic construction, it is not this kind of difference which is of direct concern here. Rather this chapter will attempt to explain certain conceptual differences associated especially with the role and computation of prime cost of hydro power in the Soviet Union. Insofar as hydro potential is concerned, standard methods of estimation are followed yet, as will become evident, the Soviet figures for potential hydro capacity cannot be unequivocally accepted.

THE CONCEPT OF HYDRO POTENTIAL

In assessing hydro potential two approaches are commonly used, estimation of the theoretical "gross" potential and the "technically exploitable", or in Soviet terminology, "possible to utilize" potential. The first is a crude assessment based simply on the product of head times the average flow of the stream and gives no consideration to the engineering feasibility of erecting hydro stations. The second approach is in
part an attempt to offset some of the inherent limitations of the former and is often derived through deducting estimated losses in head and, therefore, potential capacity, from the "gross" potential figure. In the Soviet Union the "technically exploitable" potential is generally arrived at by summing capacities at prospective dam sites. In either case the approach is intended to give a more realistic figure for potential hydro capacity.

As the technically exploitable assessment still involves serious limitations, an approach of still greater refinement has evolved, one in which previously neglected economic factors are taken into account. Unfortunately in the Soviet Union such an approach is rarely used. In most discussions of the country's water power resources the analysis ends with an estimate of "technically exploitable" potential.

It should be pointed out that although there are no grounds on which to question the Soviet estimates of potential capacity of the various streams, this does not apply to the estimated annual generation of electricity from this capacity. Frequently estimates of generation are based on a 100 percent plant factor which is definitely misleading, since the average has always been less than 50 percent. It is necessary, therefore, to regard all figures of this nature with some degree of caution.

There is one fundamental factor which the usual Soviet
method of estimating hydro potential neglects entirely—that of distribution. To know that the Eastern regions possess over 80 percent of the country's hydro resources is of little value unless one is aware of the distribution within this area.

Figure 3 depicts the principal prospective dam sites, the capacities of which are the basis for the "technically exploitable" hydro potential. While there still exists some potential in European Russia, the distribution of hydro potential for the country as a whole is largely peripheral. In the regional chapters the distribution of prospective dam sites is considered in relation to the areal extent of permafrost, as well as existing industrial and urban development. The object of this analysis is to arrive at the current "economically accessible" hydro potential, a geographic concept intended to provide a more meaningful figure than either the "gross" or "technically exploitable."

HYDRO AS PEAKING CAPACITY

Throughout the Soviet literature dealing with electric power development there is continued reference to hydro capacity being used to meet peak demand. This function does vary somewhat regionally. For example, the new large scale hydro plants in Central Siberia do not entirely comply with the standard role attributed to hydro stations because of different physical geographic conditions which permit a higher average
FIGURE 3 PROSPECTIVE DAM SITES—DISTRIBUTION AND POTENTIAL CAPACITY
annual plant factor. However, some generalizations can be made regarding the role of hydro stations in European Russia, the Caucasus and Central Asia.

As early as 1932 hydro plants were designed to meet peak load demand. Subsequently there has been a continued emphasis on assigning to hydro capacity the role of meeting the peak load in power systems. The following quotations outline some of the technical reasons behind this policy.

... In a combination of steam and hydro plants, the hydro plants should be operated to obtain the best utilization of the available water. This does not necessarily imply the most efficient operation of the hydro equipment, but such use as will result in the least overall production costs, taking into account the effect of hydro generation on the production costs of the steam plant. . . .

Since there are no fuel costs in the production of hydroelectric energy, incremental energy can be supplied by a hydro plant at practically no incremental cost. It follows therefore, that, with respect to load allocation between steam and hydro plants, the generation at the steam plants should be displaced by available generation at the hydro plants, so that the maximum decrement production costs will obtain at the steam plants. The extent to which this can be accomplished depends on the nature of the daily load curve for the system, the type of hydro plants, and the available water. . . . Plants with storage or pondage facilities may be operated to supply either base or peak load, depending on how the flow may best be utilized.

The equipment of a hydroelectric power plant is able to work satisfactorily even under sharp load fluctuations, its efficiency being hardly affected by load variations over a wide range. On the other hand, the equipment of a heat-power (thermal) plant does not have this adaptability; variation in the turbine and boiler load can be achieved only within certain limits. Operation of heat-power plants during peak load causes increased fuel consumption and reduced efficiency and reliability. Taking care of the peak
load, ... hydro plants increase the efficiency of the thermal plants by relieving them when they would have to operate under disadvantageous conditions.\textsuperscript{13}

There are two ways in which thermal plants may be used to meet peak load demand. First of all through operating at reduced load during off-peak hours, which often means at the technical minimum, and then at full capacity during the peak hours. Secondly, through discontinuous operation involving daily stops and starts. Both involve several technical problems, such as the uneven burning of fuel alluded to in the latter quote, or with regard to discontinuous operation, the actual time involved before the generators come under full load, seldom less than two hours. On the other hand, large scale hydro stations can come under full load from rest in less than two minutes.\textsuperscript{14}

Fundamental to the concept of hydro meeting peak demand is a well developed grid, preferably one with considerable east-west extent so as to be able to take advantage of the varying peak demand hours associated with different time zones. Such a grid exists in European Russia at present (Figure 2), extending from the Moscow region to the Urals and taking in three time zones.

One might still raise the question as to why hydroelectric stations generating low cost electricity would be used to meet peak demand, since it might appear logical for this power to be used in meeting base load demand. Indeed Jasny, one of the leading émigré authorities on the Soviet economy, has been
most critical of this specialized role of hydroelectric plants. His argument centers around the fact that they require a comparatively greater investment generally than thermal plants of equivalent capacity but operate fewer hours per year. In European Russia particularly one must draw a relationship between this function and the characteristic regimes of the major rivers. In general terms the following situation prevails. Interconnected hydro stations operate at full capacity during the period of maximum river flow, in which case thermal plants are often shut down completely. After this period of maximum flow the hydro station assumes the role of meeting peak demand, the number of operating hours per day or per week being governed by the storage capacity of the reservoir and the percent of this available for the generation of electricity. In addition the utilization will vary with the absolute hydro capacity within the particular systems. Excess capacity above that which is required to meet system peak demand is sometimes used to supply a small part of the base load, as the following schematic diagram illustrates. This is likely to become less common, for by 1970 total hydro installed capacity in the Unified European Power Network will be insufficient to cover the entire peak of the load curve.

It is possible to further clarify this situation if one assumes, for example, that at a given station there is available daily .5 MW of capacity. It is possible to utilize this
FIGURE 4

ALLOTMENT OF SYSTEM LOAD IN THE EUROPEAN RUSSIA POWER NETWORK
in different ways; it may be economical to "over-machine" the station, thus instead of operating the available capacity 12 hours per day, 2 MKW of capacity is installed and operated three hours per day during the peak period. Proximate location with respect to load center and the value of fuel saved by not having to install thermal capacity are two major factors in the decision as to whether or not this situation will arise.\(^{18}\) Several stations in European Russia would appear to have been designed with these factors in mind, as will be pointed out in subsequent chapters.

One of the principal reasons facilitating the implementation of such a policy in the Soviet Union as compared to the United States, where such has not been the case, is the actual organization of the industry. The organizational structure depicted in Table II has a definite hierarchial pattern. This clearly permits a far higher degree of standardization insofar as the function of a specific type of capacity is concerned, than would be the case in the United States, where both private and public interests control generation of electricity.

Characteristically, in the United States new capacity (regardless of type) has assumed the base load, displacing older, less efficient capacity into the role of meeting peak demand.\(^{19}\) Thus peak power has tended to cost about three times as much as base, in large part due to increased operating expenses.\(^{20}\) It should be pointed out that much interest is now
# TABLE II

**ORGANIZATION OF SOVIET ELECTRIC POWER INDUSTRY**

<table>
<thead>
<tr>
<th>Republic Ministries of Power, Energy and Electrification</th>
<th>Trusts</th>
<th>Regional Energy Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kazakh</td>
<td>1. Construction</td>
<td>1. Northwest</td>
</tr>
<tr>
<td>Uzbek</td>
<td>2. Construction Assembly</td>
<td>2. Center</td>
</tr>
<tr>
<td>Ukraine</td>
<td>3. Assembly</td>
<td>3. South</td>
</tr>
<tr>
<td>Chief Administrations Energy and Electrification for Soviet Ministry</td>
<td>Administration for Construction of Hydrostation</td>
<td>4. Urals</td>
</tr>
<tr>
<td>Republic Ministries of Power, Energy and Electrification</td>
<td>Management of Electric Station Construction</td>
<td>5. East</td>
</tr>
<tr>
<td>1. Azerbaydzhanshan</td>
<td>Industrial Enterprise</td>
<td>Unified Control Management for Electric System</td>
</tr>
<tr>
<td>5. Kirghiz</td>
<td>Construction</td>
<td></td>
</tr>
<tr>
<td>7. Lithuania</td>
<td></td>
<td>Central Technical Educational Institute</td>
</tr>
<tr>
<td>8. Moldavia</td>
<td></td>
<td>Bureau Material-Technical Supply</td>
</tr>
<tr>
<td>9. Tadzhik</td>
<td></td>
<td>Department Labour Supply</td>
</tr>
<tr>
<td>10. Turkmen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Estonia</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

a. As of Spring 1963.

being shown in the United States and Canada in the idea of assigning a specific role to different types of capacity for the purpose of attaining overall economy. Insofar as meeting peak demand is concerned, considerable interest is being evinced over the possibility of using pumped storage to firm up hydro capacity. In the United States enquiry is not restricted to hydro, for all means of meeting peak demand economically are being investigated. In retrospect it would appear that Soviet engineers have shown more concern over meeting peak demand economically, as one phase in obtaining optimum operation of power systems, than has been the case in the United States.

THE PRIME COST OF HYDROELECTRICITY

Hydro is often extolled as the least expensive method of generating electricity. This opinion is usually based on a comparison of prime cost of electric power at the different types of station, and frequently results in a comparison of mean costs in which hydro is certainly presented in a favourable light. For example, in 1958 the average cost of thermal power has been given as .83 kopeks per KWH, while hydro was estimated at .19 kopeks per KWH. Yet seldom does one come across any direct statement as to how the figures for either thermal or hydro have been derived. Just what factors are taken into account when determining prime cost, especially that for hydro, is important, since much of the argument favouring the construction of hydro
stations rests on the consideration that it is in fact cheaper.\textsuperscript{25} This constitutes logically the first problem to be solved before a reasoned analysis of the Soviet electric power industry can begin.

In the Soviet Union the figure for prime cost of hydroelectric power is derived from capital outlay for the power station, equipment and dam structure, in other words, the actual operating unit. It does not take into account first of all, the expenditure required for reservoir construction (costs of clearing, relocation of settlement, relocation of transportation and communication systems).\textsuperscript{26} In the case of the Imeni V.I. Lenin plant near Kuybyshev for example, reservoir construction amounted to 16.7 percent of the total expenditure for the whole development, the least yet for any of the stations of the Volga-Kama system.\textsuperscript{27} Secondly, there is neither interest charged on capital investment nor depreciation.\textsuperscript{28} The interest rate in North America of course can be the deciding factor in the development of a hydro site, so that simple cost comparisons with American hydro stations are of little value.\textsuperscript{29}

The change in prime cost of electricity when the above factors are included has been illustrated in Appendix A. In the first example, the usual Soviet method is followed (where simple amortization is the major element), giving a prime cost of .22 kopeks per KWH. By simply assuming that reservoir costs account for 20 percent of total capital outlay the prime cost
rises to 0.27 kopeks per KWH. Finally, when interest is included in the calculation, there is an increase to 0.47 kopeks. This clearly indicates the degree to which prime cost can be affected by the inclusion of these factors, and emphasizes how important it is that the method of derivation be recognized at the outset. Some Soviet economists have questioned the method of deriving prime cost of hydroelectricity and additionally, the way in which part of the expense of hydro plant construction is charged off to benefits such as irrigation and stream regulation, arguing for the inclusion of full capital expenditure in basic calculations.\textsuperscript{30}

The above is not intended to imply that all factors are necessarily taken into account when the prime cost of thermal power is computed,\textsuperscript{31} even though total investment for equivalent capacity is generally less, but it should be made clear that the cost of hydro power is underestimated to the extent at least that reservoir costs are omitted. Generally speaking, it is the small thermal stations using expensive coal (imported or of low calorific value) and to a lesser extent, peat, which collectively are responsible for the higher average cost of thermal power.\textsuperscript{32}

The foregoing discussion neglects one essential factor, that prime cost of electric power varies according to the degree of utilization of the particular station. Thus prime cost of power from a station used only 2,000 hours a year is obviously
going to be higher than that of a plant being used 4,000 hours per year, since a higher price per kilowatt hour is necessary if fixed costs are to be covered (assuming equal amortization periods). Therefore, in systems where hydro constitutes a major share of capacity there is incentive for greater interconnection so that the same capacity is alternately used in different circuits, particularly during the period of maximum runoff, thus giving a higher plant factor and consequently lower cost of power. Moreover, as the installed capacity of a grid system increases the required reserve capacity declines relatively, giving rise to additional savings.33

With these facts in mind, it is necessary now to put the topic into proper perspective through a brief consideration of the general features of the Soviet electric power industry and an analysis of the changing distribution of installed capacity.
REFERENCES: CHAPTER II


4. This is apparent from an examination of S.F. Shershov, Bely Ugol, (White Coal), Gosenergoizdat, Moskva, 1957, pp. 82-3.


8. This is not to infer that this aspect is neglected only in Soviet estimates. See K.P. Nair, loc. cit.


10. This point elaborated on in Chapter IV.


14. For a discussion of these and other technical considerations see, The Covering of Peak Loads in Electricity Supply Networks, Economic Commission for Europe, United Nations, 1963, particularly pages 13-34.


16. The storage capacity of reservoirs in European Russia tends to be affected adversely by two factors, topographic and economic. The latter because valuable agricultural land is often lost to production through extensive flooding. The effect of topography is dealt with in Chapter IV in the comparison of Bratsk and Kuybyshev hydro stations.


18. This discussion owes much to a conversation with H.M. Ellis, B.C. Hydro and Power Authority, Vancouver, March 11, 1965.


23. Optimum operation of a power system is regarded simply


26. If other factors were taken into account one would assume that this would be indicated, since prime cost would be affected adversely from the point of view of the proponent. (See Appendix A).


30. See, Z.F. Chukhanov, Soviet's Find Capital Costs Make Hydro Less Economical, (from Teploenergetika, partial translation), commented on by P. Sporn, Electrical World, August 20, 1962, pp. 56-9. In this context another interesting suggestion is to compute cost of power as a function of river flow, in other words have annual amortization charges vary according to yearly flow variation from the mean; G. Chernikov, Sebestoimost i Rechnogo Stoka, (Prime Cost and River Flow), Ekonomicheskaya Gazeta, June 23, 1962, p. 35.


32. This point will be dealt with in subsequent chapters.

33. A. Beschinskiy, Elektrifikatsiya i Progress Obschestv-. 

REFERENCES: FIGURES

Figure 3. Data on distribution of dam sites based on, S.F. Shershov, Bely Ugol, (White Coal), Gosenergoizdat, Moskva, 1957, pp. 82-83; for extent of continuous permafrost, J.P. Cole, F.C. German, A Geography of the Soviet Union: A Background to a Planned Economy, Butterworth, London, 1961, p. 72.

Figure 4. Taken from, I.T. Novikov, (ed.), Energetika SSSR, (Energy in the U.S.S.R.), Gosenergoizdat, Moskva, 1961, p. 73.
CHAPTER III

THE GEOGRAPHY OF THE ELECTRICITY INDUSTRY

1920--1965

The absolute annual rate of growth of the Soviet electric power industry has increased rapidly, especially since the end of the Second World War. Presently capacity is expanding at the rate of 10-12 MKW per year, and by 1970 this increase is scheduled to be of the order of 20-25 MKW.\(^1\) One is led to enquire as to where growth in the past has taken place, has the distribution of the industry altered and indeed, where might future growth be expected? The latter question will be dealt with in the subsequent regional chapters, only the changes up to the present being considered here. Before beginning this aspect of the study the current magnitude of the electricity industry, its general characteristics and distribution will be outlined. What factors have determined the existing pattern are the subject of the ensuing discussion.

THE ELECTRICITY INDUSTRY--SCALE, CHARACTERISTICS, AND DISTRIBUTION

The magnitude of the electric power industry has been indicated in Figure I of the introductory chapter, and this coupled with Table III provides one with an overview of the growth of capacity by type since 1920. Hydro had gradually
<table>
<thead>
<tr>
<th>Year</th>
<th>Hydroelectric Capacity MKW</th>
<th>Hydroelectric Percent of Total Capacity</th>
<th>Steam Condensing (GRES--KES) Capacity MKW</th>
<th>Steam Condensing (GRES--KES) Percent of Total Capacity</th>
<th>Heat and Power--Steam By-Product (TETS) Capacity MKW</th>
<th>Heat and Power--Steam By-Product (TETS) Percent of Total Capacity</th>
<th>Total Capacity MKW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1928</td>
<td>0.12</td>
<td>6.3%</td>
<td>1.8</td>
<td>92.1%</td>
<td>0.04</td>
<td>2.3%</td>
<td>1.9</td>
</tr>
<tr>
<td>1940</td>
<td>1.6</td>
<td>14.1%</td>
<td>7.4</td>
<td>66.0</td>
<td>2.2</td>
<td>19.7</td>
<td>11.2</td>
</tr>
<tr>
<td>1945</td>
<td>1.3</td>
<td>11.2%</td>
<td>7.6</td>
<td>68.6</td>
<td>2.2</td>
<td>19.6</td>
<td>11.1</td>
</tr>
<tr>
<td>1950</td>
<td>3.2</td>
<td>16.2%</td>
<td>13.4</td>
<td>68.6</td>
<td>3.0</td>
<td>15.2</td>
<td>19.6</td>
</tr>
<tr>
<td>1955</td>
<td>6.0</td>
<td>16.1%</td>
<td>20.2</td>
<td>54.6</td>
<td>11.0</td>
<td>29.3</td>
<td>37.2</td>
</tr>
<tr>
<td>1958</td>
<td>10.8</td>
<td>20.2%</td>
<td>31.3</td>
<td>57.9</td>
<td>12.0</td>
<td>22.5</td>
<td>53.6</td>
</tr>
<tr>
<td>1962</td>
<td>18.6</td>
<td>22.5%</td>
<td>48.3</td>
<td>58.7</td>
<td>15.6</td>
<td>18.8</td>
<td>82.5</td>
</tr>
</tbody>
</table>

increased its relative share from less than 1 to around 20 percent, where it has remained during the last few years. It has maintained its share primarily as a result of the construction of several very large hydro plants in Central Siberia, which are the most striking feature of the current distribution of installed capacity depicted on Figure 5. The stations in Central Siberia are certainly unchallenged in terms of scale, the largest North American plant is that under construction now at the Portage Mountain site on the Peace River (2.3 MKW), which is less than two-thirds their average capacity. Coupled with this increase in scale has been the growth in the size of generating units, with a rated capacity of up to .5 MKW for hydro stations and up to .3 MKW for thermal, depending on the fuel used. \(^2\) In 1962, for example, 50 percent of the generating capacity put into operation was in the .15-.2 MKW per unit range. \(^3\)

Table III indicates there is a distinction to be made within the general category of thermal plants. The difference between heat and power stations (TETS) and thermal condensation plants (GRES or KES) is one of function. \(^4\) In the first type the steam raised to turn the turbine is utilized as a by-product for heating purposes, both industrial and domestic. Condensation plants do not have this auxiliary function and are built simply to generate electricity.

Recent technical changes have contributed much to the increased efficiency of thermal plants. Operation at much higher
temperatures and pressures (500-600°C and 200-300 ata, twice that possible 15 years ago) have permitted maximum value to be derived from fuels of all types. In fact, since 1928 the required expenditure of fuel (in terms of conventional fuel equivalent) per KWH generated, has declined from 820 grams to 435 in 1960.5

Although the most striking developments in the Soviet electric power industry have been associated with hydroelectric construction, important changes have also occurred in the types of fuel consumed by thermal plants.

While coal has remained the primary fuel for thermal plants, there has been considerable shifting among the other sources. Until the Second World War, peat played a comparatively important role, and even as late as 1960 was still contributing 6 percent of total generated power (Table IV).6 The consumption of peat has from the outset been a reflection of governmental policy promoting the utilization of local energy resources, rather than importing fuels, an alternative which even at present has many disadvantages in view of the overloaded transport systems. Again these figures are totals and hide many regional variations for as will be pointed out later, peat in one region still provides close to 40 percent of total electric power.

Both oil and gas of late have completely overshadowed peat, the latter being scheduled to increase its relative share at the specific expense of coal.7 Unfortunately, 1961 is the last date for which statistical data on the types of fuel consumed by
TABLE IV

PERCENT GENERATION OF ELECTRICITY BY TYPE OF FUEL
THERMAL POWER STATIONS (TETS, KES, GRES)

<table>
<thead>
<tr>
<th></th>
<th>1935</th>
<th>1940</th>
<th>1955(^d)</th>
<th>1961(^f)</th>
<th>1965(^h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>--</td>
<td>--</td>
<td>76.4</td>
<td>65.5</td>
<td>55.0</td>
</tr>
<tr>
<td>Peat(^a)</td>
<td>2.14(^b)</td>
<td>20.0(^c)</td>
<td>9.1</td>
<td>7.0(^g)</td>
<td>5.2</td>
</tr>
<tr>
<td>Shale</td>
<td>--</td>
<td>--</td>
<td>1.22(^e)</td>
<td>2.0</td>
<td>4.6</td>
</tr>
<tr>
<td>Oil</td>
<td>--</td>
<td>--</td>
<td>8.98</td>
<td>8.5</td>
<td>15.0</td>
</tr>
<tr>
<td>Gas</td>
<td>--</td>
<td>--</td>
<td>4.1</td>
<td>17.0</td>
<td>18.0</td>
</tr>
</tbody>
</table>

a. Not indicated, but likely includes firewood, at present a very insignificant source.


e. This figure has been arrived at by subtracting the 8.98 percentage figure given for oil by Hodgkins from a 10.2 figure for both oil and shale given in the foregoing reference. J.A. Hodgkins, *Soviet Power, Energy Resources, Production and Potential*, Prentice-Hall, Englewood Cliffs, N.J., 1961, p. 121.


g. Peat and shale estimates are based on the 9 percent figure for both fuels quoted in Omuprakov, *Ibid.*
h. Figure for shale of 4.6 percent reflects increased use in the Baltic States particularly. The 2.2 percent not accounted for consists of "other fuels," (probably firewood). A.A. Stepankov, Ekonomicheskaya Effektivnost' Proizvodstva i Kapital'nykh Vlozheniy, (Economic Effectiveness of Production and Capital Investment), Izdatel'stvo Akademii Nauk SSSR, Moskva, 1963, p. 97.
electric power stations is available. However, it is possible to gain some additional insight since percentage statistics are given for the various uses of fuels. The figures for gas and oil are shown in Table V. The table indicates the rapid increase in absolute value of gas consumed in thermal plants during the two years prior to 1962. The use of gas as a fuel varies regionally, but whether this general increase will continue is an important question, discussion of which is reserved for subsequent chapters.

With this general overview of the industry's characteristics, it remains now to consider how the distribution depicted on Figure 5 has evolved, a task which must take full cognizance of government policies.

THE GOELRO AND THE FIVE YEAR PLANS

While electrification is of obvious importance in all countries, in the Soviet Union the heavy emphasis on it has in large measure been the result of Lenin's integration of the electrification concept with his scientific theory for the formation of a socialist state. Thus it has been more than simply a requisite for an expanding economy, as is implied in his oft-quoted dictum, "Communism is Soviet power plus the electrification of the whole country, for without electrification progress in industry is impossible." To realize this objective the Commission for Elaborating the Plan for The Governmental
TABLE V

SHARE OF TOTAL NATURAL GAS AND OIL PRODUCTION
USED AS FUEL IN POWER STATIONS

<table>
<thead>
<tr>
<th></th>
<th>1958a</th>
<th>1960b</th>
<th>1962c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent</td>
<td>34.6</td>
<td>23</td>
<td>22.5</td>
</tr>
<tr>
<td>Absolute Valued</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. Cubic Meters</td>
<td>9,971</td>
<td>10,419.69</td>
<td>16,175.5</td>
</tr>
<tr>
<td>Gas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td>10.1</td>
<td>11.1</td>
</tr>
</tbody>
</table>


d. Absolute value computed; total production figures of gas from, Narodnoye Khozyaystvo SSSR v 1962 Godu, Statisticheskii Ezhegodnik, (Statistical Year Book), Tsentral'noye Statisticheskoye Upravleniye pri Sovete Ministrov SSSR, p. 158.

Electrification of Russia (GOELRO) was established early in the post-revolutionary years (1920). Its aim was the restoration and reconstruction of industry generally, with increased generation of electric power and interconnection of installed capacity as the fundamental basis.

EARLY SOVIET DEVELOPMENTS

That the Soviet electric power industry was comparatively underdeveloped in the early 1920's is evident from Figure I. The GOELRO Plan was an attempt to rectify this state of affairs. This is not to infer that the industry had been neglected entirely during the pre-Soviet period, for considerable interest was accorded electrification, in particular over the possibility of extensive hydro development on the Svir River. Obviously very few plans had come to fruition. Moreover, the limited generating capacity, 1.098 MKW in 1913, was underutilized, there being but a 20 percent average plant factor. Therefore, increased utilization of existing capacity as well as new construction was promulgated under the GOELRO Plan. It was not until 1925, however, that the Soviets were able to improve on the pre-World War I situation.

The 1.5 MKW capacity target set for the 15 year GOELRO Plan does not appear especially ambitious until one realizes that it exceeded the total Soviet installed capacity in 1921. One source has suggested that the GOELRO Plan, as a plan, was not as success-
ful as is generally supposed, for between 1921 and 1930 the yearly target was never met. It should be pointed out that these deficiencies were more than made up during 1931, the overall objective being reached at this time, four years ahead of plan.\textsuperscript{13}

In accordance with the GOELRO Plan, construction of what were then large scale regional electric stations was emphasized.\textsuperscript{14} Because of the difficult physical characteristics of the river basins in European Russia, from the point of view of hydraulic engineering, thermal capacity predominated from the outset (see Table III). The general shortage of investment capital coupled with the driving desire to expand capacities as rapidly as possible also tended to encourage the building of thermal plants.

The Five Year Plans initiated in 1928 amplified the GOELRO emphasis on electrification, the objective being to "... continue the policy of utilizing more extensively such local fuels as Moscow basin, Ural, East Siberian and Central Asian coal as well as peat and oil shale, and especially the water power resources for the supply of electricity."\textsuperscript{15} In spite of this emphasis on hydro development it remained a very small share of total installed capacity. The .2 MKW Dneproges station begun in 1928 (subsequently raised to .56 MKW in 1935) while receiving the brunt of the publicity was rather an anomaly with respect to size, as Figure 6 reveals.\textsuperscript{16} The majority of plants were small in scale and located in regions for the most part conducive to
hydraulic construction, (e.g., Northwest, Central Caucasus).

Government decision to include heat and power stations (TETS) in the overall electrification plan did not come until 1931, although this had been promulgated for some time as being by far the most economic and rational use of thermal generating capacity. While heating networks were to be organized as "organic components" of the power systems, little in the way of actual development was carried out at this time (see Table III). Yet the concept of integrating the distribution of electric power and heat on a large scale, and the development that did take place, are certainly of importance.

In the Second Five Year Plan (1932-1937) there was initiated a trend which had significant ramifications for the distribution of installed generating capacity. The creation of the Urals-Kuznetsk Combine and the resultant industrial expansion in Central Siberia witnessed construction of several thermal stations, Kemerovo, .148 MKW planned capacity being the largest. While actual policy continued to emphasize the inherent advantages in harnessing water power, the absence of any hydroelectric development in the Central Siberian region was not indicative of a paucity of knowledge regarding the area's potential, for this had long been recognized. It simply reflected the absence of a market within contemporary feasible transmission distance, combined with, as mentioned before, the perennial desire to rapidly expand capacity. Figure 6 clearly indicates the change
FIGURE 6  THE CHANGING PATTERN OF GENERATING CAPACITY. 1928-1935
in distribution of electrical generating capacity between 1928 and 1935. By 1935, the end of the original GOELRO Plan, three major concentrations were evident; the Moscow urban area, the Donbass industrial belt of the South Ukraine, and the Urals, all traditional centers of Russian industry. Within these regions were also the embryo of power networks as depicted on Figure 6. Although the relative gain in installed capacity was not as great as that of the First Five Year Plan, in absolute terms considerable progress had been made (2.7 MKW as compared to 3.6 MKW).21

During the Third Five Year Plan (1938-1942) increased attention was being given the Volga-Kama system, with large scale development the keynote. Throughout this period a number of schemes were suggested, their fulfillment being precluded largely as a result of the paucity of geologic, hydrologic and engineering data.22 These plans did have a positive aspect in that detailed surveys of this nature were started. The Ivan'kovo, Uglich and Rybinsk stations on the Volga built during the mid-thirties primarily to improve navigation, did provide some important data for dam construction, apparently sufficient enough so that, "In 1937 the Party and Government adopted the decision to construct a very large hydroelectric station on the Volga (near Kuybyshev); however, the construction ceased in the preparatory stage owing to the outbreak of World War II."23

With the impending threat of war, the industrialization of
the eastern regions took on a strategic value. In conjunction with government decision erection of small scale thermal stations was emphasized. War itself saw 3.4 MW of capacity, primarily thermal, spring up in the Urals, Siberia, Kazakhstan and Central Asia and the destruction of 5 MW of capacity and 10,000 KM of transmission line in European Russia. As a result, the generation of electric power in the eastern regions (including the Urals) rose from 22 percent of the total in 1940 to 48 percent in 1945. By this latter date, the 11 MW capacity level of 1940 had been re-attained, but not without a fundamental alteration in the distribution. Thus this period is important because of the trends initiated rather than the actual scale of development.

POST-WAR POLICIES.

Only in the immediate post-war period was it finally conceded that the rural areas required attention. In 1940 the installed capacity of agricultural stations, 275 MW, produced less than 1 percent of the Soviet Union's total generation of electric power. Erich Thiel has outlined the considerable steps taken after 1945 to electrify the agricultural sector, the construction of small scale plants being the expedient alternative to "widely ramified high-tension networks." It should be recognized that the emphasis on small units at this time was in direct response to government decision. In spite of
the emphasis it was only in the late 1950's that the agricultural sector attained a relatively high level of electrification. With the subsequent promotion of large scale hydro projects and an ever growing low voltage transmission network, it is not surprising to see a rapid decline in the number of small collective and state farm hydro plants (2,600 in operation in 1962, a decline of 4,000 in a decade). These plants were generally of less than 10,000 KW capacity.

Reconstruction rather than new construction of major hydro stations in European Russia was characteristic of the Fourth Five Year Plan (1946-1950). In Central Siberia, two new projects were undertaken in order to meet the growing industrial demand for power; Irkutsk, .67 MKW, and Novosibirsk, .4 MKW. As in the immediate pre-war era, general trends were conditioned not so much by economic considerations, rather by others deemed to be of greater significance; strategic in the immediate pre-war, and in the post-war, the need to expand capacity rapidly. With regard to the latter point, there had always been a discrepancy between planned and actual expansion of installed capacity as Table VI reveals, which doubtless constituted a serious handicap to industrial expansion in certain areas. Nevertheless, the installation of 9 MKW of generating capacity in the five year period was no small achievement.

In 1950 with the introduction of a new Five Year Plan a major policy change was announced, the decision to undertake a
### TABLE VI

PLANNED AND ACTUAL EXPANSION OF INSTALLED CAPACITY
BY FIVE YEAR PLAN

<table>
<thead>
<tr>
<th>Period</th>
<th>Planned Installed</th>
<th>Fulfillment (installed as a percent of planned capacity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First 1928-32</td>
<td>5.5-6.7</td>
<td>2.9</td>
</tr>
<tr>
<td>Second 1932-37</td>
<td>6.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Third 1938-42</td>
<td>7.1</td>
<td>-1.4</td>
</tr>
<tr>
<td>Fourth 1946-50</td>
<td>11.7</td>
<td>9.3</td>
</tr>
<tr>
<td>Fifth 1950-55(^b)</td>
<td>15.6</td>
<td>17.6</td>
</tr>
<tr>
<td>Sixth 1955-60(^c)</td>
<td>32.7</td>
<td>29.5</td>
</tr>
</tbody>
</table>


\(^c\) While the Sixth Five Year Plan was interrupted, actual expansion by 1960 was considerable and as indicated, was only 5 percent off the original plan.
number of very large multi-purpose projects on the Volga-Kama cascade. Construction commenced at Kuybyshev (2.3 MKW) in 1950, but on a far larger scale than had been envisioned in 1937, and at Volgograd (Stalingrad, 2.5 MKW) in 1954. This initiated a period during which the virtues of harnessing water power were constantly extolled. The motivation behind the initiation of the Volga projects must be seen in terms of multiple functions where navigation, flood control, irrigation and even fishing, are equally as important as the electric energy generated. Although the capacity installed during the previous Five Year Plan was indeed considerable (9 MKW), there was nearly a two-fold increase in the 1950-1955 period (17.6 MKW). This trend has continued to the present.

In the mid-fifties another governmental decision was made (associated in part with the short-lived Sixth Five Year Plan, 1956-1958), which had far reaching effects insofar as hydroelectric development in the "grand manner" was concerned—the decision to tap the hydraulic resources of Central Siberia. In contrast with the European stations the prime function of the Siberian plants was to be power generation. The first major project was at Bratsk on the Angara River. The potential water resources of the Angara-Yenisey region had long been recognized and with completion of the Irkutsk hydro station a power and supply base for the Bratsk project was created. With an original 3.6 MKW capacity, subsequently raised to 4.5 MKW, it was to be the largest in the
world. As a result of this policy of promoting large scale development in order to obtain lowest cost electricity, the Krasnoyarsk hydro plant on the Yenisey was started, the capacity here to be 5 MKW thus usurping the claim of the former. The completion of Bratsk and Krasnoyarsk alone will profoundly alter the distribution of hydroelectric capacity. An analysis of this policy follows in the chapter on Central Siberia.

In 1958 the focus of attention was diverted somewhat from hydroelectric development. In August of this year and again with the initiation of the Seven Year Plan (1959-1965) early in 1959, Khrushchev officially announced that in future priority would be given to the construction of thermal power stations fired by cheap coal, oil and gas, the decision being based on the need to expand capacities as rapidly as possible. In accordance with this policy change construction of a number of large thermal stations (1-2.4 MKW) was initiated; for example Nazarovo, Tom-Usinsk, Belovo in the Central Siberian region, Troitsk in the Urals, and Konakovo near Moscow.

These speeches have subsequently created somewhat of a stir for it has been assumed by some that Khrushchev's remarks meant a de-emphasis of hydroelectric development. It appears, rather, that planners were to be more selective than had hitherto been the case in determining what hydro projects were to be undertaken. This is inferred by the following partial quote from his original statement; "... at present it is necessary to hold
back somewhat on the construction of certain hydroelectric stations so as to give priority to the construction of thermal power plants for a few years . . . " (author's emphasis).\textsuperscript{40} In consequence there appeared to be a trend toward favouring low cost, large scale developments as indicated by the initiation in 1963 of preliminary construction at a new hydro site on the Angara, Ust-Ilim, a 4.0 MKW station.\textsuperscript{41}

While the combined changes in government policy and technical developments have profoundly altered the distribution of generating capacity in general, it has been the tapping of the hydraulic resources in Central Siberia which has significantly altered the distribution of hydro capacity in particular, and from an analysis of Figure 5 the region is clearly characterized by large scale development. Thermal capacity has also increased considerably in the Eastern regions, but in relation to total installed thermal capacity the changes have not been as striking as those of hydro. In the Seven Year Plan alone, more than twice the total installed capacity of Canada will have been put into operation in the Soviet Union (about 60 MKW).\textsuperscript{42} The change through time is quite evident if Figures 5 and 6 are compared, both in terms of areal extent and scale of development. This changing distribution has increased the correlation between hydro capacity and hydro potential. Figure 7 indicates the degree of correlation as of 1964.

Since the "economically accessible" hydro resources of
FIGURE 7 HYDRO POWER—DEVELOPMENT AND POTENTIAL
European Russia are nearing complete utilization, if any new development is to take place it must of necessity be in the Eastern regions. On the basis of any criteria Central Siberia stands out as the major storehouse of hydro potential (Figure 7). How the figure for "economically accessible" hydro potential has been derived, and what is being done to utilize this resource must now be considered, within the context of the electricity industry in Central Siberia.
REFERENCES: CHAPTER III


5. Data from, D.G. Zhimerin, Istoriva Elektrifikatsii SSSR, (History of Electrification of the U.S.S.R.), Izdatel'stvo Sotsial'no-Ekonomicheskoye Izdatel'nye, Moskva, 1962, p. 357; ata—one atmosphere, approximately 15 pounds per square inch at sea level.

6. This figure from Naum Jasny, A Note on Rationality and Efficiency in the Soviet Economy I, Soviet Studies, Vol. XII, April 1961, #4, p. 369. The discrepancy between this figure and that for 1961 in Table IV is due to overlapping categories.

7. Gas production was scheduled for a five-fold increase in the current Seven Year Plan (modified slightly downward in the 1963 revision of the general plan), and a three-fold increase as a fuel for thermal plants. See, J.A. Hodgkins, Soviet Power, Energy Resources, Production, and Potential, Prentice-Hall, Englewood Cliffs, N.J., 1961, p. 136.

8. The future position of gas will be considered in subsequent chapters.


10. For an outline of its function see, I.M. Nekrasova, Leninskii Plan Elektrifikatsii Strany i Ego Osushchestvleniye v 1921-1931, (Lenin's Plan for Electrification of the Country and its Realization, 1921-1931), Izdatel'stvo Akademii Nauk SSSR,
Moskva, 1960, p. 15.


12. Calculated from data in Table III and Figure 1.


14. Their average capacity was less than 50,000 KW. B.I. Weitz (ed.), op. cit., p. 18.


16. Its completion in 1932 was almost entirely responsible for the large relative gain of hydro compared to total capacity. Destroyed during the Second World War, it has since been reconstructed and is now being expanded, see reference #54, Chapter V, page 17.


18. Sovetskaya Energetika, (unsigned), (Soviet Energy), Elektricheskie Stantsii, November, 1963, p. 4. It was only after 1950, as the article points out, that considerable progress was made in this field, with heating pipe length increasing from 646 to 4,628 KM in the decade following 1952, even though total installed capacity has always been less than in steam condensing stations (KES).


21. The increase calculated from data in Table I, Appendix D. The following table outlines the comparative regional capacities and development of grid systems to 1935.
<table>
<thead>
<tr>
<th>System</th>
<th>Capacity MKW</th>
<th>Line Length KM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moscow</td>
<td>804</td>
<td>3,362</td>
</tr>
<tr>
<td>Donbass</td>
<td>668</td>
<td>1,887</td>
</tr>
<tr>
<td>Dneiprovsk</td>
<td>611</td>
<td>476</td>
</tr>
<tr>
<td>Urals</td>
<td>568</td>
<td>1,934</td>
</tr>
<tr>
<td>Leningrad</td>
<td>545</td>
<td>1,203</td>
</tr>
</tbody>
</table>


23. Ibid., p. 7.


27. It should be pointed out that there were political boundary changes, however, the Soviet Union doubtless gained little in terms of operating capacity, (see Figure 6).


29. Erich Thiel, The Power Industry in the Soviet Union, Economic Geography, Vol. 27, 1951, p. 107. The scale of the undertaking is perhaps partially revealed when one considers for example Omsk Province, where in 1939 three collective farm power stations existed, whereas in 1949, 350 were in operation. It is interesting to note that in the late 1940's greater attention was being given the idea of inter--rather than individual collective farm electric stations, with a better co-ordination between the larger plants suggested as a means of attaining greater eco-


32. Data from Table I, Appendix D, and includes of course, repair of war damaged generating units.


34. The original desire has not come to fruition in all aspects. It was realized at a later date that to irrigate the vast tracts of land originally envisioned would be to affect adversely the flow of the Volga, thus complicating the already serious problem of the falling level of the Caspian Sea as well as generation of electric power at the downstream stations. For a brief discussion of the problem and suggested solutions see, V.P. Petrov, op. cit., pp. 20-4; and S.L. Vendrov, et al., The Problem of Transformation and Utilization of the Water Resources of the Volga River and the Caspian Sea, Soviet Geography: Review and Translation, September 1964, pp. 23-34.

35. Calculated from data in Table I, Appendix D.

36. Grand Coulee, 1.9 MKW, currently is the largest hydro station in North America. Hamilton Falls would presumably be of the same order of capacity as the Siberian stations, however, there now appears to be some doubt as to whether it will be constructed (see article by Garth Hopkins, Will Canada Hydro Remain Untapped, Vancouver Province, March 2, 1964, p. 17).


38. E.A. Trofimovskaya, Edinaya Energeticheskaya, (Single
39. For example this assumption made in, Die Energieversorgung der Sowjetunion: Gegenwartige Leistung, Ausbau des Potentials, Vergleich mit der Westlichen Welt, Deutsche Volkswirtschaftliche Gesellschaft, Hamburg, 1960, p. x, as well as in A.A. Michel and S.A. Klain, Current Problems of the Soviet Electric Power Industry, Economic Geography, July 1964, pp. 206-220. In the latter article, aside from attributing too much importance to Khrushchev's speech, the authors have also managed to make a more serious error. They attempt to compare prime costs of thermal and hydro electricity and in so doing come to several conclusions. This is done without any indication that they are aware of a difference in method of computation of prime costs at hydro and thermal stations. In fact as is pointed out in Appendix A here, the derivation of prime cost of electricity at hydro stations is based on a restricted view of total capital expenditure. Thus statements such as, "The chief advantage of hydro electric power is inexpensive power generation," (p. 211), are of little value.

40. Khrushchev at Volga Dam. . . , loc. cit.

41. For data on this plant see Chapter IV.

42. As of the end of 1964 about 104 MKW total installed capacity, an increase of just over 50 MKW since 1958, the start of the new Seven Year Plan.

43. A discussion of "economically accessible" hydro potential in European Russia follows in Chapter V.

REFERENCES: FIGURES


Figure 6. Data for 1928 from, N.M. Oznobin, Elektro-

Figure 7. Data for "economically accessible" hydro potential from Chapters 4-6; statistics for developed hydro are based on calculations in Appendices B and C, and include capacity currently under construction; data for other categories from, F.Ya. Nesteruk, Razvitiye Gidroenergetiki SSSR, (Development of Hydroelectric Energy in the U.S.S.R.), Izdatel'stvo Akademii Nauk SSSR, Moskva, 1963, pp. 59,60; I.P. Denisov, Osnovnyye Ispol'zovaniye Vodnoy Energii, (Basic Utilization of Water Power), Energiya, Moskva, 1964, pp. 35-37.
CHAPTER IV

ELECTRIC POWER IN CENTRAL SIBERIA,
POTENTIAL AND PROBLEMS

The relative importance of hydro and large scale development are the two features which differentiate Central Siberia from other regions in the U.S.S.R. The basis for this characterization will be examined, but within an overall analysis of the regional pattern of electric power production and consumption. In Soviet literature one often finds reference to the enormous hydro potential of Siberia, of which present utilization in Central Siberia (depicted on Figure 8) is deemed to be but a small beginning. Several questions naturally arise; what are the limiting factors, if any, to the growth of hydro in Siberia? Are the oft-quoted figures of 165 MW for "gross" potential and 105 MW for "technically exploitable" potential in the West and East Siberian economic regions meaningful and if not, for what reasons? On the other hand, what factors have given rise to the hydro projects now in operation or under construction and in addition, what is the position of thermal electric power in a region perhaps more often thought of in terms of the former?

In attempting to answer these questions one must not lose sight of the place of Central Siberia within the country as a whole. The region is generally regarded as the future storehouse of electric energy and the overriding purpose of this
FIGURE 8 THE CENTRAL SIBERIAN REGION
chapter is to test the validity of this concept. Such an objective requires an analysis of current and future supply and demand for electricity in Central Siberia, before any reasoned statement can be made.

HYDRO POTENTIAL

An examination of Figure 7, Chapter III, depicts the considerable difference between the Soviet estimates of hydro resources and that offered here under the heading "current economically accessible" potential. It is required, therefore, that the latter be justified. (In this regard it is reiterated that the distribution of "technically exploitable" potential provides the starting point for the derivation of a figure for this latter category).

The Lena, Yenisey and Ob river systems comprise the largest part of the Siberian "technically exploitable" potential (excluding the Far East economic region). However, data for specific sites is difficult to obtain, particularly for those streams draining into the East Siberian and Laptev Seas (see Figure 3). This appears to be simply a reflection of the paucity of detailed hydrological studies in this area. Available data has been incorporated into Table VII. While the figures for "technically exploitable" hydro resources include all sites where, from an engineering point of view, it would be possible to construct a dam, it is obvious that relative location is not taken
### TABLE VII

**SIBERIAN HYDRO RESOURCES**

<table>
<thead>
<tr>
<th>River System</th>
<th>Site</th>
<th>River Flow at Site $\text{m}^3/\text{sec.}$</th>
<th>Average Annual Flow of River $\text{KM}^3$</th>
<th>Technically Exploitable Potential Capacity $\text{MKW}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ob River</td>
<td>Lower Ob</td>
<td>12,500$^c$</td>
<td>394$^c$</td>
<td>25.7$^b$</td>
</tr>
<tr>
<td>Irtysch</td>
<td>Omsk$^d$</td>
<td>949$^d$</td>
<td>-</td>
<td>3.2</td>
</tr>
<tr>
<td>Katun</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3.7</td>
</tr>
<tr>
<td>Yenisey River</td>
<td>Yeniseyskaya$^e$</td>
<td>7,909$^e$</td>
<td>548$^e$</td>
<td>18.2</td>
</tr>
<tr>
<td>Angara</td>
<td>Bratsk$^e$</td>
<td>2,900$^e$</td>
<td>-</td>
<td>14.0</td>
</tr>
<tr>
<td>Lower Tunguska</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.2</td>
</tr>
<tr>
<td>Lena River</td>
<td>Lower Lena$^d$</td>
<td>15,300$^d$</td>
<td>488$^e$</td>
<td>20</td>
</tr>
<tr>
<td>Vilyuy</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.4</td>
</tr>
<tr>
<td>Olekma</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Aldan</td>
<td>Seron-Tiitkskaya$^d$</td>
<td>225$^d$</td>
<td>-</td>
<td>5.5</td>
</tr>
<tr>
<td>Vitim</td>
<td>Mamakan$^d$</td>
<td>186$^d$</td>
<td>-</td>
<td>5.4</td>
</tr>
<tr>
<td>Indigirka River</td>
<td>-</td>
<td>-</td>
<td>57</td>
<td>6.2</td>
</tr>
<tr>
<td>Kolyma River</td>
<td>-</td>
<td>-</td>
<td>120</td>
<td>5.2</td>
</tr>
<tr>
<td>Khatanga River</td>
<td>-</td>
<td>-</td>
<td>101</td>
<td>4.1</td>
</tr>
</tbody>
</table>

---


*b.* Includes the proposed Lower Ob station, the estimated capacity of which ranges anywhere between 6-20 MKW.


into account. The Indigirka, Kolyma and Khatanga Rivers (located on Figure 3) account for about 15 percent of Siberian hydro potential, yet all lie well within the zone of permafrost, a condition which creates special problems for dam construction.

Figure 9 illustrates the marked seasonal concentration of discharge on the latter streams as well as the Lena and two of its tributaries, compared to those on which major hydro construction has thus far taken place. The fact that on the majority of the "potential" streams over one-half of the annual flow comes in one or two months is related in large part to the existence of permafrost. On the Vilyuy for example, two-thirds of the total annual discharge occurs in May and June. Such a concentration means that very large dams must be constructed under difficult physical conditions if adequate storage is to be provided for the needs of an associated industrial complex that is usually envisioned. There is also the problem of providing access to these sites. The current difficulties associated with the construction of a very small station at Vilyuyskaya on the Vilyuy River would seem to be enough to force even the most ardent proponent of the more grandiose schemes into a reconsideration. Here costs are currently out of hand, since it is having to be serviced largely by air.

To regard all these rivers as potential is certainly misleading, thus the figure for current "economically accessible" hydro resources excludes the Lena system, as well as the
FIGURE 9 VARIATION OF ANNUAL DISCHARGE--SELECTED STREAMS

- **Volga**
  - Percent of Flow: April-June
  - Percent of Flow: June-September
  - Percent of Flow: April-September

- **Yenisey**

- **Angara**

- **Lena**

- **Vilyuy**

- **Vitim**

- **Indigirka**

- **Kolyma**

- **Khatanga**

- **Percent of Flow: April-June**
- **Percent of Flow: June-September**
- **Percent of Flow: April-September**
Indigirka, Kolyma and Khatanga Rivers. While there has been some publicity given the Lower Lena project (20 MKW) in particular, it has not yet been seriously considered in the Soviet technical literature, which is deemed the more accurate reflection of current trends. It would appear that the simple fact of relative location plus those factors discussed previously would be more than enough to outweigh the technical feasibility of transmitting energy to Central Siberia by way of extending the grid system, a possible but not probable event for at least the next decade or two. Such considerations also apply to the potential sites on the lower reaches of the Yenisey. The 20 MKW Lower Ob scheme, which can be considered more profitably in relation to the Urals grid than the Siberian, is excluded as well for reasons elaborated on in the following chapter. By deducting the potential of these streams (as given in Table VII) and projects, the figure arrived at for current "economically accessible" hydro potential is approximately 50 MKW. Although not intended to be strictly accurate in terms of precise kilowatt potential, it is nevertheless deemed to be more realistic and meaningful than the Soviet estimate of "gross" or "technically exploitable."

The exclusion of the aforementioned streams and specific proposals is not meant to infer that there will not be any hydro development outside the Central Siberian region during the next two decades. It is suggested, however, that any projects undertaken would be of small scale and of little importance in rela-
tion to the hydro developments within the region.\textsuperscript{13}

INSTALLED CAPACITY

The demand for electricity has increased rapidly in Central Siberia, the annual increase being among the highest in the U.S.S.R. The original impetus came with the organization of the Urals-Kuznetsk industrial combine in 1934, there being less than 35,000 KW of installed capacity in the Kuznetsk basin prior to this.\textsuperscript{14} With subsequent industrial growth, particularly during the Second World War, capacity in Central Siberia increased such that its share of total Soviet generation of electric power had increased from less than 2 to about 8 percent by 1945, and as Table VIII illustrates the general trend has continued.\textsuperscript{15} Moreover, Eastern Siberia which excludes the industrial centers of the Kuznetsk basin (Figure 8), has increased its share of the regional total substantially since 1940, from 26 to 47 percent (1962), a reflection of the industrial development in the Krasnoyarsk and Irkutsk areas in particular.\textsuperscript{16}

HYDRO CAPACITY

The total installed capacity in Central Siberia has been estimated at 10.5 MKW as of January 1965 of which, as Table IX indicates, almost one-half is hydro (twice the national average). The importance of hydro in this region has been stressed throughout and was related in the last chapter to a change in Soviet
**TABLE VIII**

**GENERATION OF ELECTRIC POWER BKWH**

**SHARE OF NATIONAL TOTAL**

<table>
<thead>
<tr>
<th></th>
<th>1940</th>
<th>1950</th>
<th>1955</th>
<th>1958</th>
<th>1960</th>
<th>1962</th>
<th>1964 (Estimate) ^\text{e}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. West Siberia ^\text{a}</td>
<td>1.863</td>
<td>5.871</td>
<td>11.716</td>
<td>16.225</td>
<td>22.167</td>
<td>29.114</td>
<td></td>
</tr>
<tr>
<td>2. East Siberia ^\text{b}</td>
<td>0.669</td>
<td>2.389</td>
<td>5.065</td>
<td>10.209</td>
<td>16.416</td>
<td>26.340</td>
<td>60</td>
</tr>
<tr>
<td>3. Total U.S.S.R. ^\text{c}</td>
<td>48.309</td>
<td>91.226</td>
<td>120.225</td>
<td>235.351</td>
<td>292.274</td>
<td>369.275</td>
<td>450</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percent Share ^\text{d}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 and 2 of 3</td>
</tr>
<tr>
<td>5.2%</td>
</tr>
<tr>
<td>9.0%</td>
</tr>
<tr>
<td>11.7%</td>
</tr>
<tr>
<td>11.2%</td>
</tr>
<tr>
<td>13.2%</td>
</tr>
<tr>
<td>15.0%</td>
</tr>
<tr>
<td>13</td>
</tr>
</tbody>
</table>

---


c. *Narodnoye Khozyaystvo SSSR . . ., loc. cit.*

d. Calculated.

### TABLE IX

**REGIONAL CAPACITY BY TYPE**

<table>
<thead>
<tr>
<th></th>
<th>Central Siberia 1964</th>
<th>U.S.S.R. 1962&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MKW</td>
<td>Percent</td>
</tr>
<tr>
<td>Hydro&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.7</td>
<td>45</td>
</tr>
<tr>
<td>Thermal&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensation (KES)</td>
<td>4.2</td>
<td>40</td>
</tr>
<tr>
<td>Heat and Power (TETS)</td>
<td>1.6</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>10.5</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Capacity calculated, percent of total regional capacity based on figure from *Pravda*, January 15, 1964, p. 2.


<sup>c</sup> Derived from *Elektricheskiye Stantsii*, November 1963, p. 4.
policy, with greater selectivity in construction of stations being emphasized. The reasons for this change can perhaps be best understood in terms of a specific site analysis of selected stations, taking into consideration those factors which have apparently conditioned policy. The contention here will be that the move into the Siberian region has been based primarily on economic factors (economic insofar as Soviet decision making is concerned), although it is conceded that strategic factors may have been of some importance. It must be borne in mind that with the passing of each year there are fewer prospective hydro sites in European Russia, and even fewer with benefit-cost ratios comparable to sites in the Eastern regions, particularly Central Siberia. When the physical conditions at the Bratsk station on the Angara River are contrasted with those of Kuybyshev, one of the largest multi-purpose stations on the Volga, it will become evident why engineering counsel would favour the former (see Figure 5).

Bratsk and Kuybyshev--A Contrast in Physical Geography

Two significant determinants of the hydraulic potential of a stream are the flow, discharge at a specific point represented as some quantity per unit of time, and its temporal variation throughout the year. The ratio of maximum-minimum discharge on the Angara is 7, compared to 255 on the Volga. Even with the construction of a reservoir system on the Volga, annual power
output at Kuybyshev can vary by as much as 30 percent either way, depending on the particular climatic conditions of that year as exemplified by the discharge. Figure 10 contrasts in detail the seasonal flow pattern of the Volga with the non-seasonal flow of the Angara, which is due to the fact that the Angara provides the only outlet to Lake Baykal and now is further regulated by the dam at Irkutsk (Figure 8).

River gradient as a function of regional topography is an important determinant of the potential gross head available at a particular site, (difference in elevation between the reservoir water level at intake to turbine tunnel and tail race). Other things being equal, the greater the head the greater the generating capacity. At Kuybyshev 2,200 kilometers from the Volga's source, there is a difference of 147 meters in elevation, whereas at Bratsk 720 kilometers downstream from the Angara's source, Lake Baykal, the river has descended 157 meters, 90 of which are in the immediate area of the dam site.

Situated at the Saratov Bend of the Volga, the Kuybyshev dam rests primarily on clay and alluvial sand with the limestone and dolomite higher right bank as additional support. The concrete overflow dam and the power house occupy the two channels which the Volga had formed at this point and are connected with an earthfill dam, the whole structure being almost 4,000 meters in length, but less than 50 meters in height. The normal operating head at Kuybyshev is approximately 30 meters.
FIGURE 10

ANNUAL RIVER FLOW CHARACTERISTICS--VOLGA AND ANGARA
The Padun Narrows is the site of the Bratsk dam and here physical conditions are markedly different, for the Angara squirts through a gorge of solid igneous rock 900 meters wide with banks rising 80 meters above the river. At this site it was possible to construct a 135 meter high concrete gravity dam, giving a normal operating head of 90 meters. The difference in regional topography is perhaps best illustrated when one considers that the Bratsk reservoir covers a smaller surface area than that at Kuybyshev (the Zhiguli Sea), 5,000 square kilometers as compared to 6,500, but contains three times the latter's 58 billion cubic meter volume. In both cases roughly a third is used for power generation.

One of the principal factors accounting for the difference in investment per unit of installed capacity as indicated in Table X was the greater volume of earthworks required at the Kuybyshev station, 190 million cubic meters as compared to 30. Both stations required the same volume of plain and reinforced concrete—12 million cubic meters.

The different physical conditions have given rise to different functions for each plant. At Bratsk it is possible to maintain a relatively constant generation of electricity throughout the year. This is a result of the Angara's even flow and the large volume of the reservoir storage capacity that can be used for generation. Thus Bratsk was designed to meet in large part the base load demand of an associated industrial complex, and to
TABLE X

POWER AND ECONOMIC CHARACTERISTICS OF BRATSK* AND KUYBYSHEV HYDROELECTRIC STATIONS

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Kuybyshev</th>
<th>Bratsk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed Capacity MKW</td>
<td>2.3</td>
<td>4.5c</td>
</tr>
<tr>
<td>Turbine Capacity MKW</td>
<td>.115</td>
<td>.225d</td>
</tr>
<tr>
<td>Annual Generation of Electricity BKWH</td>
<td>10e</td>
<td>22-26f</td>
</tr>
<tr>
<td>Investment for Construction of Hydro Plant (for power supply only) M. Rubles**</td>
<td>654.7</td>
<td>405g</td>
</tr>
<tr>
<td>Investment Per Unit of Installed Capacity Rubles per KW</td>
<td>284</td>
<td>90h</td>
</tr>
<tr>
<td>Investment Per Unit of Power Output Rubles per KWH</td>
<td>.06</td>
<td>.0152i</td>
</tr>
<tr>
<td>Prime Cost of Electricity at Station (assuming 46 percent plant factor) Kopeks per KWH</td>
<td>.08</td>
<td>.04j</td>
</tr>
<tr>
<td><strong>Mills per KWH</strong>*</td>
<td>.9</td>
<td>.4</td>
</tr>
<tr>
<td>Average Cost of Hydroelectric Power in 1959 Kopeks per KWH</td>
<td>.19k</td>
<td></td>
</tr>
<tr>
<td>Mills per KWH</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>Average Cost of Electric Power From All Sources in 1962 Kopeks per KWH</td>
<td>.74l</td>
<td></td>
</tr>
<tr>
<td>Mills per KWH</td>
<td>8.2</td>
<td></td>
</tr>
</tbody>
</table>

* Projected
** Kuybyshev statistics originally in 1955 rubles, corrected for 1961 devaluation by using a factor of 10.
*** Kopeks converted to mills: 1 kopek 1.11 cent (U.S.).

b. Derivation of prime cost of hydroelectricity outlined in Appendix A.


d. Ibid.


g. This figure would appear reasonable since total cost for the whole of the Bratsk development was 707 M. rubles as of January 1, 1964, which includes large expenditures for the railroad and communications into the site as well as reservoir costs. See A.M. Gindin, Organizatsiya Stroitel'stva Bratskoi GES, (Construction Organization at the Bratsk GES), Gidrotekhnicheskoye Stroitels'tvo, No. 6, 1964, p. 3.

h. Calculated: Investment (rubles) ÷ Installed Capacity (KW).

i. Calculated: Investment (rubles) ÷ Annual Generation (KWH).


a lesser extent the peak load of the Siberian system.\(^2^6\) Kuybyshev, being part of the Volga scheme, was designed to carry a large share of the peak load of the unified European power system, in addition to providing stream regulation and irrigation waters to offset the larger ratio of maximum to minimum discharge of the Volga. It should be pointed out that presently the load curve of the Central Siberian system is relatively and absolutely less than in European Russia.\(^2^7\) This is a reflection of the importance of the industrial demand in Central Siberia.

It can thus be seen that the projected low cost of large blocks of power at Bratsk (Table X), a fifth of the national average hydro cost, (which itself is considerably less than the .74 kopeks per KWH average cost of electricity from all sources in power systems) coupled with an expected high rate of return per unit of investment, has provided economic incentive for government promotion of large scale hydro projects in this region.\(^2^8\) It needs to be emphasized again that this is the result simply of propitious physical geographic conditions.

Recent Hydro Developments

There have been other large hydro projects initiated in this region during the past few years. All are part of the Angara-Yenisey scheme outlined on Figure 8, plans for which began in 1930.\(^2^9\) Since these projects are similar in scale and function to the Bratsk station only a general discussion of their location
and individual characteristics is required.

The fourth hydroelectric station to be constructed in Central Siberia was on the Yenisey River at Krasnoyarsk. Krasnoyarsk was begun under the same government policy in the mid-fifties as Bratsk and it also was to supply electricity for an associated industrial complex. (Construction of Bratsk and Krasnoyarsk followed the plant at Novosibirsk built during the Fourth Five Year Plan, and Irkutsk, which first came under load in 1956 and was designed to act as a power base for construction at Bratsk and providing, in addition, power for local industry and the easterly sections of the electrified Trans-Siberian rail-
road). To aid in meeting the demand of the industries within the city of Krasnoyarsk, construction of the Nazarovo thermal plant was started and interconnection with this plant and Bratsk was planned both to even out generation and to decrease required reserve capacities. Any surplus power was to be "exported" to the Kuznetsk basin. It has been stated that the Soviets were somewhat reluctant to undertake the Krasnoyarsk station in spite of projected lowest cost of power from any hydro station so far constructed. This is perhaps the result of placing too much emphasis on Khrushchev's statements of 1958.

At any rate hydro development in this region has not been adversely affected, for construction of the Ust-Ilim station on the Angara has subsequently been initiated and preliminary work is being carried out at Sayan, 300 kilometers upstream from
Krasnoyarsk (Figure 8). The economical construction of the Ust-Ilim station is largely dependent upon the utilization of the equipment and workers' brigades from the Bratsk project and men and equipment have been transported downstream to the site by barge. Sayan like Ust-Ilim will make use of existing equipment and construction crews, this time from Krasnoyarsk. While this station is still in the preliminary stages it is probable that the plans will be completed since there is more than simply the economics of supply and demand involved. The dam site is near the village where Lenin spent several years of confinement during the 1890's and much is being made in the press of his original vision of a hydro station and industrial complex at this location. It is desired to have Sayan in operation by 1970, in time for the one hundredth anniversary of Lenin's birth. Power generated is to be used in part in the Kuzbass, via a 400 kilometer 750 KV transmission line. Another 500 KV line is proposed, feeding the Abakan-Minusinsk area. Further discussion of developments at Sayan is reserved for the concluding chapter. In the following Table the technical and economic characteristics of these plants are outlined. The primary function of these Siberian stations is once again, power generation.

THERMAL CAPACITY

While most attention is generally accorded the Nazarovo (1.5 MKW), Belovo (1.5 MKW) and Tom-Usinsk (2.4 MKW) thermal
## TABLE XI

**TECHNICAL AND ECONOMIC CHARACTERISTICS**
**SIBERIAN HYDRO POWER STATIONS**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Krasnoyarsk(^a)</th>
<th>Ust-Ilim(^b)</th>
<th>Sayan(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>River</td>
<td>Yenisey</td>
<td>Angara</td>
<td>Yenisey</td>
</tr>
<tr>
<td>Flow at site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cubic meters</td>
<td>2,790</td>
<td>4,000</td>
<td>2,100</td>
</tr>
<tr>
<td>Average head, meters</td>
<td>93</td>
<td>130</td>
<td>206</td>
</tr>
<tr>
<td>Installed capacity MKW</td>
<td>5-6</td>
<td>4</td>
<td>6.36</td>
</tr>
<tr>
<td>Turbine capacity MKW</td>
<td>.5</td>
<td>.5</td>
<td>.53</td>
</tr>
<tr>
<td>Annual Generation BKWH</td>
<td>20</td>
<td>20</td>
<td>23.5</td>
</tr>
<tr>
<td>Year of initial operation</td>
<td>1967</td>
<td>1968</td>
<td>1970</td>
</tr>
<tr>
<td>Capital investment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>per KW of installed capacity</td>
<td>82</td>
<td>--</td>
<td>85</td>
</tr>
<tr>
<td>(rubles)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>per KWH (rubles)</td>
<td>.02</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Prime cost of electric power at site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>kopeks per KWH</td>
<td>.03</td>
<td>.03</td>
<td>.03</td>
</tr>
</tbody>
</table>

---

\(^a\) Data for Krasnoyarsk from S.S. Agalakov, *Plotina Krasnoyarskoi Gidroelektrostantsii*, (The Krasnoyarsk Hydro Station Dam), *Gidrotekhnicheskoye Stroitel'stvo*, April 1964, pp. 16-22.


plants (Figure 8), it needs to be re-emphasized that this large scale development is of recent origin (post 1958). As late as 1955 the average capacity of power stations east of the Urals was only 27,000 KW as compared to 46,000 KW in European Russia. \(^{39}\) At present, only Nazarovo, Belovo, and Tom-Usinsk are operating (although not yet at planned capacity), thus they cannot be regarded as the principal source of electric power. \(^{40}\) The older, smaller plants still comprise over one-half of the region's 6 MKW installed thermal capacity (1964), as is evident from Figure 5. \(^{41}\)

The predominance of condensation thermal plants (KES) in Central Siberia (Table IX) reflects directly the importance of the industrial sector as a consumer of electricity. \(^{42}\) The share of heat and power plants (TETS) of regional capacity, which can be used as a rough guide to the importance of the domestic sector, is currently about 15 percent. In view of the planned expansion in energy intensive industry in the region, this share cannot be expected to increase.

Nazarovo and Cherepets

As in the case of hydro it would be advantageous to compare the power and economic characteristics of representative stations from European Russia and Central Siberia. The condensation plants selected, Nazarovo (45 MKW capacity in 1963) and Cherepets (Figure 8 and in Chapter V, Figure 11) are representative of those stations currently being constructed in each region
in terms of type of fuel used, installed capacity and projected cost of electric power.\textsuperscript{43} The latter plant, begun in 1952, had been equipped at the outset with large generating units, capacity of the plant being boosted in 1963 with the addition of two .3 MKW units in accordance with recent trends (Table XII).\textsuperscript{44}

Proximity to coal deposits is a major locative force for thermal plants both to lessen transport costs and, equally as important, to avoid adding to the problem of an over-taxed rail network. Cherepets is supplied in part from the local Moscow basin deposit, yet the furnaces for the new, .3 MKW turbines, fired by anthracite from the Donbass (requiring a rail haul of over 500 kilometers) give rise to cheaper electricity (Table XII).\textsuperscript{45} This is because of the higher calorific value of this fuel compared to the Moscow brown coal and the larger scale generating units. It would appear that disadvantages of added congestion on the rail network are outweighed by the benefit derived from less expensive electricity. At Nazarovo, rail hauls are eliminated since it is situated on the Nazarovo brown coal deposit (part of the Kansk-Achinsk field), all furnaces being fired by locally strip mined coal. Another important factor in location is water supply, thermal plants of 1-1.5 MKW requiring 30-40 cubic meters per second for cooling.\textsuperscript{46} The Krasnoyarsk reservoir is intended to meet this need at Nazarovo, while an adjacent storage lake (fed by a tributary of the Oka) supplies Cherepets.

There have been several problems associated with the
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Cherepets(^a)</th>
<th>Nazarovo(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed capacity MKW</td>
<td>1.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Turbine capacity MKW</td>
<td>4 x .150</td>
<td>10 x .150</td>
</tr>
<tr>
<td></td>
<td>2 x .3</td>
<td></td>
</tr>
<tr>
<td>Annual generation BKWH(^c)</td>
<td>9-10</td>
<td>10-11</td>
</tr>
<tr>
<td>Fuel(^d)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown Coal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ash content (approx.) percent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthracite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ash content (approx.) percent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of coal per ton at plant(^e) in terms of conventional fuel equivalent (Rubles)</td>
<td>17.3</td>
<td>8.9</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>per actual ton produced (Rubles)</td>
<td>6.7</td>
<td>8.1</td>
</tr>
<tr>
<td></td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Plant factor (hours per annum)</td>
<td>6500</td>
<td>6600-7000</td>
</tr>
<tr>
<td>Capital investment (M. Rubles)</td>
<td>--</td>
<td>156</td>
</tr>
<tr>
<td>Projected prime cost of power at site(^f)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kopeks per KWH</td>
<td>.7*</td>
<td>.167</td>
</tr>
<tr>
<td></td>
<td>.4**</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Using Moscow Basin coal

\(^b\) Using Donetsk Basin coal and .3 MKW turbines

\(^c\) Using Moscow Basin coal

\(^d\) Using Donetsk Basin coal and .3 MKW turbines

\(^e\) Data from H.M. Ellis, *Power Generation and EHV Transmission in the Soviet Union*, International Power and Engineering Consultants Ltd., Vancouver, B.C., June 1960, pp. 17-8, except
where indicated.


c. Estimated.


f. Figure based on operation at planned installed capacity.
Nazarovo plant. For example, the furnaces installed had not been designed for the local coal qualities, thus required cleaning every four months and consequently generation had not exceeded 70 percent of that planned (1963). The current cost of electricity from this station is estimated to be no less than .3 kopeks per KWH (projected, .167). Basically this is a problem of organization and planning, rather than any inherent disadvantage of local resources. The projected lower cost of electricity at Nazarovo certainly supports this conclusion.

Trends in Fuel Consumption

At present all major thermal plants are coal fired. The move toward the larger thermal units was to reap the benefits of large scale and in this region specifically, to take advantage of comparatively cheap, strip mined coal as fuel. The costs at major deposits in Central Siberia are compared with those of the major fields in European Russia in Table XIII. Since the main element in prime cost of thermal power is fuel (50-80 percent), the lower cost of coal and abundant reserves in Siberia are a major attraction.

The import of oil cannot be regarded as competition to coal as fuel for thermal stations. The expanding petrochemical industry in Omsk, Krasnoyarsk and Angarsk provide a ready market and certainly give a higher marginal return than would be the case if it were consumed as fuel. With increased expansion in the
# TABLE XIII

THE COST OF PRODUCING ONE TON OF COAL  
EUROPEAN RUSSIA, SOUTH SIBERIA

<table>
<thead>
<tr>
<th>Basin or Combinat</th>
<th>Type of Coal</th>
<th>1956 (rubles)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>South Siberian Belt</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kuznetsk Basin (shaft)</td>
<td>Hard</td>
<td>5.660</td>
</tr>
<tr>
<td>Kuznetsk Basin (open pit)</td>
<td>--</td>
<td>2.900</td>
</tr>
<tr>
<td>Kansk-Achinsk Basin (open pit)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nazarovo Deposit</td>
<td>Brown</td>
<td>1.100</td>
</tr>
<tr>
<td>Irsha-Borodinsk</td>
<td>Brown</td>
<td>.670</td>
</tr>
<tr>
<td>Itatsk Deposit</td>
<td>Brown</td>
<td>.498</td>
</tr>
<tr>
<td>Cheremkovo Basin (open pit)</td>
<td>Hard</td>
<td>2.000</td>
</tr>
<tr>
<td><strong>European Russia</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Donetsk Basin</td>
<td>Hard</td>
<td>8.100</td>
</tr>
<tr>
<td>Moscow Basin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moscow Combinat</td>
<td>Brown</td>
<td>5.673</td>
</tr>
<tr>
<td>Tula Combinat</td>
<td>Brown</td>
<td>6.291</td>
</tr>
</tbody>
</table>


b. Corrected for 1961 devaluation.


d. This figure slightly lower than Hodgkin's, (8.1 as compared to 9.5), A.A. Stepankov, *loc. cit.*
industry and particularly if the Siberian fields are exploited, it is probable that residues will be used to generate electricity, but this would represent a small portion of total thermal plant fuel consumption. While oil is currently being used to fire the multitude of small diesel generating units which exist in Central Siberia, the absolute amount of oil consumed is insignificant. The argument based on marginal returns can be applied also to gas, which will be imported pending construction of the pipeline from the Lower Ob area.

Coal will remain the principal fuel in this region for at least the next decade. Indeed, plans for future thermal development center around the Itat coal deposit in the Kansk-Achinsk basin. Envisioned is a complex of thermal power stations generating 300 BKWH of electricity annually, the bulk of which is to be marketed in European Russia.

With regard to electric power development in Siberia generally, there has been put forward a three stage plan—which ultimately will see 100 MKW of installed capacity in Central Siberia. At present, development is nearing the end of the first stage which includes construction of the large scale thermal plants, Nazarovo, Tom-Usinsk and Belovo, the Krasnoyarsk and Bratsk hydro plants. The 15 MKW planned total capacity as yet has not been attained, but will be upon actual completion of the Krasnoyarsk station. The second stage involves the construction of several other large scale thermal plants as well as the Ust-Ilim and Yenisey hydroelectric
stations, giving an installed capacity of 35 MKW. It is of particular interest that the scheme revolves around developments of hydro sites and construction of thermal plants within the region as it has been defined, and does not include any major hydro development outside.

While Central Siberia is generally referred to as a power affluent region, at present this is a gross oversimplification, for many areas are still power deficient. On the regional level shortages have been noted in the Kuzbass industrial centers especially, although to a certain extent these have been offset by the recent integration of the Bratsk hydro station into the Central Siberian grid. This integration resulted from the fact that as of late 1963 the existing 3 MKW capacity was largely going unused, for construction of the associated energy intensive industrial complex had fallen behind schedule, in the case of the aluminum plant at Anzeb by as much as 50 percent of plan. To rectify this uneconomic situation immediate construction of a 1,000 kilometer 500 KV transmission line (completion of which was originally scheduled for the end of 1965) was necessitated in order to provide an outlet for the power. With its hurried completion at the end of November 1963, the geographic position of Bratsk was effectively altered since it was integrated into the Central Siberian grid supplying in part the electric energy needs of the Kuznetsk basin, and acting as an interim power supply for the industrial complex associated with the Krasnoyarsk hydro station.
As an example of the type of anomaly that had existed previously, coal had been transported from the Kuznetsk basin to the Novosibirsk thermal plant, electricity subsequently being transferred back to the basin. As might be expected with power shortages indicated in the industrial sector it has been inferred recently that the domestic consumer has been faced with power restrictions.

The current construction of large scale plants tends to create a false impression of the level of electrification existing within the region. The trend toward large scale stations has not yet seen a decline in the number of small plants (less than 1,000 kW capacity), in fact in some areas they have doubled in number during the past decade. This situation is in large part attributable to the lack of attention accorded the construction of low voltage distribution lines. The rural areas logically have been the most seriously affected as a result.

THE MARKET FOR ELECTRICITY

It has been stated here that the recent expansion of generating capacity in Central Siberia, particularly hydro, was due to economic incentive, that is, the potential large blocks of low cost electricity. Yet it should be pointed out that the full benefits of recently constructed large scale capacity have not as yet been realized. Neither the thermal plants nor Bratsk are operating at full capacity. Indeed the cost of electricity from
Bratsk in 1963, .15 kopeks per KWH, was four times that projected, (see Table X). This is simply because the plant is not operating at full capacity--it generated 8 BKWH in 1963, one-third of the planned annual output.

Within the next year or two this situation will be improved but at present, Central Siberia is a region of comparatively high cost electricity. On the basis of reports in the press the cost here is estimated to be not less than the national average, .74 kopeks per KWH. Indeed considerable concern has been evoked recently over the fact that the comparative high cost of electricity has prevented the adoption of electrification in certain enterprises. While the enterprises are not specified it is of significance that the reason offered is high cost and not shortage, which could perhaps be expected. As it stands this is a rather incongruous situation and one which requires further examination.

The high cost of electricity from some thermal plants has been attributed in turn to the cost of coal (which accounts for over half of thermal power cost). Strip mined coal from the Kuznetsk basin deposits and to a lesser extent, from the Kansk-Achinsk deposit, has largely replaced shaft mined coal as fuel for thermal stations, yet there has been no alteration in price per ton. Thus the complaint has been lodged that the failure to reduce price per ton to thermal plants has contributed to higher operating costs, therefore higher prices, since calorific value of the strip mined coals is generally lower and moisture content
higher. Moreover, the multitude of small generating units will adversely affect the average cost of power in the region, as cost of power at these plants can be anywhere from ten to fifteen times the average for the grid system.69

While high cost has apparently restricted electricity consumption in Central Siberia it is necessary now to determine which are the principal consumers.

Although production figures for the Soviet electric power industry are "comparatively easy" to obtain, there is a definite paucity of data concerning consumption of power, particularly on a regional level. An attempt has been made in Appendix B, (Part 1), to account for the major consumers in Central Siberia, wherever data permitted. The results of this analysis are set down in Table XIV, and as indicated three-quarters of the installed capacity has been accounted for. The balance would be taken up in large part by the ferro-alloy industry (located primarily in the Kuznetsk basin) for which, unfortunately, production data in any form is not available.

It is interesting to note that close to one-half of the present installed capacity is required for what might be considered non-productive activities; domestic and communal economy, electric railway and associated uses, line loss and station consumption (Table XIV). The importance of the latter sector is not generally recognized, but usually requires about 10 percent of total regional installed capacity. This figure will vary depending on the length
TABLE XIV

ESTIMATED CONSUMPTION OF ELECTRIC POWER--CENTRAL SIBERIA\textsuperscript{a}
JANUARY 1965

<table>
<thead>
<tr>
<th>Sector</th>
<th>KWH Consumed Annually (BKWH)</th>
<th>Required KW Capacity to Meet Demand (MKW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Domestic and Communal Economy</td>
<td>3.0</td>
<td>0.857</td>
</tr>
<tr>
<td>2. Agricultural Economy</td>
<td>1.2</td>
<td>0.923</td>
</tr>
<tr>
<td>3. Electric Railway and Associated Uses</td>
<td>6.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Aluminum</td>
<td>7.6</td>
<td>0.915</td>
</tr>
<tr>
<td>2. Iron and Steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>\hspace{2em} i Integrated</td>
<td>1.27</td>
<td>0.292</td>
</tr>
<tr>
<td>\hspace{2em} ii Electric Furnace</td>
<td>0.011</td>
<td>0.0016</td>
</tr>
<tr>
<td>3. Pulp, Paper and Cardboard</td>
<td>0.1192</td>
<td>0.0278</td>
</tr>
<tr>
<td>4. Synthetic Rubber</td>
<td>0.360</td>
<td>0.057</td>
</tr>
<tr>
<td>5. Nitrogenous Fertilizer</td>
<td>0.35</td>
<td>0.044</td>
</tr>
<tr>
<td>6. Agricultural Machinery</td>
<td>0.286</td>
<td>0.13</td>
</tr>
<tr>
<td>7. Metal Fabrication and Custom Machinery</td>
<td>2.0</td>
<td>0.91</td>
</tr>
<tr>
<td>8. Cement</td>
<td>0.525</td>
<td>0.086</td>
</tr>
<tr>
<td>Line Loss and Station Consumption</td>
<td>6.0</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Total Installed Capacity Required 7.997
Total Installed Capacity--Central Siberia 11.0
Percent of Capacity Accounted For 72.7

\textsuperscript{a} All figures have been derived from calculations in Appendix B.
and use of higher voltage transmission lines, (220 KV and above).

The significance of load factor is revealed through a consideration of the agricultural sector. Consumption of electricity amounted to only 2 percent of total regional output, but in order to meet this demand over 8 percent of the installed capacity was required. The agricultural sector, as well as domestic, and electric railway consumption, are analogous in that they have comparatively low load factors and consequently are expensive to service. Yet, even in Central Siberia where shortages of electricity have been noted and current average cost is comparatively high, the standard rate to domestic consumers, about 4 kopeks per KWH, still exists. The differential between average cost (.7 kopeks per KWH) and selling price, while high, is not excessive and is comparable to the North American situation. The standard rate clearly is not analogous.

Within the region, the Kuznetsk basin is at present the principal consuming area. Expansion of aluminum production, the largest single industrial consumer, is likely to cause a shift in the center of gravity of electricity consumption toward the Eastern part of the region, since expansion is associated particularly with the centers of Krasnoyarsk and Bratsk. Indeed, as two-thirds of the generating capacity now being installed lies east of the Kuznetsk basin, one can expect that the center of gravity of production will shift as well. In this regard the Krasnoyarsk node is emerging as a focal point in the Central Siberian electricity
industry. Machine fabricating industries (numbers 6 and 7, Table XIV) will remain the major consumers of electricity in the Kuznetsk basin for at least the next few years. Industries of importance to Central Siberia generally, for example the wood products industry, are unimportant as consumers of electricity as Table XIV indicates. Transfer of electric power will of necessity be oriented to the west within the areal extent of the grid at present; but what of the intertie with European Russia?

It is doubtless apparent from the foregoing discussion that there does not exist in Central Siberia currently a surplus of electric power that could be transmitted to European Russia. However, excluding Sayan, about 11 MKW of capacity can conceivably come under load in the next five or six years. It has been stated that by 1970 Central Siberia would generate 140 BKWH per annum, and by assuming an average 65 percent plant factor for the region this would indicate an installed capacity of 24.6 MKW. While certainly a considerable annual generation of electricity, it can hardly be considered unrealistic in view of the fact that about 22 MKW is accounted for by existing capacity, 10.5 MKW, and the 11 MKW under construction.

The important consideration here is whether or not there will be a large block of surplus power in 1970. If such is the case then an interconnection with European Russia could be justified. Once again in Appendix B, (Part 2) the potential consumers of electricity in 1970 have been estimated. These results are
incorporated into Table XV. On the basis of planned and assumed expansion in the various industries and sectors, it was only possible to account for 52 percent of expected capacity. Even allowing a wide margin of error for such industries for which production data is not available (e.g. ferro-alloy), Central Siberia could well be an area of surplus electric power in 1970, perhaps as much as 15-20 BKWH annually. This would still permit as much as 50 BKWH to be consumed in those industries which are not included in Table XV. Of the energy intensive industries however, it should be pointed out that these are few. These tentative conclusions support Soviet statements that 10-15 percent of annual generation in Central Siberia (about 15-20 BKWH) will be transmitted to the Urals at this date. This electricity could be consumed in any one of the industries in the Urals having a high load factor.

From a technical point of view the transmission of large blocks of power over long distances is now feasible. It has just recently been announced that the 800 DC line from Volgograd to the Donetsk basin, (a distance of about 500 kilometers) has been tested successfully over its entire length, (a 750 KV line is to be constructed during 1965 from Konakova to Moscow). In Central Siberia, an important development in this respect was the construction of the 500 KV line from Bratsk to Kemerovo in the Kuznetsk basin. This, as Figure 8 indicates, is the "backbone" of the grid system. There is at present a weak intercon-
### TABLE XV

ESTIMATED CONSUMPTION OF ELECTRIC POWER—CENTRAL SIBERIA

1970

<table>
<thead>
<tr>
<th>Sector</th>
<th>KWH Consumed Annually (BKWH)</th>
<th>Required KW Capacity to Meet Demand (MKW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic and Communal Economy</td>
<td>3.3</td>
<td>.940</td>
</tr>
<tr>
<td>2. Agricultural Economy</td>
<td>1.2</td>
<td>.923</td>
</tr>
<tr>
<td>3. Electric Railway and Associated Uses</td>
<td>7.2</td>
<td>3.240</td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Aluminum</td>
<td>29.4</td>
<td>3.540</td>
</tr>
<tr>
<td>2. Iron and Steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i Integrated</td>
<td>2.1</td>
<td>.480</td>
</tr>
<tr>
<td>ii Electric Furnace</td>
<td>.011</td>
<td>.0016</td>
</tr>
<tr>
<td>3. Pulp, Paper and Cardboard</td>
<td>.471</td>
<td>.0566</td>
</tr>
<tr>
<td>4. Synthetic Rubber</td>
<td>.360</td>
<td>.057</td>
</tr>
<tr>
<td>5. Nitrogenous Fertilizer</td>
<td>.7</td>
<td>.088</td>
</tr>
<tr>
<td>6. Agricultural Machinery</td>
<td>2.86</td>
<td>.130</td>
</tr>
<tr>
<td>7. Metal Fabrication and Custom Machinery</td>
<td>2.0</td>
<td>910</td>
</tr>
<tr>
<td>8. Cement</td>
<td>.525</td>
<td>.086</td>
</tr>
<tr>
<td>Line Loss and Station Consumption</td>
<td>14.0</td>
<td>2.460</td>
</tr>
<tr>
<td>Total Installed Capacity Required</td>
<td></td>
<td>12.9122</td>
</tr>
<tr>
<td>Total Installed Capacity--Central Siberia</td>
<td></td>
<td>24.6</td>
</tr>
<tr>
<td>Percent of Capacity Accounted For</td>
<td></td>
<td>52.4</td>
</tr>
</tbody>
</table>

a. All figures have been derived from calculations in Appendix B.
nection between the Central Siberian-Ural grid, which certainly is viewed as a forerunner to an EHV intertie which will permit the transfer of large blocks of power from Central Siberia to European Russia.78

Insofar as costs are concerned, preliminary estimates indicate that blocks of power from Siberia can be transferred to the Urals via an EHV DC line giving a market prime cost of .3 kopeks per KWH, of which half is made up by actual cost of transmission.79 This is certainly lower than the average prime cost of electricity in the Urals region, (to be discussed in Chapter V). While the actual cost of the line itself has been estimated at 127 M. rubles,80 it has been indicated that a transfer of 10-15 BKWH annually to the Urals would result in an annual saving of some 15-20 M. rubles through reduced fuel consumption by thermal plants.81 On the basis of this estimated saving, total expenditure on the line would be amortized in less than 10 years.

In view of the technical feasibility, economic incentive, and of importance, the political gain to be derived from the final completion of the "All-Union grid" over which so much publicity has been evinced, it appears that the interconnection with the Unified European Power Network is not so much a question of if, but rather when. A surplus of electric power in 1970, as Table XV indicates, could very well be the deciding factor.
Although the "economically accessible" hydro resources are considerably less than the Soviet figures for "gross" and "technically exploitable," Central Siberia still has considerable hydro potential, perhaps more than will ever be harnessed. While the motive behind development has been economic, Central Siberia has not realized as yet the full benefit of the large scale projects thus far undertaken. At present, the region is not characterized by low cost electricity, though a decreasing average cost can be expected during the next few years as the recent projects come into full operation. The demand for electricity currently is not characterized by any particular industry or sector. In the future, aluminum production will constitute an important share of total demand for electricity in this region. The concept that Central Siberia is currently a region of surplus electric power has been shown to be without foundation, yet it is entirely possible that such will be the case in 1970. In this event an intertie with European Russia can be expected.
REFERENCES: CHAPTER IV

1. While this chapter is concerned primarily with a region delimited on the basis of the existing grid system, much of the data used is ascribed to the East and West Siberian economic regions, the mutual boundary of which cuts through the grid just east of the Kuznetsk Basin. However, this does not constitute the handicap that might be expected, since for both regions about 90 percent of total installed capacity is embodied by the grid system; Elektrifikatsiya SSSR, 1:8,000,000, (Electrification of the U.S.S.R.), Glavnoye Upravleniye Godezii i Kartografii, Gosudarstvennogo Geologicheskogo Komiteta SSSR, Moskva, 1963. While prior to 1962 two thermal plants at Tyumen and Kurgan (part of the Urals grid system) were included in the West Siberian economic region, these, like the several isolated stations, particularly in the Trans-Baykal zone (Chita, Nerchinsk, Borzya), are of small capacity and therefore do not negate any generalization based on regional statistical data and applied to the Central Siberian grid system; Narodnoye Khozyaystvo RSFSR v 1962 Godu, Statisticheskii Ezhegodnik, Statistical Yearbook, Tsentral'noye Statisticheskoye Upravleniye pri Sovete Ministrov RSFSR, Moskva, 1963, p. 28.) The Ust-Kamenorgorsk industrial area, as pointed out in the opening chapter is not included in the Central Siberian regional grid, since no intertie exists at present, nor is one planned.


4. Ibid., p. 61.

5. From discussion concerning concept of hydro potential in Chapter II.

6. Three very small dams have been constructed or are being constructed under permafrost conditions, Irelyakhskaya, Mamakan, and Vilyuyskaya projects, Large Dams of the U.S.S.R., A Translation Prepared by the National Science Foundation, U.S. Government Printing Office, Washington, D.C., 1963, p. XVI.

8. Clearly, the storage capacity would have to be considerable if two months' discharge was to be used throughout the year.


10. Fantastic Power from Siberia, loc. cit.

11. There are three potential sites, Osinovsk, Nizhnetungsk and Igarsk, none of which are considered to fall into the category of "economically accessible" hydro potential. For location of sites see, A.I. Zubkov, Osobennosti Razmeshcheniya Promyshlennosti RSFSR, (Distributional Features of Industry in R.S.F.S.R.), Izdatel'stvo Sovetskaya Rossiya, Moskva, 1964, p. 52.


13. For example, the Vilyuyskaya station and the Mamakan plant (64,000 KW) on the Vitim River. Data on the Mamakan station, Large Dams of the U.S.S.R., op. cit., p. XVI.


15. Ibid., p. 30.

16. Calculation from data in Table VIII.

17. It would not be possible now to accept Hardt's earlier conclusion that the movement into the eastern regions was largely the result of non-economic factors. See, J.P. Hardt, Economics of the Soviet Electric Power Industry, PhD. Thesis, Cornell University, 1955, Microfilm, p. 343.


28. The following Table while somewhat theoretical does, nevertheless, reveal the expected higher rate of return per unit of investment in hydro stations in the eastern regions.

<table>
<thead>
<tr>
<th>Region</th>
<th>River System</th>
<th>Capital Expenditure for 1 KWH of electric energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. Siberia</td>
<td>Angara-Yenisey</td>
<td>100</td>
</tr>
<tr>
<td>W. Siberia</td>
<td>Verkhnye-Irtysh</td>
<td>140</td>
</tr>
<tr>
<td>Volga</td>
<td>Volga</td>
<td>220</td>
</tr>
<tr>
<td>South</td>
<td>Dnieper</td>
<td>370</td>
</tr>
<tr>
<td>Ural</td>
<td>Kama</td>
<td>250</td>
</tr>
<tr>
<td>Northwest</td>
<td>Leningrad</td>
<td>400</td>
</tr>
<tr>
<td>Center</td>
<td>Center</td>
<td>450</td>
</tr>
</tbody>
</table>


30. Ministerstvo Elektrostantsii SSSR, Energeticheskoye Stroitel'stvo SSSR za 40 Let (1917-1957), (Energy Construction in the U.S.S.R. over 40 Years [1917-1957]), Gosudarstvennoye Energeticheskoye Izdatel'stvo, Moskva, 1958, p. 49. Amount of power transmitted to Bratsk, however, not as great as might be expected; 60,000 KWH (220 KV line) x 8760 x .3 (load factor) approximately
160 MKW annually. Method from G. Nash, B.C. Hydro and Power Authority, Vancouver, B.C.; 220 KV line equivalent assumed since 500 KV line actually constructed was not operating at full capacity.


33. S.S. Agalskov, Plotina Krasnoyarskoi Gidroelektrostantsii, (Krasnoyarsk Hydroelectric Station Dam), Gidrotekhnicheskoye Stroitel'stvo, April 1964, p. 16.

34. For data on Ust-Ilim see, Khronika Stroitel'stvo i Ekspлуatatsii, (Construction and Operating News), Gidrotekhnicheskoye Stroitel'stvo, June 1963, p. 41; and for Sayan, G.A. Pretvo, Plotina Sayano-Shushenskoi Gidroelektrostantsii po R. Enisey, (Dam of the Sayan Hydroelectric Station on the R. Yenisey), Gidrotekhnicheskoye Stroitel'stvo, April 1964, pp. 10-4.

35. In spite of a heated controversy, the State Production Committee on Energy and Electrification has refused to build a railroad from Bratsk to the site, although a road and 220 KV line have apparently now been completed. See Navigation Over Dangerous Angara Rapids, (unsigned), Sovetskaya Rossiya, July 12, 1963, Translations on U.S.S.R. Electric Power (21076), J.P.R.S., Microfilm, October 1963, Reel #2, p. 9.

36. See for example, Stroitel'naya Gazeta, January 5, 1964, p. 4.


38. One other recent development which suggests that work at another site in the region could be started in the near future, is the construction of the Reshoty-Boguchany railroad, little publicized but now at least half completed. It is being built presumably to service a proposed large scale pulp and paper mill at Boguchany, but could conceivably be utilized to provide access to a planned hydro site near this center (Figure 8). To date there has been no mention of any plans along this line, however, since there are comparative economic advantages in hydro construction on the Angara-Yenisey, Boguchany would be the logical next step in harnessing the cascade. Information in, Building the


40. Current capacities of these plants listed in Appendix B.

41. The 6 MKW figure is based on data in Table IX.

42. This relationship should not be confused with the required KW capacity to meet the demand, a consideration of greater importance, see Appendix B.


45. Ibid., p. 18.

46. I.P. Butyagin, op. cit., p. 36.

47. Pravda, loc. cit.

48. The problems as mentioned and the fact that the plant is not yet operating at full capacity, support this estimate.


50. This view is supported by Die Erdölwirtschaft der UdSSR Förderung und Vorkommen, Insbesondere in Siberien, Der Aktuelle Osten: Kommentare und Nachrichten aus Politik, Wirtschaft und Technik der UdSSR und der Satellitenländer, Bonn, No. 43, December 2, 1963, pp. 4-8.


53. Ekonomicheskaya Gazeta, June 20, 1964, p. 64.

54. For an outline see, Akademiya Nauk SSSR, Energetika;
55. It appears that the Sayan station has replaced the Yenisey proposal in the second stage of the plan.


60. It is possible that during the interim before the aluminum plant at Anzeb is complete, as much as 3-5 BKWH annually could be transmitted to the Kuznetsk Basin from Bratsk, (assuming the 500 KV line to be operating at full capacity).


64. Ibid.


66. Ibid.

67. It would be expected that when hydro capacity currently under construction is in operation, average cost will drop markedly.

L. Melent'yev, the author of this article, is a leading Soviet authority on the electric power industry.


70. The load factors for sectors and industries are given in Appendix B.

71. Percentages calculated from data in Table XIV.


73. Assuming about .5 MKW of capacity still to be brought under load at Bratsk, 5 MKW at Krasnoyarsk, 4 MKW at Ust-Ilim, and approximately 1.5 MKW at the thermal plants, Nazarovo, Belovo, and Tom-Usinsk.


75. As pointed out in Appendix B, 65 percent is not an unreasonable assumption for plant factor.


78. *Elektrifikatsiya SSSR*, *loc. cit.*


80. See Akademiya Nauk SSSR, Energetika . . ., *loc. cit.*


REFERENCES: FIGURES

Figure 8. Primary source, *Elektrifikatsiya SSSR*, (1:8,000,000), Glavnoye Upravleniye Geodezii i Kartografii, Gosudarstvenogo Geologicheskogo Komiteta SSSR, Moskva, 1963; additional information drawn from, I.P. Butyagin, *et al.*, *Energetika Sibiri*, (Energy in Siberia), Gosudarstvennoye
Figure 9. Data has been drawn from, Akademiya Nauk SSSR, Geograficheskaya Problemy Razvitiya Krupnikh Ekonomicheskikh Rayonov SSSR, (Geographical Problems in the Development of Large Economic Regions in the U.S.S.R.), Izdatel'stvo Mysl', Moskva, 1964, pp. 86, 140-158.

CHAPTER V

EUROPEAN RUSSIA

It has been shown that the center of gravity of generating capacity has gradually edged eastward, especially that of hydro, a shift which reflects the diminishing European Russian energy resource base. The one feature common to the four regions dealt with in this chapter is dependence to a greater or lesser degree on external sources of energy for the generation of electricity. Yet one must not lose sight of the fact that European Russia, including the Urals, still possesses well over one-half of total installed capacity. Demand has been such, however, that electric power shortages have been noted in many areas recently and doubtless constitute a handicap to industrial production. The planned EHV intertie with Central Siberia is one example of an attempt to overcome this deficiency.

The still growing unified power network is a basic requirement if all areas are to bring supply and demand for electricity into balance. The network as it currently exists (Figure 11) is not entirely a product of the past decade, for it has its roots in the "local" power systems which have been evolving steadily since the early 1930's. That of the Moscow industrial area (Mosenergo) is a case in point.¹ It is the high voltage interties which are of recent origin. By the end of 1965 the unified system is expected to have an aggregate capacity of 53 MKW (excluding the
FIGURE 11 THE REGIONS OF EUROPEAN RUSSIA
In this chapter the major regional grids are examined in terms of distribution and type of generating capacity, function, the principal fuels consumed by thermal plants, and finally costs of electricity. For European Russia as a whole the major consumers of electricity are estimated, (including a brief consideration of external export arrangements and interconnected power systems). The Northwest region has been included since it is to be interconnected this year (1965).

Before the regional analysis, a consideration of the "economically accessible" hydro potential of European Russia will perhaps clarify the contribution that hydro can make toward meeting the ever increasing demand for electric energy. In this discussion the Caucasus has been omitted, since this area is dealt with separately.

**HYDRO POTENTIAL**

The Volga, Kama and Dnieper Rivers (Figure 3), comprise about 80 percent of the Soviet figure for "technically exploitable" hydro potential in European Russia (set down in Table XVI). Only the northern areas, therefore, require consideration. Of the northern streams the Pechora has by far the largest estimated potential capacity (1.6 MW), but is not considered to fall within the bounds of "economically accessible" hydro potential for the following reasons. Firstly, there has been no evidence in the
### TABLE XVI

**TECHNICALLY EXPLOITABLE HYDRO CAPACITY—EUROPEAN RUSSIA**

**BY ECONOMIC REGION*\(^a\)**

<table>
<thead>
<tr>
<th>Economic Region</th>
<th>Potential Capacity MKW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center</td>
<td>1.71</td>
</tr>
<tr>
<td>Povolzhe</td>
<td>4.91</td>
</tr>
<tr>
<td>Urals</td>
<td>2.17</td>
</tr>
<tr>
<td>West</td>
<td>1.14</td>
</tr>
<tr>
<td>South</td>
<td>2.17</td>
</tr>
<tr>
<td>Northwest (and North)</td>
<td>5.25</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17.35</strong></td>
</tr>
</tbody>
</table>

---

recent technical literature of a desire to tap the hydro potential here; it is mentioned in the context of the long discussed diversion of the Pechora and Vychegda Rivers (Figure 3) into the upper reaches of the Kama. The purpose of this is to improve navigation on the Volga-Kama system and perhaps most important, to offset the falling level of the Caspian Sea. As yet nothing concrete has been done. Secondly, there are coal and possibly gas deposits in the northern areas of European Russia which could provide alternative sources of electric power should additional be required. While precise data on other northerly streams such as the Northern Dvina and its tributary the Sukhona, is not available, one source giving relative capacity at prospective dam sites indicates they are of minor importance. On the basis of this information the figure for current "economically accessible" hydro potential has been estimated at 16 Mkw. The significant aspect of this consideration of hydro potential is to what extent it is currently being utilized.

It has been estimated, as late as 1960, that European Russia excluding the Northwest and Caucasus, was utilizing but 25 percent of the "technically exploitable" hydro resources. Such a statement is indeed misleading. As is often the case it was based on potential annual generation assuming a 100 percent plant factor at proposed sites (see Chapter II). It is the potential installed capacity which is the prime criterion.

Since 1960 two comparatively large stations have come into
full operation, at Kuybyshev (2.3 MKW) and Volgograd (2.5 MKW) and recently the station on the lower Kama (1 MKW) has also come under load, although it is not as yet operating at normal head (see Figure 11). In Table XVII an estimate of current utilization, based on "economically accessible" potential, has been offered. The purpose of the Table is simply to point out that over four-fifths of potential hydro capacity has already been utilized. Insofar as the long run contribution of hydro toward alleviating power shortages is concerned, little can be expected. What is being done in the various regions must now be considered.

THE CENTER-VOLGA REGION

Basically, it is the functional interconnection of the Center and Volga areas which justifies their combination into one region (Figure 11), for more than a third of the 1962 annual generation in the Povolzhye (Volga economic region) was to be transmitted to the Center. The Center is a power deficient area, the EHV interconnection with the Povolzhye being a direct reflection of this fact. In terms of electricity supply it is expected that by the end of 1965 the Center will have a deficit the equivalent of 0.6 MKW of installed capacity. While in terms of total regional installed capacity this may appear relatively insignificant, it is anticipated that this deficit will double in the next five years. It is apparent that keeping supply abreast of demand is a problem of major proportion, even with an 11 MKW capacity expansion under
TABLE XVII

UTILIZATION OF ECONOMICALLY ACCESSIBLE HYDRO POTENTIAL
EUROPEAN RUSSIA

<table>
<thead>
<tr>
<th>Potential Hydro Capacity</th>
<th>16 MKW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible Annual Generation at 50 Percent Plant Factor</td>
<td>$16 \text{ MKW} \times (8760)(.5) = 70.0 \text{ BKWH}$</td>
</tr>
</tbody>
</table>
| Existing Installed Hydro Capacity 1964 | $10.3 \text{ MKWC}$
| (3.6 MKW currently under construction) | |
| Estimated Generation from Existing Capacity | $10.3 \text{ MKW} \times (8760)(.5) = 45.1 \text{ BKWH}$ |
| Including Capacity Under Construction | $3.6 \text{ MKW} \times (8760)(.5) = 15.7 \text{ BKWH}$ |
| Estimated Percent Utilization of Economically Accessible Hydro Resources (including capacity under construction) | 86% |

a. Derivation of figure in the foregoing text.

b. Based on an average plant factor for 1962 of 4,314 hours per annum, Narodnoye Khozyaystvo SSSR v 1962 Godu, Statisticheskii Ezhegodnik, (Statistical Yearbook), Moskva, 1963, p. 162. (8760—total number of hours per year).

the Seven Year Plan. What is being done to meet this problem is outlined in the ensuing discussion.

It is evident from Figure 5 that the Center-Volga region, together with the Urals and South (Donbass), constitute the three major concentrations of currently operating capacity. Although data on installed capacity is not available at this level, figures for total generation by economic region are, therefore estimates of regional installed capacity may be derived. Such calculations have been carried out in Appendix C, with the results summarized in the following Table.

Although hydro capacity comprises a comparatively large share of the regional total (Table XVIII), the lower average plant factor compared to thermal stations decreases its share of total annual generation of electricity. The hydro plants on the Volga nevertheless play a focal role in the whole Unified European Power Network, meeting a large part of the peak demand as mentioned earlier. The stations at Kuybyshev and Volgograd, for example, were designed at the outset to provide peaking power for the Moscow industrial area during the late summer and winter months particularly. The intertie by 500 KV line of Kuybyshev to Moscow and to Chelyabinsk in the Urals, and of Volgograd with Moscow and by 800 DC line to the Donbass, were certainly basic requirements for such a role, (Figure 11). Over 14 of the 20 BKWH plus combined annual generation of the two plants is scheduled to be transmitted to the Moscow area, the largest part of the balance
### TABLE XVIII

**ESTIMATES OF REGIONAL INSTALLED CAPACITY BY TYPE**

**EUROPEAN RUSSIA 1962**

<table>
<thead>
<tr>
<th>Region</th>
<th>Hydro Capacity MKW</th>
<th>Thermal Capacity MKW</th>
<th>Total Installed Capacity MKW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center-Volga</td>
<td>4.9</td>
<td>11.3</td>
<td>16.2</td>
</tr>
<tr>
<td>Ural</td>
<td>0.753</td>
<td>11.0</td>
<td>11.753</td>
</tr>
<tr>
<td>South</td>
<td>2.7</td>
<td>11.3</td>
<td>14.0</td>
</tr>
<tr>
<td>Northwest</td>
<td>1.0</td>
<td>5.4</td>
<td>6.4</td>
</tr>
<tr>
<td><strong>Total for European Russia</strong></td>
<td></td>
<td></td>
<td><strong>48.353</strong></td>
</tr>
</tbody>
</table>

*a. All figures have been derived from calculations in Appendix C.*
being split between the Urals and the Donbass.\textsuperscript{15}

This role permits the thermal capacity to operate closer to the optimum plant factor, thus achieving greater economy in operation. Indeed, as a result of the interconnection of the Center with Kuybyshev alone, annual generation has been increased 150 MKWH, and an annual saving on fuel requirements has been estimated at .507 M. rubles, almost one-quarter the total expenditure on the intertie.\textsuperscript{16} The focus on the Moscow area has been largely an attempt to offset the expected .6 MKW capacity deficit in 1965. However, if the tenor of the complaints in the press are any indication, it has been far from successful.\textsuperscript{17}

In view of the current construction at Saratov, Cheboksary and the Lower Kama (3.4 MKW combined capacity, Figure 11), it is likely that hydro will maintain its relative share of regional capacity for the next few years. With the completion of these stations the hydro resources in the region will be near full utilization, therefore in the long run the share must decrease relatively.

With respect to thermal plants, almost two-thirds of the 11.3 MKW capacity is made up by heat and power stations (TETS).\textsuperscript{18} As the steam by-product is used extensively for domestic heating the greatest concentration is in the Moscow urban area. This share is likely to decrease relatively in the near future, as several large condensation plants come into operation. Konakowo, a projected 2.4 MKW capacity now under construction northwest of
Moscow, is the largest. This station alone comprises a fifth of the planned 11 MKW capacity expansion for this region during the Seven Year Plan and moreover, in terms of using gas as fuel typifies a recent trend in the region. As in the case of Central Siberia, these large scale plants do not represent the greatest share of regional thermal capacity.

As late as 1958 coal and peat comprised about three-quarters of the fuel consumed by power stations (in terms of conventional fuel equivalent), a reflection of the government policy of utilizing local fuel resources. With the recent construction of pipelines to the Center (Figure 11) the relative share of natural gas is to increase somewhat, primarily at the expense of peat. There had been an earlier, less publicized increase in the use of gas for by 1958 its share had more than doubled that of 1951. Compared with local coal and peat as fuel, the selling price of gas is approximately 50 percent less (in terms of conventional fuel equivalent, see Table XX). This is because of the lower calorific value of Moscow brown coal, and peat. Yet whether gas will increase its share beyond that indicated in the following Table is debatable, since industrial consumers as well as the domestic market constitute an important growing demand. In determining the best alternative use, fuel for power stations could easily come out second best. This is elaborated on shortly. At present it is used as fuel primarily during the summer months, when industrial and domestic heating demands are at a minimum.
<table>
<thead>
<tr>
<th>Fuel</th>
<th>1958 Percent</th>
<th>1965 (Planned) Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>57</td>
<td>53</td>
</tr>
<tr>
<td>Donetsk Basin</td>
<td>24</td>
<td>32.3</td>
</tr>
<tr>
<td>Moscow Basin</td>
<td>26.5</td>
<td>15.2</td>
</tr>
<tr>
<td>Others</td>
<td>6.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Peat</td>
<td>16.5</td>
<td>8.4</td>
</tr>
<tr>
<td>Oil</td>
<td>4.6</td>
<td>14.5</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>15.4</td>
<td>21.0</td>
</tr>
</tbody>
</table>

It is interesting to note that coal from the Donetsk basin is scheduled for greater use in the Center, while local coals will decline (Table XIX). The reasons for this situation were outlined in the foregoing discussion of the Cherepets thermal plant (Chapter IV). Some criticism has been voiced over the fact that coal is still being imported from such remote deposits as the Kuzbass and Karaganda and burned as fuel in the Volga zone. As a result greater emphasis is being placed on using residual oils as fuel for power plants in this area.

Considerable intra-regional variations exist in prime cost of electricity which, in view of the concentration of hydro capacity in the Volga area and in light of the method by which prime cost of hydro is derived, are to be expected. The average prime cost at site in the Povolzhye economic region, where hydro constitutes over half the installed capacity, is from .3-.4 kopeks per KWH, about one-half the national average (.7 kopeks per KWH), while in the Center where peat and coal fired thermal plants still predominate, it is closer to .9 kopeks per KWH, slightly above the national average. The extent to which hydro can affect the regional average prime cost is revealed in part by the delivered cost of electricity at Moscow from the Kuybyshev station—.17 kopeks per KWH (which line loss accounts for .074 kopeks per KWH). This is down somewhat from an earlier estimate of .29 kopeks per KWH. The increased emphasis on large scale thermal plant construction in both the Center and Povolzhye,
together with hydro meeting part of peak demand, facilitated by increasingly ramified EHV interties, should have the long run result of diminishing this range of prime cost variation.

THE URAL REGION

This region, like the foregoing, has been a net importer of energy in one form or another for at least the past two decades, but imports of large blocks of electric power have only taken place subsequent to the completion of the Kuybyshev-Chelyabinsk 500 KV intertie. The regional grid is composed of five power systems which radiate from the major urban centers, interconnected by either 220-330 or 500 KV lines (Figure 11). Additional interconnection with hydro stations has been effected with a 500 KV line linking up the Votkinsk (1 MKW) and perhaps eventually the Lower Kama (1.4 MKW). Such an intensive internal interconnection clearly makes for a highly functional regional unit.

While no specific statistic has been uncovered, it would be a safe estimate that an electricity shortage equivalent to that in the Center exists in the Ural region. Thus far there is no indication that the objective of 9 MKW of capacity to be installed during the Seven Year Plan has been attained. Even if it has, supply still has not kept pace with demand as there have been reports of power shortages as late as summer, 1964. During recent years several suggestions as to how this seemingly perennial situation might be improved have been put forward, and
these will be examined in the ensuing discussion.

It is apparent from Table XVIII that the absolute share of hydro capacity is by no means comparable with that of the Center-Volga, but it would be incorrect to assume that within the Ural region hydroelectricity is of little importance. The import of hydro power during the first nine months of 1962 resulted in a saving of 52,000 tons of fuel in the Sverdlovsk power system alone.\(^{36}\) In a region where less than one-half of fuel requirements are satiated by local resources, such savings are significant.

One suggested alleviant to the electricity shortage is the Lower Ob hydro scheme. The preliminary estimate of prime cost of power at site from a 6 MKW capacity plant is 0.03 kopeks per KWH which, according to its proponents, is low enough to give a competitive market price in the Urals after transfer costs.\(^{37}\) As has been stressed, the "economically accessible" hydro resources in European Russia are nearing complete utilization, but this scheme cannot be regarded as the next logical step. Interconnection of the Urals with Central Siberia, where in 1970 there could conceivably be a "surplus" of electricity equivalent to the potential annual generation from the station, is one of two far likelier alternatives. The second is increased emphasis on construction of large scale thermal plants fired by imported fuels.

Condensation electric plants (KES) comprise over half of the 11 MKW thermal capacity, a two-fold increase relatively over
their share in the Center-Volga region.\textsuperscript{38} This is indicative of the high degree of industrialization in the Urals and the consequent demand for power. Construction of several new condensation plants in the 1-2 MKW capacity range has started recently. The Iriklinskaya station near Orsk in the Southern Urals is typical of the new developments (Figure 11).\textsuperscript{39} It has a planned capacity of 1.8 MKW (.15 MKW turbines), and will operate on both natural gas from Bukhara and oil residuals from the refinery at Omsk. This station exemplifies the necessary trend toward using imported fuels (in 1955 only about one-half of total fuel consumption in the Urals was supplied by local resources).\textsuperscript{40}

There is at least one atomic power plant in the Urals (near Sverdlovsk) as there is in the Center (the first at Obninsk, west of Moscow, another at Voronezh).\textsuperscript{41} Being located in regions of high cost electricity and situated near load centers helps in part to offset their higher cost of electricity mentioned in Chapter I. Since there have not been any definite plans for expansion, atomic power plants will remain at least in the near future, unimportant in terms of total regional capacity.\textsuperscript{42}

According to the Seven Year Plan gas is to increase from 8 to 32 percent of the fuel consumed by thermal plants.\textsuperscript{43} Gas is currently being piped to the Urals from Bukhara and construction is underway on the pipeline from the field in the Berezovo area.\textsuperscript{44} Both these lines are to extend to Sverdlovsk. This increase is primarily at the expense of imported coal, which is scheduled to
to drop to 14 percent from a high in 1958 of 34.5 percent of all fuel consumed at power stations. Oil and locally mined coal will maintain the same relative share.

The regional average prime cost has been estimated at .8 kopeks per KWH (1958), just under the national average at that time. With the trend toward large scale thermal plants, it is conceivable that it has been reduced. This would be a minor reduction since it must be remembered that the bulk of the power is still generated from a multitude of small scale thermal plants. Currently, the lowest at site prime cost of electricity is about .23 kopeks per KWH. This will alter slightly when the recently completed Votkinsk hydro station comes into full operation, (estimated prime cost of power .18 kopeks per KWH).

THE SOUTH REGION

This region now includes the North Caucasus and Moldavian power systems as both were recently interconnected with the extensive network of the South Ukraine. Neither of these new additions, however, contributed very much in terms of installed capacity (approximately 3 MKW). The grid evolved from the 110 KV line interconnection between the Dneproges hydro station and the Donbass industrial belt in the early 1930's and as Figure 11 clearly indicates is at present widely ramified. The Donbass is now linked by 800 DC line with the Volgograd hydro station. This line was designed at the outset to test the technical
feasibility of EHV long distance transmission of electric power from Siberia to European Russia.

The South regional grid, unlike those previously dealt with, has apparently not been afflicted with serious electric power shortages.\textsuperscript{52} This is perhaps due to the comparatively early emphasis placed on building large scale thermal plants. Six, each with a capacity greater than 1 MKW, are currently operating in the region (see Figure 11). Under the Seven Year Plan a further 10 MKW capacity expansion is scheduled.\textsuperscript{53}

Aside from the Dneproges hydro station, constructed under the original GOELRO plan (1932), little publicity has been accorded hydro development in this region, which simply reflects the minor importance of the South's hydro potential.\textsuperscript{54} With the completion of the station at Kiev nearly all potential will be utilized. The majority of the plants are of comparatively small scale and as characteristic of hydro plants in European Russia, were designed to meet peak load.\textsuperscript{55}

With regard to thermal capacity, the large share of condensation plants (KES), 60 percent of total thermal capacity, again reflects the high degree of industrialization, particularly in the Donbass.\textsuperscript{56} In contrast to the Ural and Center-Volga regions, however, the larger thermal plants are oriented not toward gas as fuel, but coal. This is despite the fact that a major gas field at Shebelinka is close to the Donetsk basin, the greatest concentration of installed capacity, and that the pipeline from
Stavropol (situated in the Caucasian foreland) to Moscow, passes through the same area (Figure 11). This clearly indicates that gas has better alternative uses than to be consumed as fuel; to satisfy part of the demand of the energy deficient Center and increasingly, as a raw material for industry.

Typical of the larger thermal stations fired by coal is Starobeshevo (1.1 MKW) a condensation plant southeast of the city of Donetsk. Here local coal is consumed at a cost of 8.4 rubles per ton at plant, at least three times as expensive as gas or oil residuals from the Volga fields (in terms of conventional fuel equivalent, and taking into account cost of transport), but which still permits generation of electricity between .4-.5 kopeks per KWH at site, a comparatively low cost.

The rather minor role of gas as fuel in this region is indeed interesting in light of existing, proximate reserves. The use of coal and coal fines particularly as fuel, is a logical means of consuming what might otherwise be waste. According to one source, coal will constitute over 80 percent of all fuel consumed by thermal plants, and gas but 11 percent (conventional fuel equivalent) in 1965. Oil and peat will play a very minor role on the average, (within the region there are variations, for example, oil residuals are of greater importance locally in the Caucasian foreland).

In the generation of thermal electricity, obviously a number of different fuels may be used. In Table XX both the cost
TABLE XX

PRIME COST AND SELLING PRICE OF SELECTED FUELS 1958a, b
(EUROPEAN RUSSIA AND IMPORTED)c

<table>
<thead>
<tr>
<th>Region</th>
<th>Cost</th>
<th>Selling Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per Actual Ton Produced</td>
<td>Conventional Fuel Equivalent</td>
</tr>
<tr>
<td>Center-Volga</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moscow Basin Coal</td>
<td>6.7</td>
<td>17.3</td>
</tr>
<tr>
<td>Ural</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chelyabinsk Coal</td>
<td>4.7</td>
<td>9.1</td>
</tr>
<tr>
<td>Kizel Coal</td>
<td>8.8</td>
<td>11.4</td>
</tr>
<tr>
<td>South</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Donetsk Anthracite</td>
<td>8.1</td>
<td>8.9</td>
</tr>
<tr>
<td>Ukrainian Gas</td>
<td>.58</td>
<td>.48</td>
</tr>
<tr>
<td>(East and West Fields)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stavropol Gas</td>
<td>1.08</td>
<td>.90</td>
</tr>
<tr>
<td>(Caucasus Foreland)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imported</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vorkuta (Northwest European Russia)</td>
<td>10.6</td>
<td>11.9</td>
</tr>
<tr>
<td>Karaganda Coal</td>
<td>5.1</td>
<td>6.9</td>
</tr>
<tr>
<td>Kuznetsk Coal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shaft Mined</td>
<td>5.7</td>
<td>6.1</td>
</tr>
<tr>
<td>Open Pit</td>
<td>2.8</td>
<td>3.4</td>
</tr>
</tbody>
</table>

a. Price of gas as fuel not as raw material for industry.


c. Regions are as delimited in this study; principal fuels being currently imported.
and selling price of those fuels commonly consumed in European Russia (excluding peat) are outlined. In terms of production costs gas was the least expensive of fuels in European Russia. But even with the 2 rubles per 1,000 cubic meter standard price reduction to thermal stations, it constitutes an expensive fuel. The small share of gas in the South's regional fuel balance clearly indicates that the consideration of alternative use was, and remains, of importance in Soviet decision making, and logically so. While it is a fact that fuel constitutes over half the operating expenses of a thermal station, it is also true that with regard to the capacity of thermal stations, within limits, increasing returns to scale are in effect. It would appear that in the Ukraine especially this latter fact, combined with utilization of a potentially waste energy resource, is being effectively implemented. While current cost figures are not available the very fact that new thermal plants are not fueled by gas would imply that a similar price differential still exists for gas from the Ukraine and Caucasian foreland (Stavropol). This conclusion is supported by the fact that the gas reserves in this region are being rapidly depleted. The new Bukhara-Urals pipeline to the southern Urals probably supplies gas at a lower price, since it is being promoted as a fuel for the Southern Ural plants, but here a different situation exists as there are no alternative economic sources of electricity.

The average prime cost of electricity from those plants in
the Donbass-Dnieper bend region (the area of greatest concentration of generating capacity as shown on Figure 11) was in 1958, slightly under the national average. In view of subsequent construction of large scale thermal plants, the current average prime cost is estimated to be .5 kopeks per KWH. With regard to the peripheral regions of the grid, the prime cost is higher, particularly in the recently integrated Moldavian system where small scale plants (less than .5 MKW) predominate.

THE NORTHWEST REGION

In comparison with the foregoing regions, the Northwest is less important, both with regard to existing installed capacity and potential expansion. Most of the area covered by the grid is indeed marginal in relation to the overall national economy. The nucleus of the grid centers around the Leningrad industrial area, the balance of the power systems, as Figure 12 indicates, being rather weakly interconnected (usually 220-330 KV, but sometimes as low as 110 KV). The transfer of large blocks of electric power, common in other regions, is here absent. Yet the Northwest with the construction of several hydro plants on the Svir River system, was one of the first areas to feel the impact of the early Soviet concern over electrification. Several projects are now underway or planned that will bring at least the Leningrad area abreast of current developments in the electricity industry characteristic of other regions in the country. One of these is
FIGURE 12 THE NORTHWEST REGION AND EAST EUROPEAN GRID
the 330 KV, (possibly 500 KV), intertie between Kalinin (north-west of Moscow) and Leningrad, to be completed by the end of 1965.64

In view of the areal extent of the grid, it is not surprising that hydro is of comparatively little importance (less than 20 percent of total capacity, Table XVIII). To be certain, the hydro resources of the Baltic States and Byelorussia are minimal, but this fact is brought out even more since the North-west regional grid excludes the Murmansk area for which no intertie is planned, (to be discussed in the following chapter on Peripheral Regional Grids).65 Once again new hydro plants are to be used for peaking purposes. The planned Plyavinskaya station (.825 MKW) on the Western Dvina in Latvia is scheduled to fulfill this role for the whole Northwest grid.66 Indeed, this plant appears to be a good example of "over-machining" a stream since one source indicates that the hydro potential of the Western Dvina is less than the capacity being installed. As is pointed out in Chapter II, proximity to load center and costs of fuel are important factors behind the decision to build such a plant. Within the region, the majority of stations are of small capacity, less than .1 MKW.67

Condensation stations, (KES), have in the past (1958) comprised the same share of thermal capacity as the heat and power plants (TETS), however, in the Leningrad area the latter is scheduled for more rapid growth and by 1965 is expected to consti-
tute one-half of total thermal capacity. A similar trend for the rest of the region can be expected.

Traditionally, peat and oil shale have played a major role in meeting the fuel requirements of thermal stations. In Byelorussia for example, peat is scheduled to meet a third of the fuel requirements for the Republic's thermal plants (1965). In the Leningrad area, peat-fired thermal plants are by no means uncommon, even with the increased use of gas as fuel. Coal as a fuel, (coming principally from the Pechora basin), is generally replaced by oil shale as one moves farther south into the Baltic States.

The utilization of local energy resources as fuel for thermal plants is quite logically given priority, for transfer costs on Pechora coal, and gas would be high and as mentioned earlier, there are doubtless far better alternative uses. Indicative of this is the renewed construction on the Narva plant (now 0.8 MKW, planned 1.6 MKW) in Estonia, fueled by locally mined shale, but which still generates comparatively low cost electricity (.56 kopeks per KWH).

In a region characterized by small scale thermal plants (less than 0.5 MKW) and fired by comparatively expensive fuels, (i.e. peat and imported coal), it is little wonder that the average prime cost of electricity (1.1-1.5 kopeks per KWH) is above the national average (.7 kopeks per KWH). As indicated fuel costs are a major factor, and even with a growing trend to-
ward large scale plants and the scheduled intertie with the Center-Volga grid, the Northwest will remain a region of comparatively high cost electricity.

THE MARKET FOR ELECTRICITY IN EUROPEAN RUSSIA

It is evident from the foregoing discussion that in some areas of European Russia, the expansion of generating capacity is not keeping pace with demand. The evolution of a unified power system has in large part been justified as being an important step toward equating supply and demand. It is necessary now to examine the demand for electricity. The principal consumers of electricity have been estimated in Appendix B, (Part 3), and are listed in Table XXI.

Just under one-half of the total installed capacity (48 MKW) of European Russia is required to meet the demand of non-productive activities; domestic and communal economy, electric railways and associated uses, line loss and station consumption. This importance as consumers is due to comparatively low load factors. For example, in 1962 12 percent of total generation was consumed by the domestic sector, but to meet this demand entailed using almost one-fifth of the installed capacity. Since the largest urban population is concentrated in the Center-Volga region, one can understand the urgency of the requests for domestic consumers, particularly in Moscow, to avoid "wasting" electricity. In this region the domestic sector requires a higher percent of regional
TABLE XXI

ESTIMATED CONSUMPTION OF ELECTRIC POWER—EUROPEAN RUSSIA* 1962

<table>
<thead>
<tr>
<th>Sector</th>
<th>KWH Consumed Annually (BKWH)</th>
<th>Required KW Capacity to Meet Demand (MKW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Domestic and Communal Economy</td>
<td>31.5</td>
<td>9.0</td>
</tr>
<tr>
<td>2. Agricultural Economy</td>
<td>7.8</td>
<td>6.0</td>
</tr>
<tr>
<td>3. Electric Railway and Associated Uses</td>
<td>15.7</td>
<td>7.1</td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Aluminum</td>
<td>11.4</td>
<td>1.37</td>
</tr>
<tr>
<td>2. Iron and Steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i Integrated</td>
<td>13.7</td>
<td>3.1</td>
</tr>
<tr>
<td>ii Electric Furnace</td>
<td>1.9</td>
<td>.27</td>
</tr>
<tr>
<td>3. Pulp</td>
<td>1.1</td>
<td>.148</td>
</tr>
<tr>
<td>4. Synthetic Rubber</td>
<td>1.39</td>
<td>.213</td>
</tr>
<tr>
<td>5. Nitrogenous Fertilizer</td>
<td>7.0</td>
<td>.9</td>
</tr>
<tr>
<td>6. Cement</td>
<td>1.155</td>
<td>.188</td>
</tr>
</tbody>
</table>

Line Loss and Station Consumption 31.5 5.5

Total Installed Capacity Required 33.789
Total Installed Capacity—European Russia 48.35
Percent of Capacity Accounted For 69.0

a. All figures derived from calculations in Appendix B.
installed capacity than the average for European Russia, about one-quarter of the 16 Mkw installed capacity. 75

Of the industrial consumers dealt with, the integrated iron and steel industry demands the greatest installed capacity. However, in comparison with the smelting of non-ferrous metals it is of less importance, (as mentioned, production data is not available). One or two industrial consumers tend to characterize the demand for electricity in certain of the regions. In the Urals production of aluminum alone requires 10 percent of installed capacity. This demand coupled with the requirements of integrated iron and steel, and nitrate fertilizer production, accounts for almost a third of the estimated regional capacity.

The location of "electricity intensive" industry in the next few years would logically be decided on the basis of availability of electric power. In this case European Russia, even with the advantage of market accessibility, could very well be second choice in comparison with a region such as the Kuznetsk basin wherein the possibility of surplus electricity exists.

While the export of electricity may seemingly appear incongruous in view of the foregoing, it is in fact being actively promoted, particularly with respect to the East European countries. 76 As emphasized, while European Russia generally is an electric power deficient area, there are variations within, from a serious shortage (Center) to apparent sufficiency (South). It is with the latter that the most significant interties and exports will be
The export of electricity is of minor importance in relation to total Soviet annual generation, but is scheduled to increase during the next few years. Since 1961 when electricity exports were split between Finland and Poland, an interconnection with Hungary has altered the pattern of export. In 1962 Hungary accounted for 171 of the 203 MKWH exported from the Soviet Union. Poland maintained the same position, whereas Finland did not import any electricity during this year.

There has emerged in Eastern Europe a unified power network with an aggregate capacity of 19 MKW in 1961. The current areal extent of the network is depicted on Figure 12. Development of this system is under the general guidance of the CMEA (Council of Mutual Economic Aid), and is viewed as an important step in furthering cooperation between the member countries and the Soviet Union.

Within East Europe the primary function of the grid is the same as that of the unified system of European Russia; to bring about a semblance of balance between supply and demand for electricity.

The interconnection with the Soviet Union is of varying importance to the member countries. Imported electricity amounted to less than 1 percent of total consumption in East Germany, Poland, and Czechoslovakia during 1962. Although actual export of electricity to East Europe is scheduled to increase, it is doubtful whether imported power would ever amount to more than 5
percent of consumption in any of the foregoing countries. With regard to Hungary it is of greater significance. One source estimates that as much as 1 BKWH could be imported annually, almost 15 percent of Hungary's 1962 total generation. \(^84\) The grid is shortly to be extended to Bulgaria, where imported electricity would also be of significance. \(^85\) On the other hand, while the export of electricity is planned to increase considerably during the next few years, it is unlikely to be more than 1 percent of total Soviet annual generation at any time. \(^86\)

**SUMMARY**

In European Russia there has been continued emphasis on the utilization of local energy resources for the generation of power. This utilization has not been sufficient to meet demand. Hydro potential is rapidly diminishing and the import of coal, recently gas, and to a lesser extent the import of electricity per se, reveal the growing energy demand in European Russia. Thus far, the Urals and Center-Volga have experienced the most serious power shortages, due primarily to the high degree of industrialization and heavy concentration of urban population respectively. The South in contrast appears not to be in quite the same situation, the result both of its broader energy resource base and a more diversified demand. Other than the high cost of electricity, the electric power
industry in the Northwest region lacks any distinguishing feature and will remain of peripheral importance.

What effect the inadequate European energy supply will have on the existing spatial pattern of production and consumption of electricity is uncertain, but clearly regions like Central Siberia are assuming greater significance, either in terms of possible location for new "electricity intensive" industry or as a source of electric power. Of the possible effectiveness of an EHV intertie with Central Siberia more will be said later. Regarding the export of electricity, it is and will continue to be of varying importance to the member countries of the East European grid, but in relation to total Soviet generation will remain inconsequential.
REFERENCES: CHAPTER V


3. See following section of Northwest region.


8. Data on prospective dam sites from map in S.F. Shershov, Bely Ugol, (White Coal), Gosenergoizdat, Moskva, 1957, pp. 82-3.


10. The Center region for the most part delimits the Moscow industrial zone. The areal extent of the regions used in this chapter is discussed in Appendix C.


13. For calculations see Appendix C.

15. Data on amount of power to be transmitted from V.I. Popkov, EES; Rasskaz o Edinoi Energeticheskoj Sisteme SSSR, (E.E.S.; Development of a Single Energy System in the U.S.S.R.), Molodaya Gvardiya, Moskva, 1961, p. 32; since the line to the Donbass has just recently been put into operation, little power was actually transmitted to this area. For additional information regarding the role of the Volga area within the European grid, see Referativnyi Zhurnal: Elektrotekhnika i Energetika #E. Elektricheskiye Stantsii, Seti i Sistemi, Akademiya Nauk SSSR, May 1964, (5 E163), p. 24.

16. Elektricheskiye Stantsii, February 1964, p. 34.


18. A discussion of the function of TETS plants can be found in Chapter III, data on share from Elektricheskiye Stantsii, November 1963; p. 47, and D.G. Zhimerin, op. cit., p. 399.


20. According to Hodgkins, "Conventional Fuel in the Soviet Union is similar to the bituminous equivalents used in publications of the Western world. Simply stated, all energy resources are converted to units of 7,000 calories; this is equal in heating capacity to a kilogram of Kuznetsk bituminous coal." J.A. Hodgkins, Soviet Power: Energy Resources, Production and Potentials, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1961, p. 102, Footnote #1, Table 10.


22. In addition to Table XX see J.A. Hodgkins, op. cit., p. 137.

23. Ibid., p. 136.


30. Data from D.G. Zhimerin, op. cit., p. 371. Cost would be somewhat higher from Volgograd in view of the greater distance.


34. Elektrifikatsiya SSSR, (1:8,000,000), Glavnoye Upravleniye Geodezii i Kartografii, Gosudarstvennogo Geologicheskogo Komiteta SSSR, Moskva, 1963.

35. See Footnote #15; and Ekonomicheskaya Gazeta, June 27, 1964, p. 44, for specific power deficiency in the Urals.


37. Referativny Zhurnal: Geografiya, Akademiya Nauk SSSR, January 1963, p. 4, considerable fuel savings are also indicated.
38. Elektricheskiye Stantsii, November 1963, p. 47, (5.61 MKW installed capacity in condensation plants [KEs]).


41. Location from Elektrifikatsiya SSSR, loc. cit. For a listing of atomic power plants and capacities see, H. Machowski, Die Entwicklung der Electroindustrie in dem Ostblockstaaten, Ost Europa Wirtschaft, April 1963, p. 214. See additionally Footnote #7, Chapter I.

42. H. Machowski, Ibid.


44. Izvestiya, March 15, 1965, p. 4.

45. S.G. Prociuk, op. cit., p. 76.

46. L.A. Melent'ev, loc. cit.


52. The South at least has not been referred to in the recent press reports concerning power shortages, see Footnotes #15, 35.

54. It has recently been announced that the Dneproges plant will be doubled in capacity with the addition of six 125 MW turbines. *Soviet News Bulletin*, Ottawa, February 2, 1965, p. 2.


58. H.M. Ellis, *Power Generation and EHV Transmission in the Soviet Union*, International Power and Engineering Consultants Ltd., June 1960, p. 22. See also Table XX.


63. Elektrifikatsiya SSSR, *loc. cit.*

64. *Ibid.*


January 1964, Reel #12, p. 34.


71. Ibid., p. 171.


73. L.A. Melent'ev, loc. cit.

74. In Moscow, for example, 20 percent of electricity consumed by households. Moskovskaya Pravda, loc. cit.

75. Calculated from data in Tables XVIII and XXI.


86. This would indicate an export of 5 BKWH at the end of 1965, a figure which is not likely to be exceeded.

REFERENCES: FIGURES


Figure 12. Primary sources are, Elektrifikatsiya SSSR, (1:8,000,000), Glavnoye Upravleniye Geodezii i Kartografii, Gosudarstvennogo Geologicheskogo Komiteta SSSR, Moskva, 1963; The Situation and Future Prospects of Europe's Electric Power Supply Industry in 1961-62, United Nations, Geneva, 1963, Map 3.
CHAPTER VI

THE PERIPHERAL REGIONS

The peripheral regions are unimportant in terms of absolute size of installed capacity, but are of interest since developments often reveal most clearly current trends. In this chapter the electricity industry is discussed by region, emphasis being placed on current trends with only a general outline of the principal features of the industry, (i.e. installed capacity, generation of power by type of capacity, and costs of electricity). Finally, the consumption of electricity in the various regions is compared but again in less detail than heretofore.

HYDRO POTENTIAL

While the Far East, Central Asia, and the Caucasus possess a third of the Soviet's "technically exploitable" hydro resources, only a small portion of this potential has thus far been developed. Before proceeding with the regional discussion, the basis of the Soviet figures for "technically exploitable" potential are examined and for two areas estimates of "economically accessible" potential are offered.

THE FAR EAST

The "technically exploitable" hydro potential of the Far East, as depicted by Table XXII, is considerable, yet the region
<table>
<thead>
<tr>
<th>Potential Capacity MKW</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Far East$^b$</td>
</tr>
<tr>
<td></td>
<td>Central Asia$^c$</td>
</tr>
<tr>
<td></td>
<td>Caucasus$^d$</td>
</tr>
</tbody>
</table>


b. Refers to the Far East economic region. See Figure 7.

c. Figure applies to the economic regions of Central Asia and Kazakhstan.

d. Refers to the Transcaucasus and North Caucasus economic regions.
has witnessed very little hydro development. Thus, is the figure 28 MKW realistic as a measure of hydro resources? The distribution of potential constitutes the critical frame of reference in this respect.

The Amur River represents the largest potential of any single stream in the Far East (over 10 MKW), but current political relations with Communist China preclude any large scale development of common dam sites, (Figure 3). Sites on the headwaters of the Kolyma and Maya Rivers comprise about 30 percent of the "technically exploitable" potential (Figure 3), but there exist several negative features. Permafrost, extreme concentration of annual discharge, and relative location, stressed in the discussion of Central Siberia, are equally applicable to the situation here. The market for electricity in the Far East is not such to engender optimism over the possibility of development at these sites and the emergence of industrial complexes proximate to this remote potential is at present only a nebulous concept.

Using Shershov as a guide to capacity at prospective dam sites, almost 18 MKW can justifiably be excluded. There remains, therefore, 10 MKW of "economically accessible" hydro potential.

CENTRAL ASIA

In Central Asia hydro resources are peripherally located, (Figure 3). Of the Republics comprising the 32 MKW "technically exploitable" hydro potential, (Table XXII), the Tadzhik SSR has
the largest share. The majority of sites on two of the three rivers in Central Asia having more than 4 MKW potential capacity are located in this Republic.

Relative location does not play the same role as in the Far East, since all sites lie within 400 miles of the potential market, a distance over which EHV transmission of electricity has proven successful. Nevertheless, sites accounting for 10 MKW are not part of existing plans for utilizing hydro resources. These are found on the upper reaches of the Pyandzh and the Naryn Rivers especially. Inaccessibility, and the fact that the Pyandzh is common to Communist China, appear to be the principal reasons for the omission of many sites from current plans. By deducting this potential approximately 20 MKW remain in the "economically accessible" category. Of this, 4.5 MKW is represented by hydro stations in operation or under construction.

THE CAUCASUS

Traditionally the hydro resources of the Caucasus have been accorded considerable publicity, although constituting a comparatively small share of the national total. Within the area, the potential is again unevenly distributed, the Georgian SSR having about one-half, (Table XXII). Accessibility is not here a factor of major importance inasmuch as the majority of sites lie within feasible transmission distance and in a terrain which can only be considered less rugged than in Central Asia. Additionally there
is not the problem of prospective sites being contiguous with foreign states.  

As recently as 1959, it has been stated that only 7 percent of the hydro resources of the Caucasus were being utilized. Based on possible generation at 100 percent plant factor this was very much an underestimation. In fact by 1962 the 4.5 MW of capacity operating or under construction constituted nearly 40 percent of the area's "technically exploitable" hydro potential, (in terms of installed capacity). Hydro, therefore, cannot be regarded as providing a source of electricity indefinitely. Moreover, the value of several schemes has been questioned. It is feared, in the case of the Razdan River project in Armenia, that if a series of dams are built the level of Lake Sevan (important locally for irrigation), will be affected adversely. Future hydro development is likely to depend as much on the need for irrigation waters as on the demand for electricity.

With this overview of hydro potential in mind, it is necessary now to consider actual development with the peripheral regions.

THE CAUCASUS REGION

With the recent interconnection of the Caucasian Republics, a power network extending from Baku to Tkvarcheli has been created, (Figure 13). Inter-republic transfer of electricity had taken place prior to 1963, but the present network will permit
greater bulk transfer than had previously been possible. As there are no definite plans for an intertie with the North Caucasus (part of the South regional grid), the system currently constitutes a distinct and functional region.

On the basis of calculations carried out in Appendix C, the installed capacity for the network has been estimated at just over 3 MKW for 1962, (Table XXIII), of which hydro is about 55 percent. This share, however, is currently in a state of change. Azerbaydzhan SSR accounts for half of the capacity, and closer to 60 percent of generation, the difference being due to the higher average plant factor of the principally thermal generating capacity in this Republic.

During the past several years new capacity put into operation has been predominantly thermal. In Azerbaydzhan, the existence of oil and gas deposits and a limited hydro potential would appear to give rise naturally to this situation, but it is also true for Armenia and Georgia, both of which lack a diversified energy base and traditionally have been supplied by hydro-electricity. Because of a long history of development, fewer propitious sites are available as was inferred above. Thus in Armenia for example, the share of hydro has declined from 90 percent of total generation in 1956 to 80-85 percent in 1964. Only the construction of the Ingirsk station (1.7 MKW), will impede temporarily hydro's diminishing share in Georgia.

New thermal plants have been fueled primarily by oil or
TABLE XXIII

ESTIMATES OF REGIONAL INSTALLED CAPACITY BY TYPE
PERIPHERAL REGIONS 1962\(^a\)

<table>
<thead>
<tr>
<th>Region</th>
<th>Hydro Capacity MKW</th>
<th>Thermal Capacity MKW</th>
<th>Total Installed Capacity MKW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasus</td>
<td>1.62</td>
<td>1.4</td>
<td>3.02</td>
</tr>
<tr>
<td>Central Asia</td>
<td>1.1</td>
<td>1.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Northeast Kazakhstan</td>
<td>.83</td>
<td>1.16</td>
<td>1.99</td>
</tr>
<tr>
<td>Far East</td>
<td>.06</td>
<td>1.7</td>
<td>1.76</td>
</tr>
<tr>
<td>Murmansk</td>
<td>.68</td>
<td>.05</td>
<td>.73</td>
</tr>
</tbody>
</table>

\(^a\) All figures have been derived from calculations in Appendix C.
gas. In both instances, however, there are complications. Gas reserves are comparatively small and are currently being depleted, therefore expansion of gas fired thermal capacity based on local deposits must be subject to some restriction. Baku oil, being of high value has warranted further explorations and production (i.e. off-shore drilling), but this has led to higher capital investment per ton produced and thus higher selling price. Production has not been sufficient to utilize fully the existing refining capacity in the Baku area, and oil has been imported from the Volga zone. It has been this oil which has generally been used to fire thermal plants. As Table XXIV indicates, both local oil and gas are comparatively expensive, therefore external fuel sources must be attractive. The quantities of oil imported are not indicated, though it can be said that oil is of less importance than gas. The majority of new large plants recently completed or currently under construction are gas fired. This has been made possible by the construction of pipelines from Baku to Tbilisi and to Yerevan.

Costs of electricity reflect to a large extent the main type of capacity. In Azerbaydzhan, where hydro accounted for only 15 percent of generation in 1962, there exists the highest cost of electricity, (approximately the national average). In Georgia and Armenia, where hydro has predominated, costs are somewhat lower, in 1956 .6 kopeks per KWH in the former, 1.41 kopeks per KWH in the latter. With the creation of the network, hydro as
### TABLE XXIV

**COMPARATIVE COST OF SELECTED FUELS PER TON OF FUEL EQUIVALENT**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Location</th>
<th>Cost (rubles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>Azerbaydzhan</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>Stavropol</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>Saratov</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Komi</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Krasnodar</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>West Ukraine</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>East Ukraine</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Uzbek</td>
<td>0.5</td>
</tr>
<tr>
<td>Oil</td>
<td>Azerbaydzhan</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>Bashkir</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Kuybyshiev</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>Orenburg</td>
<td>2.7</td>
</tr>
<tr>
<td>Coal</td>
<td>Open-cast</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ekibastuz</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Angren</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>Kuznetsk</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Itat</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Shaft</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Karaganda</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>Donetsk anthracite</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>L'vov-Volynsk</td>
<td>7.3</td>
</tr>
</tbody>
</table>

---


peaking capacity is scheduled to assume even a more important role than heretofore has been the case and is expected to result in additional savings.\textsuperscript{29}

It has been suggested that by 1970 the Caucasus will of necessity have to look to external sources in order to meet the demand for electricity.\textsuperscript{30} Several schemes have been put forward indicating how the expected future deficit of electricity may be avoided. An EHV intertie with the North Caucasus has already been mentioned, but there exists also the possibility of importing gas from either the Grozny or Krasnodar deposits. Construction of an underwater EHV transmission line between Baku and Krasnovodsk (in turn linking up with the Central Asian grid) is being promulgated as a more economical means of overcoming the Caucasus' expected fuel and power shortage than importing natural gas.\textsuperscript{31} The plausibility of this is clearly subject to question.

\textbf{THE CENTRAL ASIAN REGION}

There exists currently the skeleton of a ramified grid system in Central Asia with the nucleus centered on the Tashkent-Fergana Valley area, (Figure 14).\textsuperscript{32} The retarded development of the region's electricity industry has only been recently offset and in large part as a consequence of the exploitation of the Bukhara gas deposit.\textsuperscript{33} Previously there had not existed an inexpensive local fuel, the demand for electricity being satiated primarily by hydro. As late as 1958 for example, hydro accounted
FIGURE 14 THE CENTRAL ASIAN REGION
for 63 percent of total electric power generated in the Uzbek SSR, where other energy sources exist. Gas is to reduce this percentage to 22 by 1965, increasing itself from 1.1 in 1958 to 42.6 in 1965.34 As a result natural gas has tended to spur transmission line as well as pipeline construction. Only within the past half dozen years has Central Asia emerged as a potential surplus power region.

The calculated regional capacity had reached only 2.5 MKW in 1962, about 45 percent of this being hydro (Table XXIII), an absolute decline from earlier years. While it can be expected that this trend will continue for the whole region, the decline will be gradual in view of the hydro capacity under construction at present, (approximately 3.5 MKW).35

Electricity consumption in Central Asia is expected to reach 60 BKWH by 1970, five times that of 1962.36 Such a demand will require 10-12 MKW of capacity (depending on the share of hydro), which is in no way an unrealistic objective. A 1.2 MKW gas fired plant under construction near Tashkent, designed to facilitate industrial expansion, is at present the region's largest.37 The 24 billion cubic meters of natural gas earmarked for consumption in Central Asia in 1970 would be adequate to meet the demand of thermal plants.38 Coal is also scheduled for an increased share of the electricity generated, the demand to be met through increased production within the region.39 However, it is comparatively expensive, as the cost of coal at Angren
reveals (Table XXIV), and emphasis will likely remain on natural gas.

Hydro, while overshadowed, has continued to play a highly functional role. In 1962, 80 percent of the existing system's annual peak load demand was met by hydro capacity. Stations constructed are largely multi-purpose, irrigation and stream regulation being important benefits. The Nurek plant on the Vaksh River, 2.5 MKW, and the Toktogul on the Naryn River .5 MKW, comprise the largest share of the 3.5 MKW under construction, (Figure 14). While these plants are significant locally for irrigation and power, both will provide additional peaking capacity for the system.

In the past, electricity costs in Central Asia have been above .8 kopeks per KWH. Costs at hydro plants currently under construction are expected to be between .1-.2 kopeks per KWH, depending on plant factor and installed capacity. With the increasing emphasis on gas fired thermal stations of 1-1.5 MKW capacity, where costs average .2-.3 kopeks per KWH, the mean cost of electricity for the region should decline.

THE NORTHEAST KAZAKHSTAN REGION

Presently in an embryonic stage, this system consists of only two lines emanating from the Ust-Kamenogorsk area (Figure 15), consequently planned interconnections have had to be used as a basis for regional delimitation. Completion of the Yermak
FIGURE 15 PERIPHERAL REGIONS
thermal plant, 2.4 MKW, will necessitate construction of a 500 KV line from this site to Akmolinsk, thus linking the Ust-Kamenogorsk and Semipalatinsk systems with that of Karaganda, (Figure 15).45

The regional installed capacity in 1962 was calculated at 1.99 MKW, of which .83 MKW was hydro, (Table XXIII). Since this time, the relative share of hydro and thermal capacity has altered somewhat. The trend has been toward large scale thermal plants, a conscious attempt to move away from the predominance of very small generating units. As late as 1955, for example, virtually all electricity in the Kazakh SSR was generated by plants of less than .1 MKW.46 An increasing industrial demand has necessitated greater emphasis being placed on larger generating units, and presently 75 percent of the power is generated by stations having more than .1 MKW.

In line with the trend toward large scale units is the recently announced plan for construction over the next decade of a complex of thermal power plants, each with a capacity of 3.8 MKW.47 Like most thermal plants in this region they are to be fired by the inexpensive Ekibastuz coal, (Table XXIV). Although initiation of the project is not scheduled until 1966, it is significant that an intertie with European Russia is an integral part of the development.48 This tends to support earlier statements regarding the function of this region as being a bridge in the linking of the Central Siberian and Ural Power Networks.49
Hydro, historically, has played an important role in the development of the region's electric power industry, particularly on the upper Irtysh River, (Figure 15). Currently about one-quarter of the "technically exploitable" potential is now being utilized. Only one hydro plant is actually scheduled for construction, Shulba on the Irtysh, although thus far there has been no definite information regarding commencement of construction at this site, (Figure 15). The existing hydro capacity, concentrated in the upper Irtysh, does not play any specific role in meeting the energy requirements in this area. It is at present the principal source of electricity. With completion of the power network this situation may alter.

Because of the proliferation of small stations, electricity costs have been high. As late as 1959 they were somewhat above the national average of .8 kopeks per KWH. It is estimated that current costs are at least equal to the national average. With the planned expansion of large scale capacity a decreasing regional mean should ensue.

THE FAR EAST REGION

As inferred at the outset, the Far East has witnessed very little development in the electricity industry. Generating plants tend to be of small capacity (seldom more than .5 MW), and coal fired. The development of a power network has similarly been retarded and as late as 1963 there was but a single 220 KV
Therefore the region dealt with here has once again been delimited on the basis of proposed interconnections, (Figure 15).

As Table XXIII indicates, hydro comprised a miniscule share of the calculated 1.76 MKW regional capacity as of 1962. There were less than a dozen stations making up hydro's share, these being located for the most part on state farms and kolkholzes. Clearly these were of small capacity. While there have been several tentative plans put forward for the utilization of the considerable hydro potential within the region, only one plant is currently under construction. With the completion of this station on the Zeya River, .9 MKW, the planned interconnection with the industrial centers to the east should come to fruition, (Figure 15).

Alarm has been expressed at the high cost of electricity in the Far East. In 1956 it was ten times the national average, or approximately 90 kopeks per KWH. This was due to the large number of small scale plants, the lack of interconnection, and especially the low degree of utilization (only a 30 percent average plant factor in 1959). Construction of the Zeya hydro station and recent plans for thermal plant construction on the Raychikhinskoye coal deposit (Figure 15), represent an attempt to improve the situation, but the region is likely to remain one of comparative underdevelopment and high cost of electricity.
The electric power industry in this region has from the outset been associated almost entirely with hydroelectric development. Although the potential of the region is comparatively small, the demand for electricity coupled with propitious physical conditions for dam construction and the absence of an alternative source of inexpensive power have resulted in an almost continuous program of harnessing hydro potential during the past 20 years. While by no means a widely ramified network, the existing capacity is interconnected by a 220 KV line (Figure 15).

On the basis of calculations in Appendix C, summarized in Table XXIII, aggregate capacity in 1962 was .73 MKW, over 90 percent of which was hydro. As Figure 15 indicates, there are close to a dozen hydro stations, however, the largest, Nivskaya, has only a capacity of .15 MKW.60

Cost of electricity has averaged about .4 kopeks per KWH, approximately half the national average.61 This is because of the predominance of hydro, and as stressed in this study, reflects in part the method by which prime cost of hydroelectricity is determined. As current expansion in the electricity industry centers around construction of additional hydro capacity, a similar cost structure is likely to continue.

THE MARKET FOR ELECTRICITY

Since the total capacity of the peripheral regions is but
10 MKW, only a general outline of the demand for electricity is warranted.

In the peripheral regions there exists a higher degree of industrial demand for electricity than has previously been the case. Industry requires at least 60 percent of regional installed capacity, from an estimated 53 percent in the Caucasus to 63 percent in Northeast Kazakhstan. The production of aluminum constitutes one of the largest requirements in the Caucasus and Murmansk regions and with the completion of the plant in Pavlodar it will be a major consumer in Northeast Kazakhstan as well.

In the latter region, demand has been characterized by the processing of base metals, particularly in the upper Irtysh, (Ust-Kamenogorsk). Industrial demand in the Far East is not concentrated in any one industry, a reflection in part of the region's comparative underdevelopment.

It is possible to obtain some measure of domestic use of electricity if one assumes that 10 percent of total generation is allotted to this sector in all regions. Thus, for an approximate population of 15 million, Central Asia has available about 1.3 BKWH, whereas the Caucasus, with 10 million inhabitants, has 1.5 BKWH allotted to consumer demand. In order to appreciate the relative difference between representatives of the peripheral regions, and an area where industrialization is very much in progress, a comparison can profitably be made with Central Siberia. In this region, 3 BKWH are currently being consumed per annum by
the 10 million population. This clearly indicates a far higher degree of consumer consumption of electricity than is characteristic of the peripheral regions.

It is only in the Caucasus that the sector, electric railway and associated uses, has to be taken into account. However, its requirements are comparatively small (consumption amounted to 4 percent of total generation in 1959). Line loss and station consumption vary little from region to region, consuming about 10 percent of electricity generated, but requiring a slightly larger percent of regional installed capacity.

SUMMARY

In the peripheral regions there exists considerable hydro potential, even in the "economically accessible" category. However, much of this is likely to remain undeveloped, especially in the Far East where the possibility of a large market emerging is slight. In regions where hydro constitutes a relatively large share of regional capacity, but does not predominate, (i.e. Caucasus and Central Asia), it has assumed the role of meeting peak demand. This role is likely to expand with the construction of additional hydro capacity and the gradual emergence of power systems.

In two of the peripheral regions gas has made striking inroads as a fuel for thermal plants. In the Caucasus limited reserves will of necessity force the region to look to external
sources if expansion of gas fired thermal stations is to con-
tinue. This is not a problem in Central Asia where gas
reserves are sufficient to meet the demands of thermal stations
for at least the next two or three decades. The recent ex-
ploration of the gas reserves has certainly provided a
stimulus for the expansion in the electricity industry.

Only Central Asia and possibly Northeast Kazakhstan
stand out as being potential regions of surplus electric power.
The latter region is scheduled to act as a bridge in the oft-
discussed Central Siberian-Urals intertie, supplying in addition
electricity to the industrial area around Voronezh. Whether
Central Asia will actually export electricity per se, as has
been suggested, remains a moot point. That it will continue
to export energy in the form of natural gas, which can be
converted to electricity at market, is certain.

It is the consensus here, that the Murmansk and Far East
regions will remain of minor importance in the Soviet electricity
industry.
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1. F. Ya. Nesteruk, Razvitiye Gidroenergetiki SSSR, (Development of Hydroelectric Energy in the U.S.S.R.), Izdatel'stvo Akademii Nauk SSSR, Moskva, 1963, p. 59; see also Table XXII.

2. Ibid., p. 61.

3. This figure is an estimate based on the map of prospective dam sites in S.F. Shershov, Bely Ugol, (White Coal), Gosenergoizdat, Moskva, 1957, p. 83; and data in F. Ya. Nesteruk, op. cit., p. 61.

4. This discussion can be found in Chapter IV.


7. In this discussion of hydro potential the following Republics are included: Kazakh, Kirgiz, Tadzhik, Uzbek and Turkmen. Data on individual Republic's "technically exploitable" hydro potential from, F. Ya. Nesteruk, op. cit., p. 59.


9. S.F. Shershov, loc. cit.

10. The particular stations making up this figure are discussed shortly.

11. As pointed out in Chapter V, the discussion of hydro potential in the Caucasus logically includes the potential of the North Caucasus economic region, (see Table XXII), although the latter area is not part of the Caucasus region.

12. Location of sites from, S.F. Shershov, loc. cit.

13. This figure applies only to the three Caucasian Republics, but since developed hydro in the North Caucasus economic region, (which constitutes a third of the "technically exploitable" hydro potential under discussion here), is only a
fifth of total installed capacity (.3 MKW), the point being made here is not negated. That is, when installed capacity is used as the criterion for utilization of hydro potential, such figures are very much an underestimation. Figure from, N. Ya. Koval'skaya, et al., Ekonomicheskaya Geografiya SSSR: Volg-Donskoy Rayon, Severny Kavkaz, Zakzyk'ye, (The Economic Geography of the U.S.S.R.: The Volga-Don Region, North Caucasus, Transcaucasus), Geografichesky Fakul'tet, Moskovsky Gosudarstvenny Universitet im. M.V. Lomonosova, Moskva, 1959, p. 141. For data on relative shares of installed capacity in the North Caucasus see, Referativny Zhurnal: Elektrotekhnika i Energetika #E, Elektricheskiye Stantsii, Seti i Sistemi, Akademiya Nauk SSSR, May 1964, (5 E169), p. 26.

14. Less than .5 MKW of this capacity is located in the North Caucasus economic region.


17. Capacity of the line would limit exchanges to less than .5 BKWH annually; see calculation in Chapter IV, Footnote #30.

18. No interconnection indicated on map Elektrifikatsiya SSSR, (1:8,000,000), Glavnoye Upravleniye Geodezii i Kartografii, Gosudarstvennogo Geologicheskogo Komiteta SSSR, Moskva, 1963.


20. For data on this station see F. Ya. Nesteruk, op. cit., p. 236.

21. Reserves, according to Hodgkins, were 1.5 x 10^{12} cubic meters in Azerbaydzhan. This figure was based on data drawn from 1957 sources and with the recent increase in proven reserves in Central Asia particularly, its relative national share has decreased considerably. J.A. Hodgkins, Soviet Power; Energy Resources, Production, and Potential, Prentice-Hall, Englewood Cliffs, N.J., 1961, p. 139.

22. Selling price of Baku oil is about five times that in the Kuybyshev area or about 6 rubles per ton (in terms of fuel

23. Akademiya Nauk SSSR, op. cit., p. 272, the oil generally has a high sulfur content.


25. The line is currently under construction between Tbilisi and Batumi, Izvestiya, March 15, 1965, p. 4.


28. Ibid.

29. Mingechaur for example, is used extensively for peaking purposes.

30. For discussion see, Central Asia in Seven Years, Narodnoye Khozyaystvo Vo Sredney Aziya, Tashkent, May 1964, (pp. 13-8), The Soviet Economic System, (27588), J.P.R.S., Microfilm, October 1964, Reel #34, p. 6.

31. Ibid.

32. This region includes most of the following administrative units: in the Uzbek SSR; Kashka-Dar'ya, Surkham-Day'ya, Namangan, Fergana, Andizhan, Samarkand Oblasts, and the southern part of the Bukhara Oblast. The Stalinabad, Garm, Leninabad, and Kulyab Oblasts are included in the Tadzhik Republic. In the Kirgiz Republic, the Talas, Dzhalal-Abad and Frunze Oblasts are included. Only the southern part of the South Kazakh, Dzhambul and Alma-Ata Oblasts of the Kazakh Republic are part of the region. At present the grid does not extend into the Turkmen Republic.


34. Figures from, M.P. Munko, Gazovaya Promyshlennost'
35. The Nurek plant, 2.5 MKW, represents the largest share of the capacity currently under construction.

36. Central Asia in Seven Years, loc. cit.

37. Capacity of the Tashkent plant was .3 MKW as of September 1964, Pravda, September 21, 1964, p. 2.

38. Central Asia in Seven Years, loc. cit.


41. The line to the Toktogul station is currently under construction.


43. N.P. Munko, op. cit., 123.

44. The grid includes the following Oblasts: Kustanay, North Kazakh, Karaganda, Akmolinsk, Kokchetav, Pavlodar, Semipalatinsk, and East Kazakh. Only one interconnected station lies outside the Kazakh Republic, Rubtsovsk.

45. Capacity of the Yermak plant was scheduled to be .3 MKW at the end of 1963. Elektricheskiye Stantsii, loc. cit.


48. Ibid.


52. L.A. Melent'yev, loc. cit.

53. Only the southern part of the Far East economic region is included in the region as delimited here.

54. No information regarding completion of the planned transmission lines has been uncovered.


56. Ekonomicheskaya Gazeta, February 1, 1964, p. 16.

57. Data from, Akademiya Nauk SSSR, Energetika: Razvitiye Proizvoditel'nykh Sil Vostochnoy Sibiri, op. cit., p. 255.

58. Ibid.

59. Ekonomicheskaya Gazeta, loc. cit.

60. Joint Hearings ..., op. cit., p. 206.

61. L.A. Melent'yev, loc. cit.


63. Central Asia in Seven Years, loc. cit.

64. While this may be something of an underestimate, the actual figure being used does not negate the point being made here.


66. Ibid.

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CHAPTER VII

CONCLUSIONS

In concluding this study it is necessary to survey and evaluate those factors which have conditioned, and in some instances fostered, the spatial pattern and characteristics of Soviet electricity generation, consumption and transfer. The prospect for further hydro development in Central Siberia, where the function of large scale plants is different from that typical of the Soviet Union, is considered at some length. To facilitate the discussion several specific comparisons will be made with developments in North America.

CHARACTERISTICS AND SPATIAL PATTERN

The spatial pattern of the Soviet electricity industry clearly bears the stamp of past governmental policies. Recent government promotion of hydro development in Central Siberia has been responsible for the shift eastward of the center of gravity of hydro capacity, a shift far more rapid than is the case for generating capacity as a whole.

The electricity industry has traditionally been one of high priority and currently is expanding at a rate of 10-12 MKW per annum. Yet this rate of growth is inadequate as power deficits exist in many regions of the U.S.S.R. The situation is especially serious in European Russia, (even though possessing over one-half
of total installed capacity), the Center-Volga and Ural regions being the most acutely affected. Consequently European Russia has had to look to external sources to meet her energy requirements.

Insofar as the generation of electricity is concerned, there has been a traditional emphasis placed on the utilization of local low calorific fuels, particularly lignite, peat and shale, which do not constitute important raw materials in industry. While coal still meets the largest share of the fuel requirements of thermal power stations, the recent use of gas as fuel is notable. Its impact has been most effective in areas where local fuel costs are high, either because of scarcity or poor quality (i.e., in the Ural region). Since natural gas is an important industrial raw material it is not to be expected that the demand of industry will be disregarded in favour of the fuel needs of thermal stations, which generally speaking cannot be considered an optimum utilization. A rational use of natural gas as a fuel is exemplified in the Moscow area where it is burned for the most part during the summer months when industrial and domestic demands have slackened, thus replacing comparatively expensive local fuels. For gas particularly, and to a lesser extent oil, these alternative uses are made possible by the network of pipelines now focussed on European Russia.

The supply of electricity in European Russia is scheduled to be stabilized through an interchange of electric power among the regions via widely ramified EHV interties. In this context
the proposed intertie between the Central Siberian and Ural grid is one of the most controversial topics of the Soviet electricity industry.

There are several questions regarding the proposed intertie. First of all, is it technically feasible; secondly, is it economic; and finally, what impact would it have on the consumption of electricity in European Russia and especially the Urals? That the Soviets could technically carry out the construction and operation of an EHV DC line is an assumed conclusion in view of recent successes in this field.

The economic aspect of this proposal is complex. Electricity is generally regarded as being one of several competitive forms of energy. Coal and recently natural gas have been imported into European Russia from the eastern regions and both have been used to generate electricity. Consequently, the cost of importing electricity is frequently compared with the cost of importing fuel which subsequently may be converted into electricity. In cost comparisons, in terms of fuel equivalents, the transmission of electric power is invariably the most expensive manner of transporting energy. Yet the intertie is still being promoted—why? First of all, electricity is a finished product. When fuels are converted into electricity a loss ensues, the extent of which is determined by the efficiency of conversion.

Preliminary figures quoted in Chapter IV indicate that the delivered cost of electricity in the Urals could be economically
competitive. This assumed the existence of a ready market and one possessing a high load factor as well. There is such a market in the Urals.

On the basis of available data, it has been estimated here that a 15-20 BKWH annual surplus of power could exist in Central Siberia by 1970. This surplus may be the critical factor in determining whether or not the intertie will be constructed. An EHV DC line to the Urals would certainly complement recently announced plans for construction of a complex of thermal power stations centered on the Ekibastuz coal deposit and EHV intertie with European Russia. Insofar as the possible effect of imported Siberian power on the consumption of electricity in European Russia is concerned, it should be pointed out that in 1962 almost 70 BKWH were consumed in the Ural region alone. Subsequent construction of new capacity has not been able to keep abreast of demand and it is reasonable that this potential Siberian surplus block might well be consumed within the Ural region alone in 1970. Even so, it would comprise no more than 10-15 percent of annual electricity consumption in this region, if in fact the presumed surplus of power is as high as has been estimated. Therefore, the total impact on European Russia at this date would be of only minor proportion.

On the basis of calculations in Appendix C the Center-Volga region had the largest estimated installed capacity during 1962 (16.8 MKW) with the South (14 MKW) and the Urals (11.7 MKW)
following. This is not unexpected as these regions have long been the principal centers of industry. Central Siberia ranked fourth in terms of total installed capacity (an estimated 8.5 MKW), but by 1964 in absolute terms it had the largest share of hydro, about a third of national capacity, including capacity under construction. Because none of the larger scale hydro or thermal plants is operating at full capacity, this is not yet a region of low cost electric power as is often assumed.

Following Central Siberia was the Northwest region (6 MKW as of 1962), a region which has experienced only limited development. Of the peripheral regions which in aggregate had a capacity of only 10 MKW, 12 percent of total in 1962, Central Asia stands out as having the greatest potential for future expansion. This is due to the recent exploitation of natural gas reserves. In terms of installed capacity (2.5 MKW) it ranked behind the Caucasus region (3 MKW), where possible future expansion of generating capacity based on local energy resources is limited. At present 40 percent of hydro potential is being utilized and with limited reserves of coal, natural gas and the high cost of local oil, additional thermal capacity will have to depend largely on external fuels. Of minor importance are the three remaining regions, Northeast Kazakhstan, the Far East and Murmansk, each with less than 2 MKW generating capacity. Only the Northeast Kazakhstan grid is scheduled to play a role in the unification of the European and Eastern Power Networks.
There are significant regional variations in the relative importance of hydro capacity, from less than 1 percent in the Far East to over 95 percent in the Murmansk region. In regions where hydro is of some importance but does not predominate, it has assumed a specific function, that of meeting peak load demand. Assigning a specific role to hydro capacity is doubtless facilitated by the centralized control of the Soviet electricity industry. It was pointed out that during the past thirty years more concern has been evidenced in the Soviet Union over meeting peak demand economically, than has been characteristic in North America. Continued emphasis has been placed on the interconnection of power systems and where load centers are proximate, hydro stations on occasion have been intentionally "over-machined," a practice in which interest has only recently been shown in North America. It is interesting to note however, that several new hydro plants planned for the U.S. Pacific Northwest will be designed for peaking purposes denoting, if not an adoption of Soviet policy, at least recognition of its value.5

Figure 16 summarizes the regional variations in hydro and thermal capacities, as well as indicating the relative regional shares of total installed capacity. Generating capacity not accounted for in this study, about 15 percent, is located for the most part in urban centers, which have not been included in the regional system used here.

Consumption of electricity has been calculated both by
sector of the economy and industry, and the principal consumer has been shown to vary from region to region. The Center-Volga, with the largest installed generating capacity, possesses as well the greatest concentration of urban population and thus the domestic sector requires a relatively larger share of installed capacity than in any other region. In neither European Russia nor Central Siberia does a power intensive industry require the largest share of regional capacity. The sectors, agricultural economy and electric railway and associated uses, both rank higher than aluminum production, the principal industrial consumer in Central Siberia. If current plans are brought to fruition, by 1970 aluminum production in Central Siberia will rank first. In European Russia the aluminum industry ranks fourth after iron and steel production, the domestic, and electric railway sectors.

While not a consumer in the context used above, line loss and station consumption is nevertheless significant. In Central Siberia and European Russia, the KW capacity required to meet this demand was such as to make it the second and fourth largest consumer respectively. Because of the low load factor, further electrification of railways will ensure the continuance of this sector as another generally unrecognized but major consumer of electricity.

In comparison with North America, the basic difference in the consumption of electricity lies in the relative unimportance
of the domestic sector. In 1961 this sector required only 17 percent of total Soviet installed capacity, but over 55 percent in the U.S. While the Soviet domestic sector is gradually increasing its relative share it is not reasonable to expect that it will in the near future reach the same percentage as in the United States. The difference in social structure precludes the spread in required KW capacity from being used as a direct measure of consumer well-being.

Insofar as the cost of electricity is concerned this study has dealt primarily with hydro power. It has been emphasized that the manner in which prime cost of hydroelectricity is derived tends to underestimate actual cost and thus precludes the possibility of any meaningful comparison with North American figures.

HYDRO—POTENTIAL AND PROSPECTS

The considerable hydro potential of the Soviet Union east of the Urals has long been recognized and publicized, but the now near complete utilization of the hydro resources of European Russia has focussed attention on the possibility of harnessing this potential. It is important therefore to give detailed consideration to its actual scope. As a result it was found that the inherent limitations of the concepts which have been used to measure Soviet hydro potential have resulted in figures which are not meaningful. An attempt has been made to provide here a
more suitable frame of reference within which to assess hydro resources. Thus estimates of "economically accessible" hydro potential have been offered. In aggregate this figure is 40 percent lower than the oft-used Soviet estimate for total "technically exploitable" potential--110 MKW as compared to 196 MKW. Including capacity currently being installed almost a third of the Soviet "economically accessible" hydro potential is now being utilized.

Many of the proposals which have not fallen into the economically accessible category have counterparts in North America. The Yukon-Teslin-Taku proposal for the Northern British Columbia and Yukon area, is comparable in terms of relative location and scale to many of the Soviet proposals for the Lena River and its tributaries. Considerable publicity has been accorded each, yet neither can be considered economically accessible.

There is emerging a marked concentration of hydro capacity in Central Siberia, the consequence of recent government promotion of hydro construction in this region. A consistent policy regarding hydro development in the Soviet Union has been absent, however, and since the mid-fifties several vacillations, some more apparent than real, have occurred. One important "real" change was the curtailment of the program for hydro development under the Seven Year Plan, with a smaller share of funds allotted to the electricity industry being assigned to hydro construction.
As a result selection of projects deemed most economic has been encouraged. It has been stressed here that in Central Siberia there exist propitious physical conditions for hydro construction. But what of future development?

CENTRAL SIBERIA

The factors which militate against and the benefits which are deemed to accrue from additional large scale hydro construction in Central Siberia, must be accorded objective and careful weighing if a reasoned appraisal of the prospects is to be obtained. It has been illustrated in the comparison of Bratsk and Kuybyshev that because of different physical conditions the hydro stations in Central Siberia differ in function from those in other areas of the Soviet Union. In fact it is because they are not multi-purpose that has led in large part to much of the argument against further development.

Significant arguments for curtailment of hydro development in Central Siberia center around the supply of investment capital. Of total Soviet capital investment, Siberia in the past two or three years has claimed around 15 percent (5,836 out of 37,010 M rubles in 1963) and it is notable that the rate of investment has not been increasing. Large scale hydro plants characteristic of this region require anywhere from 700 M-1 B rubles, which is again about 15 percent of the total capital investment in Siberia annually. Thus, construction of any
new station such as Sayan must increasingly be in competition with other proposals for funds. In this regard it should be noted that Central Siberia is frequently touted as the logical location for energy intensive industry, for example, the new chemical industry which is currently receiving much attention.

Moreover, with the recent change of government leaders, indications are that consumer goods may very well be given increased priority in the overall allotment of investment capital between the consumer and industrial sectors. These factors plus previous indications of a stringency of capital supply within the Soviet Union, in aggregate lend considerable weight to the argument that hydro development must of necessity generate substantial benefits before being undertaken. In Central Siberia the primary benefit is large blocks of inexpensive electricity. Were these stations multi-purpose, hydro projects in this region would certainly be in a more competitive position than they are at present.

From a macro point of view, investment in the Soviet Union has often been seen in terms of east versus west. Some authorities have pointed out that returns on capital investment are higher in the west (European Russia including the Urals), which has by far the largest share of fixed capital and at least two-thirds of the potential market of the Soviet Union. If within this frame of reference consumer goods are to be given increased emphasis, then the west logically would be accorded
favour.

A skilled labour shortage currently exists in Siberia generally and it is felt most acutely within the Central Siberian region. In fact during the last seven years 400,000 more people have left Siberia than have entered. Thus there arises the suggestion that a curtailment of hydro construction would release many skilled workers into the Siberian labour pool. How would such a move affect the electricity supply of the region? Further development of thermal power stations utilizing low cost strip mined coal is the suggested alternative as it is well recognized that labour requirements for the installation of equivalent installed capacity are less. Directly or indirectly, such considerations as these will play a part in the field of Siberian hydro development.

Some of the reasons for hydro development in this region will be considered now, using the most recent project, Sayan, as a specific example. It is not intended that Soviet policy be justified, but to the extent possible, explained. To determine the stage of construction at Sayan the most recent reports have been used.

In an earlier chapter some major arguments for the continuance of hydro development in Central Siberia were outlined. For optimum utilization of the increasing experience and knowledge of the construction crews and the existing fixed capital for erection of hydro stations, a continuing program of develop-
ment is viewed by the proponents as essential. The success of this is reflected by a lower prime cost of hydroelectricity. When Krasnoyarsk comes under load, probably in 1967, it is expected that a gradual shift of equipment to Sayan will have taken place. This shift will parallel that from Bratsk to the Ust-Ilim site.

From reports in the press one can only deduce that construction at Sayan, while certainly in the preliminary stage, is nevertheless underway. Preparation at the Sayan dam site has reached the advanced stages of engineering and geophysical studies, which began in 1963. Immediate expansion of housing facilities for the anticipated influx of labourers is planned, and additionally, mention has been made of constructing a bridge across the Yenisey to the site at Sayan during the summer of 1965, since access is restricted during spring and fall months when ice either hinders travel by boat or is not of sufficient thickness to permit crossing.

In the majority of articles relative to Sayan examined in this study over a period of two years, there is reference to Lenin's original vision of an industrial complex at this location. The initial operation of Sayan is regarded as an integral part of the commemoration of the 100th anniversary of Lenin's birth. While admittedly it is possible to attach too much significance to such eulogy it must be borne in mind that as yet, in face of the very significant arguments outlined above, no decision to
suspend construction at Sayan has been indicated. The traditionally close association between investment policy in hydro construction and politics in the Soviet Union has been discussed by others, but the existence of such an association lends weight to such subjective factors. Moreover, with the proposed erection of the large scale hydro projects subsequent to Bratsk, much critical discussion has been evoked, yet the Krasnoyarsk and Ust-Ilim projects have gone ahead. At this point the same appears to be true with regard to Sayan. Perhaps with the introduction of the new Five Year Plan in the fall of 1965, more definitive information will be available.

In spite of hydro development that has been undertaken and is currently underway in Central Siberia there is a cloud over future prospects. Arguments on both sides have been presented, possibilities outlined, and problems emphasized. At this point one cannot justifiably make a definitive statement regarding the course of hydro development in this region. If construction continues it will likely be at a less rapid pace than heretofore. It is certain that much will continue to be said regarding the hydro resources of the east, particularly the Angara-Yenisey Cascade, which falls well within the "economically accessible" category established in this study. It is equally certain that hydro in other regions where benefits other than just electricity accrue, will continue with little opposing argument.

This study has attempted to present the spatial aspects
of the generation and consumption of electricity in the Soviet Union. While emphasis was intentionally accorded hydroelectric power and hydro potential, simply because it was felt that considerable clarification of the role of hydro in the Soviet power industry was required, the attention given the consumption of electricity is regarded here as a starting point for further research. The location of energy intensive industry is of critical importance in the Soviet Union today. It has been shown that in many regions power needs and power supply are thus far incompatible. Suggestions regarding the import of electricity from Central Siberia were considered, but the whole question of the location of energy intensive industry has yet to be dealt with. The data which has been provided in this study can profitably be used as a basis for appraising the possible ramifications of locating such industry in a specific region. In this regard the approach advocated here for the analysis of the consumption of electric power is viewed as being of considerable potential value.
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2. See Appendix B, Part II.


4. See Appendix C, Part II.


6. Calculated from data in Table I, p. 5. Load factor the same as used in Appendix C calculations.


8. The Yukon-Teslin-Taku proposal like those of the Lena River area has only been given preliminary study. It has, however, a potential capacity of at least 3.5 MKW at a 65 percent load factor. Data obtained from J.D. Watts, Hydraulic Engineer, Water Resources Service, Government of British Columbia, Victoria, British Columbia.


13. For an interesting discussion see, N.M. Budtolayev, V.P. Novikov, and Yu. G. Saushkin, *Problems of Economic Develop-


16. Ibid.

17. Aside from the foregoing quote see as an example, *Stroitel'naya Gazeta*, January 5, 1964, p. 4.

18. All reference to Sayan in Pravda and Izvestiya during the winter of 1965-65 have been checked and there is no indication that construction will be suspended.


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Figure 16. Data for this map drawn from calculations in Appendix C.
NOTE: The transliteration system used is that suggested by *Soviet Geography: Review and Translation*. Where a different transliteration system has been used by another author no changes have been made.

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E. INTERVIEWS AND UNPUBLISHED MATERIAL


APPENDICES
APPENDIX A

DERIVATION OF PRIME COST OF HYDROELECTRIC POWER IN THE SOVIET UNION

The prime purpose of this Appendix is to illustrate the effect that the inclusion of reservoir costs and interest charges will have on the ultimate per KWH prime cost of electricity. To achieve this end, a formula given by J.F. Muir and E. Ruus has been used with but slight modification:

\[
\frac{\text{Total Cost per KW of Capacity}}{(8760)^a \cdot (0.46)^b \cdot (0.95)^c} = \text{prime cost of electricity.}
\]

- \(a\) - Total number of hours per year.
- \(b\) - Plant factor. This would appear to be the minimum plant factor used when calculating prime cost, i.e., 46 percent or 4,000 hours per annum. The average plant factor for all hydro plants in 1963 was 3,906 hours; Narodnoye Khozyaystvo SSSR v 1963 Godu, Statisticheskii Ezhegodnik, (Statistical Year Book), Tsentral'noye Statisticheskoye Upravleniye pri Sovete Ministrov SSSR, Moskva, 1965, p. 159.
- \(c\) - Energy loss component, primarily as a result of transmission.

Taxation and insurance charges have not been included since they are not germane in the Soviet scene (and have a negligible effect on the result). In addition, annual operating and maintenance costs have been set arbitrarily.

In the following examples then, it has been assumed first of all that reservoir construction accounts for 20 percent of the theoretical total capital outlay for a hydro plant.\(^2\) The interest rate has been set at 3 percent, which
ordinarily would be reasonable for a government project, but if applied to the Soviet Union currently, might well be somewhat on the low side in view of the apparent stringent supply of investment capital. For the purpose here these problems are of little direct concern. The period for amortization is based on that for the Bratsk hydro plant.\(^3\)

In the first case, the Soviet method is followed:

1. **Prime Cost Based on Simple Amortization Charges.**

<table>
<thead>
<tr>
<th>Description</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total capital outlay for 2 MKW hydroelectric plant</td>
<td></td>
<td>500 M rubles</td>
</tr>
<tr>
<td>Costs of reservoir construction (equals 20 percent of total capital outlay)</td>
<td>0.20 x 500</td>
<td>100 M rubles</td>
</tr>
<tr>
<td>Capital outlay for actual operating unit</td>
<td>500 - 100</td>
<td>400 M rubles</td>
</tr>
<tr>
<td>Investment per KW</td>
<td>400 M rubles / 2 MKW</td>
<td>200 rubles</td>
</tr>
<tr>
<td>Simple amortization assuming 25 year period</td>
<td>400 M rubles / 25 years</td>
<td>16 M rubles</td>
</tr>
<tr>
<td>Annual amortization cost per KW</td>
<td>16 M rubles / 2 MKW</td>
<td>8 rubles</td>
</tr>
<tr>
<td>Annual operating and maintenance cost per KW</td>
<td></td>
<td>0.50 rubles</td>
</tr>
<tr>
<td>Total annual cost per KW</td>
<td></td>
<td>8.50 rubles</td>
</tr>
</tbody>
</table>
Prime cost of electricity per KWH

\[
\frac{8.50}{(8760)(.46)(.95)} = .22 \text{ kopeks per KWH}
\]

In the second estimate, reservoir costs are included.

2. Prime Cost Including Simple Amortization Charges and Reservoir Costs.

Total capital outlay for 2 MKW hydroelectric plant = 500 M rubles

Investment per KW

\[
\frac{500 \text{ M rubles}}{2 \text{ MKW}} = 250 \text{ rubles per KW}
\]

Simple amortization assuming 25 year period

\[
\frac{500 \text{ M rubles}}{25 \text{ years}} = 20 \text{ M rubles per year}
\]

Annual amortization cost per KW

\[
\frac{20 \text{ M rubles}}{2 \text{ MKW}} = 10 \text{ rubles per KW}
\]

Annual operating and maintenance cost per KW = .50 rubles per KW

Total cost per KW = 10.50 rubles per KW

Prime cost of electricity per KWH

\[
\frac{10.50}{(8760)(.46)(.95)} = .27 \text{ kopeks per KWH}
\]

Finally, interest charges are taken into account as well as the above factors.

3. Prime Cost Including Amortization, Reservoir Costs and Interest Charges.
Total capital outlay for 2 MKW hydroelectric plant = 500 M rubles

Investment per KW = \frac{500 \text{ M rubles}}{2 \text{ MKW}} = 250 \text{ rubles per KW}

Interest charge per KW at 3 percent for first year = .03 \times 250 = 7.50 \text{ rubles per KW}

Total cost per KW without interest (from part 2) = 10.50 \text{ rubles per KW}

Total cost per KW = 18.00 \text{ rubles per KW}

Prime cost of electricity per KWH = \frac{18.00}{(8760)(.46)(.95)} = .47 \text{ kopeks per KWH}

REFERENCES:


3. The 25 year period for amortization of the dam at Bratsk is indicative of the new policy in the Soviet Union. Previously an average of a 100 year period for repayment had been used. In this case only a span of 16 years is allowed for total depreciation of machinery, again somewhat lower than the average; Joint Economic Committee, Congress of the United States, Comparisons of the United States and Soviet Economies, Part II, United States Government Printing Office, Washington,
APPENDIX B

THE MARKET FOR ELECTRICITY IN THE SOVIET UNION

In this Appendix a regional breakdown of consumption of electric energy has been worked out wherever data permitted. Central Siberia will be considered in greatest detail as it is this region which is considered the future storehouse of electric power. Consequently it is essential that one have some idea of the KW capacity required to meet the demands of the important sector and industrial consumers, if a reasoned conclusion regarding the plausibility of exporting power to European Russia is to be arrived at. Once these capacities are determined one can compare the planned installed capacity in 1970, for example, with what will be required to meet the planned expansion in industrial and sector needs at that time, any residual thus adding weight to the possibility of export.

In determining the consumers for which required KW capacity would be estimated, the following points have been used as guides in selection:

- Productive processes consuming large blocks of electricity.
- Those consumers with low load factors.
- Data availability.

The concern in this Appendix is with estimating required installed KW capacity rather than consumption simply in terms
of KWH. It will be evident that while two consumers are equal in terms of KWH used, because of a difference in load factor the KW capacity required to supply these demands may be quite different. This certainly is the most important consideration.

There is an extreme dearth of statistics concerning the consumption of electric power in the Soviet Union, virtually nothing existing on a regional level. As a result figures have been arrived at, in some cases, by rather indirect means. However, it is felt that they offer a credible, albeit rough, estimate of the real situation. The loadings for sectors of the economy (e.g., Domestic and Communal Economy) and specific industries were offered by C. Nash (B.C. Hydro and Power Authority, Vancouver, B.C.), and these are used throughout on the assumption that there would be no marked difference between the Canadian and Soviet scene.

LOAD FACTORS

<table>
<thead>
<tr>
<th>Sector</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Domestic and Communal Economy</td>
<td>40</td>
</tr>
<tr>
<td>2. Agriculture</td>
<td>15</td>
</tr>
<tr>
<td>3. Electric Railways and Associated Uses</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Industry</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Aluminum</td>
<td>95</td>
</tr>
<tr>
<td>2. Iron and Steel, non-electric</td>
<td>50</td>
</tr>
<tr>
<td>3. Iron and Steel, electric</td>
<td>80</td>
</tr>
<tr>
<td>4. Pulp and Paper</td>
<td>85</td>
</tr>
<tr>
<td>5. Synthetic rubber</td>
<td>75</td>
</tr>
<tr>
<td>6. Nitrogenous fertilizers</td>
<td>90</td>
</tr>
<tr>
<td>7. Machine industry (general)</td>
<td>25</td>
</tr>
</tbody>
</table>
Industry (ctd.)

8. Metal Fabrication and Custom Machine Building 25
9. Cement 70

Line Loss and Station Consumption 65

PART I

MAJOR CONSUMERS OF ELECTRIC POWER IN CENTRAL SIBERIA,
JANUARY 1st, 1965.

Installed Capacity. ¹

The installed capacity in the Central Siberian System at the end of 1964 has been estimated at 10.5 MKW, giving an annual generation of about 60 BKWH (assuming an average 65 percent plant factor). The following plants comprise the bulk of the installed capacity:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Capacity (MKW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bratsk Hydro Station</td>
<td>4.0</td>
</tr>
<tr>
<td>Irkutsk &quot; &quot;</td>
<td>.66</td>
</tr>
<tr>
<td>Novosibirsk Hydro &quot;</td>
<td>.44</td>
</tr>
<tr>
<td>Nazarovo Thermal &quot;</td>
<td>.9</td>
</tr>
<tr>
<td>Tom-Usinsk &quot; &quot;</td>
<td>1.4</td>
</tr>
<tr>
<td>Novosibirsk &quot; &quot;</td>
<td>.1</td>
</tr>
<tr>
<td>Kuznetsk &quot; &quot; (total)</td>
<td>1.815</td>
</tr>
<tr>
<td>Small city &quot; Stations &quot;</td>
<td>9.315</td>
</tr>
</tbody>
</table>

Required KW Capacity by Sector.

1. Domestic and Communal Economy.

It is expected that 5 percent of total generation in 1965 will be required to meet the needs of this sector. ² The term "communal economy" covers such items as street lighting and miscellaneous city needs. On the basis of this
figure, the KW capacity required to meet the demand is:

\[
\begin{align*}
&i \quad 60 \text{ BKWH} \times 0.05 = 3 \text{ BKWH} \\
&ii \quad 3 \text{ BKWH} \\
&\quad \frac{3 \text{ BKWH}}{(8760) \times 0.4} = 0.857 \text{ MKW}
\end{align*}
\]

a. total number of hours per year
b. load factor

2. Agriculture.

In 1965, this sector is expected to consume 2 percent of total generation. Required KW capacity is, therefore:

\[
\begin{align*}
&i \quad (60 \text{ BKWH}) \times 0.02 = 1.2 \text{ BKWH} \\
&ii \quad \frac{1.2 \text{ BKWH}}{(8760) \times 0.15} = 0.923 \text{ MKW}
\end{align*}
\]

3. Electric Railways and Associated Uses.

In 1965, this sector is expected to consume approximately 12 percent of total generation. This figure has been reduced to 10 percent since the Abakan-Tayshet railway is not as yet in full operation. Required KW capacity is:

\[
\begin{align*}
&i \quad (60 \text{ BKWH}) \times 0.1 = 6 \text{ BKWH} \\
&ii \quad \frac{6 \text{ BKWH}}{(8760) \times 0.25} = 2.7 \text{ MKW}
\end{align*}
\]

Required KW Capacity by Industry.

1. Aluminum.

It has been assumed that 19,000 KWH are consumed in producing one ton of aluminum. Production of aluminum in Siberia was calculated from Shabad, as 0.4 M tons for 1965 (January).
2. Integrated Iron and Steel (non-electric).

Production of steel from integrated iron and steel plants was estimated at 5.1 M tons for 1965. Consumption of electric power per ton produced was estimated to be of the order of 250 KWH.

\[
\text{i. } (250 \text{ KWH}) (5.1 \text{ M tons}) = 1.27 \text{ BKWH} \\
\text{ii. } \frac{1.27 \text{ BKWH}}{(8760) (.5)} = .292 \text{ MKW}
\]

3. Iron and Steel (electric).

Production of electric steel was estimated to be .020 M tons. Consumption of electric power per ton produced was estimated at 550 KWH per ton for 1965. Required KW capacity is:

\[
\text{i. } (550 \text{ KWH}) (.02 \text{ M tons}) = .011 \text{ BKWH} \\
\text{ii. } \frac{.011 \text{ BKWH}}{(8760) (.8)} = .0016 \text{ MKW}
\]


Production of pulp was estimated at .147 M tons and paper and cardboard, .103 M tons. Consumption per ton was taken at 600 KWH for pulp, and 300 KWH for paper and cardboard. Required KW capacity is:

a. Pulp

\[
\text{i. } (600 \text{ KWH}) (.147 \text{ M tons}) = .0882 \text{ BKWH} \\
\text{ii. } \frac{.0882 \text{ BKWH}}{(8760) (.85)} = .0118 \text{ MKW}
\]
b. Paper and Cardboard.

i \( (300 \text{ KWH}) (0.103 \text{ M tons}) = 0.031 \text{ BKWH} \)

ii \( \frac{0.031 \text{ BKWH}}{(8760)(0.85)} = 0.016 \text{ MKW} \)

5. Synthetic Rubber.

Production in 1965 was estimated to be 0.180 M tons.^{12} Consumption of electric power per ton produced was estimated at 2,000 KWH.^{13} Required capacity is:

i \( (2000 \text{ KWH}) (0.180 \text{ M tons}) = 0.360 \text{ BKWH} \)

ii \( \frac{0.360 \text{ BKWH}}{(8760)(0.75)} = 0.057 \text{ MKW} \)


Production was estimated at 0.250 M tons (1955),^{14} of which it has been assumed 10 percent was produced using an electrolysis process (calcium cyanamide). Consumption of electric power required per ton produced was estimated at 14,000 KWH. Required capacity is:

i \( (14000 \text{ KWH}) (0.025 \text{ M tons}) = 0.35 \text{ BKWH} \)

ii \( \frac{0.35 \text{ BKWH}}{(8760)(0.90)} = 0.044 \text{ MKW} \)


Production has been estimated at 13,000 machines per year (1965), with total value of 130 M rubles. Consumption of electric energy is 110 KWH per 100 rubles production, according to one source.^{15} Required KW capacity is:

i \( (110 \text{ KWH}) (130 \text{ M rubles}) = 0.143 \text{ BKWH} \)
8. Metal Fabrication and Custom Machine Building.

An estimate was arrived at by assuming that one plant of this type would consume .070 BKWH per annum. Number of plants was estimated at 29.16 Required KW capacity is:

\[ \text{i} \quad (.070 \text{ BKWH per annum}) \times (29) = 2 \text{ BKWH} \]

\[ \text{ii} \quad \frac{2 \text{ BKWH}}{(8760) \times (.25)} = .910 \text{ MKW} \]


Production for 1962 was estimated to be 15 M tons.17 One ton produced consumed 35 KWH.18 Required capacity is:

\[ \text{i} \quad (35 \text{ KWH}) \times (15 \text{ M tons}) = .525 \text{ BKWH} \]

\[ \text{ii} \quad \frac{.525 \text{ BKWH}}{(8760) \times (.7)} = .086 \text{ MKW} \]

Line Loss and Station Consumption.

It was assumed that 10 percent of total generation was used in this manner.19 Required capacity is:

\[ \text{i} \quad (60 \text{ BKWH}) \times (.1) = 6 \text{ BKWH} \]

\[ \text{ii} \quad \frac{6 \text{ BKWH}}{(8760) \times (.65)} = 1.05 \text{ MKW} \]

Total Required KW Capacity - Central Siberia 1965 - 7.9816 MKW.
MAJOR CONSUMERS OF ELECTRIC POWER IN CENTRAL SIBERIA, 1970.

Installed Capacity.

The figure of 140 BKWH annual generation was taken for 1970. At 65 percent average plant factor, this could mean a total installed capacity of:

\[
\frac{140 \text{ BKWH}}{(8760)(.65)} = 24.6 \text{ MKW}
\]

Required KW Capacity by Sector.

1. Domestic and Communal Economy.

A 10 percent increase over 1965 was assumed:

1965: 3 BKWH = .857 MKW, therefore,
1970: 3.3 BKWH = .940 MKW

2. Agriculture.

Assumed no change from 1965 .923 MKW

3. Electric Railways and Associated Uses.

It was assumed that absolute consumption has increased by 20 percent over 1965. Required KW capacity is:

1965: 2.7 MKW
1970: (2.7 MKW)(1.2) = 3.24 MKW

Required KW Capacity by Industry.

1. Aluminum.

It was assumed that production was of the order of
1.55 M tons, assuming 19,000 KWH per ton produced was consumed. Required capacity is:

\[
\begin{align*}
\text{i } & (19000 \text{ KWH}) (1.55 \text{ M Tons}) = 29.4 \text{ BKWH} \\
\text{ii } & \frac{29.4 \text{ BKWH}}{(8760) (.95)} = 3.54 \text{ MKW}
\end{align*}
\]

2. Integrated Iron and Steel (non-electric).

It was assumed that total integrated production would be 8.4 M tons. Again, 250 KWH consumption was assumed for production of 1 ton of steel. Capacity required is:

\[
\begin{align*}
\text{i } & (250 \text{ KWH}) (8.4 \text{ M tons}) = 2.1 \text{ BKWH} \\
\text{ii } & \frac{2.1 \text{ BKWH}}{(8760) (.5)} = .480 \text{ MKW}
\end{align*}
\]

3. Iron and Steel (electric)

Assumed no change from 1965 .0016 MKW


a. Pulp

The production of pulp for 1970 was estimated to be 1.36 M tons. Consumption of electricity per ton produced would be 600 KWH. Capacity required is:

\[
\begin{align*}
\text{i } & (600 \text{ KWH}) (.447 \text{ M tons}) = .268 \text{ BKWH} \\
\text{ii } & \frac{.268 \text{ BKWH}}{(8760) (.85)} = .0322 \text{ MKW}
\end{align*}
\]

b. Paper and Cardboard.

Paper and cardboard production was expected to reach .676 M tons, thereby consuming about 300 KWH per ton. Capacity required is:

\[
\begin{align*}
\text{i } & (300 \text{ KWH}) (.676 \text{ M tons}) = .203 \text{ BKWH}
\end{align*}
\]
220

\[
\frac{0.203\text{ BKWH}}{(8760) (.85)} = 0.0244\text{ MKW}
\]

5. Synthetic Rubber.
Assumed no change from 1965 \(0.057\text{ MKW}\)

It was assumed that a twofold increase occurred over 1965, since the latter was based on 1955 production without change.\(^{26}\) Capacity required is:

1965: \(0.0440\text{ MKW}\)
1970: \((0.0440\text{ MKW}) (2)\) \(= 0.0880\text{ MKW}\)

Soviet plans are not known and therefore assumed no change.
Assumed no change from 1965 \(0.13\text{ MKW}\)

8. Metal Fabrication and Custom Machine Building.
Assumed no change from 1965 \(0.910\text{ MKW}\)

Assumed no change from 1965 \(0.086\text{ MKW}^{27}\)

Line Loss and Station Consumption.
It was assumed that the same percentage consumption would exist as in 1965, i.e., about 10 percent of annual generation. Capacity required is:

\[
\begin{align*}
\text{i} & \quad (140\text{ BKWH}) (.1) = 14\text{ BKWH} \\
\text{ii} & \quad \frac{14\text{ BKWH}}{(8760) (.55)} = 2.46\text{ MKW}
\end{align*}
\]

Total Required KW Capacity - Central Siberia 1970 - 12.9122 MKW
MAJOR CONSUMERS OF ELECTRIC POWER IN EUROPEAN RUSSIA 1962.

Installed Capacity.

The installed regional capacities (and annual generation of electricity) for European Russia have been calculated in Appendix C, and as indicated are based on 1962 data. The following is a summary of the regional figures.

<table>
<thead>
<tr>
<th>Region</th>
<th>MKW</th>
<th>BKWH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center-Volga</td>
<td>16.2</td>
<td>86</td>
</tr>
<tr>
<td>Ural</td>
<td>11.75</td>
<td>66</td>
</tr>
<tr>
<td>South</td>
<td>14</td>
<td>81</td>
</tr>
<tr>
<td>Northwest</td>
<td>6.4</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total U.S.S.R. (1962)</strong></td>
<td><strong>48.35</strong></td>
<td><strong>263</strong></td>
</tr>
</tbody>
</table>

European Russia makes up 57 percent of total Soviet installed capacity and 71 percent of annual generation. (The difference is simply a reflection of the higher than average annual plant factor, and larger operating units characteristic of the industrial areas of European Russia).

Since the installed capacity of European Russia has been calculated on the basis of 1962 data, in estimating the KW capacity required to meet the major demands, the same base year has been used wherever possible, (especially in the industrial sector).
Required KW Capacity by Sector.

1. Domestic and Communal Economy.

Figure for this sector has been based in part on that for the nation as a whole in 1955, (16.7 percent), but with the rapid increase in annual generation this has been decreased slightly, to 12 percent. This corresponds well with the general range of estimates from different sources. Required KW capacity is:

\[
\begin{align*}
\text{i} & \quad (263 \text{ BKWH}) \cdot (0.12) = 31.5 \text{ BKWH} \\
\text{ii} & \quad \frac{31.5 \text{ BKWH}}{(8760) \cdot (0.40)} = 9 \text{ MKW}
\end{align*}
\]

2. Agriculture.

In arriving at a figure for this sector, the total generation from agricultural plants in 1962, about 2 percent, has been taken into consideration. This neglects obviously, the "import" of electricity facilitated by the distribution of lower voltage lines, which are tied in with other sources of electricity, (i.e., regional grid). Consequently it has been set at 3 percent of total generation. Capacity required is:

\[
\begin{align*}
\text{i} & \quad (263 \text{ BKWH}) \cdot (0.03) = 7.8 \text{ BKWH} \\
\text{ii} & \quad \frac{7.8 \text{ BKWH}}{(8760) \cdot (0.15)} = 6 \text{ MKW}
\end{align*}
\]

3. Electric Railways and Associated Uses.

It has been estimated that 6 percent of total generation was consumed by this sector in 1962, again, a relative decrease from its position in 1958. Required
capacity is:

\[ \begin{align*}
\text{i} & \quad (263 \text{ BKWH}) (0.06) = 15.7 \text{ BKWH} \\
\text{ii} & \quad \frac{15.7 \text{ BKWH}}{(8760) (0.25)} = 7.1 \text{ MKW}
\end{align*} \]

Required KW Capacity by Industry.

1. Aluminum.

Total production in 1962 has been estimated at .6 M tons. Consumption of electricity per ton produced - 19,000 KWH. Capacity required is:

\[ \begin{align*}
\text{i} & \quad (19000 \text{ KWH}) (0.6 \text{ M tons}) = 11.4 \text{ BKWH} \\
\text{ii} & \quad \frac{11.4 \text{ BKWH}}{(8760) (0.95)} = 1.37 \text{ MKW}
\end{align*} \]

2. Integrated Iron and Steel (non-electric).

Production in 1962 for European Russia estimated to be 55 M tons. Consumption of electricity per ton produced - 250 KWH. Capacity required is:

\[ \begin{align*}
\text{i} & \quad (250 \text{ KWH}) (55 \text{ M tons}) = 13.7 \text{ BKWH} \\
\text{ii} & \quad \frac{13.7 \text{ BKWH}}{(8760) (0.5)} = 3.1 \text{ MKW}
\end{align*} \]

3. Iron and Steel (electric).

It has been assumed that 80 percent of electric steel production originates in European Russia, (1962). Total production 4.3 M tons. Assumed that 550 KWH required for every ton produced. Capacity required is:

\[ \begin{align*}
\text{i} & \quad (550 \text{ KWH}) (3.5 \text{ M tons}) = 1.9 \text{ BKWH} \\
\text{ii} & \quad \frac{1.9 \text{ BKWH}}{(8760) (0.8)} = 0.27 \text{ MKW}
\end{align*} \]
4. Pulp.

In view of the fact that paper and cardboard production is an insignificant consumer of electricity, (see Part I), only production of pulp has been taken into consideration. Production for 1962 estimated to be 1.9 M tons, 75 percent of the national total. Consumption of electricity per ton produced - 600 KWH. Capacity required is:

\[
\text{i} \quad (600 \text{ KWH}) (1.9 \text{ M tons}) = 1.1 \text{ BKWH}
\]

\[
\text{ii} \quad \frac{1.1 \text{ BKWH}}{(8760) (0.85)} = 0.148 \text{ MKW}
\]

5. Synthetic Rubber.

Production in 1962 estimated at .695 M tons, per ton consumption of electricity during processing being 2,000 KWH. Required KW capacity is:

\[
\text{i} \quad (2000 \text{ KWH}) (.695 \text{ M tons}) = 1.39 \text{ BKWH}
\]

\[
\text{ii} \quad \frac{1.39 \text{ BKWH}}{(8760) (0.75)} = 0.213 \text{ MKW}
\]


Production in 1962, 6.9 M tons, of which European Russia and the Urals are estimated to account for 75 percent of total. However, the amount of calcium cyanamide produced, (nitrate fertilizer) which involves an electrolysis process is comparatively small. It has been estimated that it is of the order of 10 percent, (.5 M tons) of total nitrate production. Consumption of electricity per ton produced - 14,000 KWH. Capacity required is:
7. Cement.

Total production for European Russia in 1962 was estimated to be 33 M tons. It has been assumed as before that 35 KWH of electricity are consumed per ton produced. Capacity required is:

\[
\text{i} \quad (35 \text{ KWH}) (33 \text{ M tons}) = 1.155 \text{ BKWH}
\]

\[
\frac{1.155 \text{ BKWH}}{(8760) (.7)} = .188 \text{ MKW}
\]

Line Loss and Station Consumption.

Assumed that 12 percent of total regional generation consumed in this manner. Capacity required is:

\[
\text{i} \quad (263 \text{ BKWH}) (.12) = 31.5 \text{ BKWH}
\]

\[
\frac{31.5 \text{ BKWH}}{(8760) (.65)} = 5.5 \text{ MKW}
\]

Estimated Total Installed Capacity Required by Selected Major Consumers - 33.789 MKW

REFERENCES:

1. Compiled from Pravda, January 17, 1964, p. 2. Estimate of total generation was obtained from an estimate of 65 percent plant factor for Central Siberia. This figure, perhaps an overestimate, was taken to reduce inflation of required KW capacity by sector of industry.

3. Ibid.


8. V.S. Makarov, Sovremennoye Nakopleniye i Perspektivy i Ispol'zovaniya Loma Chernykh Metallov v Vostochnoy Sibiri, (Contemporary Accumulation and Future Utilization of Heavy Scrap Metals in Eastern Siberia), Chernaya Metallurgiya Razvitiye Proizvoditel'nykh Sil, Vostochnoy Sibiri, Akademii Nauk SSSR, Moskva, 1960, p. 203; estimated recovery of 90 percent steel from scrap at Western Canada Steel (Cominco), Vancouver, Canada.

9. Based on consumption of electric power in production of steel at Western Canada Steel, *loc. cit.*, (550 KWH per ton of steel using a 16 inch electrode).


13. Estimated from, General Review of the Manufacturing Industry 1961 (31201), Dominion Bureau of Statistics, pp. 205, 225. Soviet 1958 estimate of 20,000 to 22,000 KWH per ton was considered too high in view of technological changes in the Soviet rubber industry during the Current Seven Year Plan, A.E. Probst, op. cit., p. 16.


15. Based on; estimated cost per grain-combine of 5,000 new rubles obtained from Professor H.E. Ronimois, Department of Slavonic Studies, University of B.C.; 110 KWH consumed per 100 rubles of combine production, A.E. Probst, loc. cit.; annual production of combines in Krasnoyarsk, Krasnoyarskiy Rabochiy, February 1, 1964, p. 1.


18. KWH consumption estimated from Canadian production and consumption figures, 1961; production of 6 M tons required 207 MKWH. Therefore, 35 KWH per ton was adopted. Cement Manufacturers 1961 (44204), Dominion Bureau of Statistics, Table 3. It was assumed that Central Siberian cement plants had similar heat requirements as Canadian plants.

19. Russian estimate of 14 percent was reduced to 10 percent; John P. Hardt, Economics of the Soviet Electric Power Industry, PhD. Thesis, Cornell University, 1955, Microfilm, p. 4.


21. Original 1965 estimate was 12 percent but for reasons explained previously 10 was used. By 1970, it is assumed that the Abakan-Tayshet electric railway will be in full operation. Therefore, power consumption in this sector estimated to be 120 percent of 1965 consumption.

22. Total aluminum production by 1970 is estimated at
1.55 M tons (Krasnoyarsk 400,000 tons, Shelekhov, 300,000 tons, Novo-Kuznetsk, 50,000 and Bratsk 800,000 - calculated on the basis of the percentage of total generation from Bratsk hydro station to be consumed locally, i.e., 16 out of 22 BKWH). Associated industrial complexes in Bratsk area are not intensive users, i.e., pulp and paper and iron ore concentration (excluding Ust-Ilim construction project). With a 19,000 KWH consumption per ton of aluminum produced, it was estimated that plant capacity would be of the order of 800,000 tons, i.e., twice the capacity of Krasnoyarsk; T. Shabad, op. cit., pp. 20-2.

23. It was assumed that the new Kuzbass plant (4.4 M tons) would be in full production by 1970.


25. B.M. Barr, loc. cit.

26. Based on new Soviet policy of fertilizer production.

27. It is estimated that consumption of cement, largely in hydro station construction at Bratsk and Krasnoyarsk, will be shifted to Ust-Ilim and Sayan.


31. Akademiya Nauk SSSR, Energetika, loc. cit. As
mentioned, rapid increase in generation of electricity makes a relative decline probable.

32. Ibid.


34. Figure lowered somewhat from total U.S.S.R. figure of 64.9 M tons, Promyshlennost' SSSR, Statisticheskii Sbornik, Tsentrall'noye Statisticheskoye Upravleniye pri Sovete Ministrov SSSR, Moskva, 1964, p. 167, P.E. Lydolph, op. cit., p. 355.

35. Calculated from data given in, Promyshlennost' SSSR, loc. cit.

36. This share probably an underestimation. Total production figures from Promyshlennost' SSSR, op. cit., p. 302.

37. J.P. Cole, F.C. German, A Geography of the Soviet Union: A Background to a Planned Economy, Butterworth, London, 1961, p. 139; T. Shabad, P.E. Lydolph, op. cit., p. 174; estimated tire weight derived from information provided by, Bourne and Weir Division of Dunlop Canada Limited, (i.e., average weight of tire for single axle dump trucks - 100 lbs.).

38. Production data from, Promyshlennost' SSSR, op. cit., p. 142; and Planovoye Khozyaystvo, August 1964, p. 9.

39. Information on the small share of nitrate fertilizer produced using an electrolysis process, using Canada as an example, from Green Valley Fertilizer and Chemical Company Limited, Surrey, B.C. Similar situation assumed to exist in the Soviet Union.

40. Of total R.S.F.S.R. production 15 M tons accounted for by Central Siberia, see Part I. Production figures from Promyshlennost' SSSR, op. cit., p. 323.

41. Figure based on data in, Water Resource Programs of the United States, Russia and (Red) China, loc. cit.
It has been necessary to use an indirect method to calculate installed operating capacities for the various regions under consideration, since data on this level is not available. Annual generation of electricity is given by Republic and Economic region. With this information and the percentage of regional capacity by type (e.g., hydro and thermal), which in some instances has to be estimated, it is possible to obtain an estimate of installed capacity. The load factors used in these calculations are based on averages for the country as a whole, but have been altered subjectively in accordance with known regional variations from the mean. While admittedly only an approximation the results obtained have proven credible.

PART I--CENTER-VOLGA REGION.

In view of the areal extent of the grid network, the following economic regions have been included: Central, Central Chernozem, Volga Vyatka, and Povolzhye. Hydro comprised 40 percent of total installed capacity as of January 1, 1962. As no other hydro capacity was brought into operation during that year, its share of total installed capacity as of December 1962 was assumed to be only
35 percent. The figures for annual generation of electricity by economic region were compiled at this latter date. Because of the lower average plant factor of hydro plants, (.5), the share of total generation is somewhat less, and has been estimated here at 25 percent.² (Volgograd could not have been operating at maximum efficiency - completed 1961).³ Thus thermal capacity assumed to produce 75 percent of total generation. It has been further assumed that there existed a 65 percent average plant factor for thermal plants.⁴

Total Generation of Electricity 1962⁵ 86 BKWH

Thermal Capacity⁶

\[
\frac{(86 \text{ BKWH}) \times (0.75)}{(8760) \times (0.65)} = 11.3 \text{ MKW}
\]

Hydro Capacity⁷

\[
\frac{(86 \text{ BKWH}) \times (0.25)}{(8760) \times (0.5)} = 4.9 \text{ MKW}
\]

Estimate of Total Installed Capacity⁸ 16.2 MKW

Percent of National Total⁹

\[
\frac{16.2 \text{ MKW}}{82.4 \text{ MKW}} = 19.6 \text{ Percent}
\]

PART II—URAL REGION.

In this case the Ural economic region corresponds for the most part with the areal extent of the grid. As of January 1, 1962, hydro stations made up only 9.8 percent of the regional installed capacity.¹⁰ By year end it was estimated
that hydro accounted for no more than 7 percent of total installed capacity. For reasons outlined previously it has been assumed that hydro accounted for not 7 but 5 percent of total generation. Therefore 95 percent of total generation from thermal sources; 65 percent plant factor again assumed.

\[
\text{Total Generation of Electricity 1962}^{11} \quad 66 \text{ BKWH}
\]

\[
\text{Thermal Capacity} \quad \frac{(66 \text{ BKWH}) (0.95)}{(8760) (0.65)} = 11 \text{ MKW}
\]

\[
\text{Hydro Capacity}^{12} \quad \frac{(66 \text{ BKWH}) (0.5)}{(8760) (0.5)} = 0.753 \text{ MKW}
\]

\[
\text{Estimate of Total Installed Capacity} \quad 11.753 \text{ MKW}
\]

\[
\text{Percent of National Total}^{13} \quad \frac{11.753 \text{ MKW}}{82.4 \text{ MKW}} = 14.2 \text{ Percent}
\]

PART III—SOUTH REGION.

In view of the recent extension of the grid, Moldavia SSR and North Caucasus economic region as well as the Ukraine SSR, are included in the South.\(^{14}\) Hydro plants accounted for 18.5 percent of total installed capacity for the region by January 1, 1962. This percent has not been altered since the additional hydro capacity in the newly integrated power systems is assumed to be equivalent to the thermal (all plants are of very small scale).\(^{15}\) By assuming that hydro accounts for 15
percent of generation, one can obtain an approximation of the balance between hydro and thermal in the South region as it is here defined. Since this grid has the highest average plant factor for thermal stations, a 70 percent factor has been assumed.

Total Generation of Electricity 1962\(^{16}\) 81 BKWH

\[
\text{Thermal Capacity} = \frac{(81 \text{ BKWH}) \times (.85)}{(8760) \times (.7)} = 11.3 \text{ MKW}
\]

\[
\text{Hydro Capacity}^{17} = \frac{(81 \text{ BKWH}) \times (.15)}{(8760) \times (.5)} = 2.7 \text{ MKW}
\]

Estimate of Total Installed Capacity 14 MKW

\[
\frac{14 \text{ MKW}}{82.4 \text{ MKW}} = 16.9 \text{ Percent}
\]

PART IV—NORTHWEST REGION

This region includes the Northwest economic region, the Baltic Republics of Latvia, Lithuania, Estonia, and Byelorussia SSR. It excludes the Murmansk area, since it is not interconnected with the Northwest.\(^{19}\) To determine total capacity, the capacity of hydro plants for the region under consideration has been estimated first, and on the basis of 50 percent plant factor, annual generation calculated.\(^{20}\) This was then subtracted from the known annual generation for the
region as a whole, and using a 55 percent plant factor capacity of thermal plants was estimated. Shabad reported a 3.5 MKW capacity for the Northwest as of January, 1963. This is too low in view of the total generation of electric power from the region from which installed KW capacity has been computed.22

| Total Generation of Electricity 1962 | 26 BKWH |
| Thermal Capacity | 26 BKWH |
| | (8760) (.55) |
| = | 5.4 MKW |
| Hydro Capacity | 1 MKW |
| Estimate of Total Regional Installed Capacity | 6.4 MKW |
| Percent of National Total24 | 6 MKW |
| | 82.4 MKW |
| = | 7.2 Percent |

PART V—CAUCASUS REGION.

For this region the absolute shares of hydro and thermal capacities have been calculated first for the Azerbaydzhan Republic and then for the Georgian and Armenian Republics together. This has been done since 90 percent of the generation of power in Georgia and Armenia is from hydroelectric stations, whereas in Azerbaydzhan 85 percent of electricity is generated by thermal plants.25 The capacities calculated were then
aggregated. A 65 percent plant factor for thermal stations and 50 percent for hydro stations again assumed.

Azerbaydzhan

Total Generation of Electricity 1962 \(^{26}\) 8.3 BKWH

Thermal Capacity

\[
\frac{8.3 \text{ BKWH}}{8760} \cdot 0.65 = 1.26 \text{ MKW}
\]

Hydro Capacity

\[
\frac{8.3 \text{ BKWH}}{8760} \cdot 0.15 = 0.29 \text{ MKW}
\]

Armenia and Georgia

Total Generation of Electricity 1962 \(^{27}\) 6.5 BKWH

Thermal Capacity

\[
\frac{6.5 \text{ BKWH}}{8760} \cdot 0.65 = 0.113 \text{ MKW}
\]

Hydro Capacity

\[
\frac{6.5 \text{ BKWH}}{8760} \cdot 0.9 = 1.33 \text{ MKW}
\]

Estimate of Total Installed Capacity 3.02 MKW

Percent of National Total

\[
\frac{3.02 \text{ MKW}}{82.4 \text{ MKW}} = 3.7 \text{ Percent}
\]

PART VI--CENTRAL ASIA REGION.

In determining the installed generating capacity of this region, an estimate of the generation for the part of the Kazakh Republic (the Chimkent area) included, has had to
be estimated. Since the grid does not yet extend into the Turkmen Republic it has not been taken into account. For the region as a whole hydro capacity constituted 50 percent of total (as of the beginning of 1962), but it has been assumed that hydro accounted for only 40 percent of total generation for that year. Plant factor for thermal capacity has been given as 5,200 hours per annum; for hydro 4,700 hours.

<table>
<thead>
<tr>
<th>Total Generation of Electricity 1962</th>
<th>13.04 BKWH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Capacity</td>
<td></td>
</tr>
</tbody>
</table>
| \[
\frac{(13.04 \text{ BKWH}) \times .65}{5200} = 1.4 \text{ MKW}
\] |
| Hydro Capacity                      |            |
| \[
\frac{(13.04 \text{ BKWH}) \times .35}{4700} = 1.1 \text{ MKW}
\] |
| Estimate of Total Installed Capacity | 2.5 MKW    |
| Percent of National Total           |            |
| \[
\frac{2.5 \text{ MKW}}{82.4 \text{ MKW}} = 3.0 \text{ Percent}
\] |

PART VII--NORTHEAST KAZAKHSTAN REGION.

Hydro capacities of known plants have been aggregated for this region, and using a 50 percent plant factor, the generation for 1962 has been estimated. This total has been deducted from that remaining after assigning the Chimkent area to the Central Asian region. For calculations a 65
percent plant factor for thermal plants has been assumed.

Total Generation of Electricity 1962\(^{32}\) 10.3 BKWH

Hydro Capacity 0.83 MKW

Total Possible Generation

\[
\frac{0.83 \text{ MKW} \times 8760 \times 0.50}{8760 \times 0.65}
\]

= 3.7 BKWH

Thermal Capacity\(^{33}\)

\[
\frac{10.3 \text{ BKWH} - 3.7 \text{ BKWH}}{8760 \times 0.65}
\]

= 1.16 MKW

Estimate of Total Installed Capacity 1.99 MKW

Percent of National Total

\[
\frac{1.99 \text{ MKW}}{82.4 \text{ MKW}}
\]

= 2.4 Percent

PART VIII--THE FAR EAST REGION.

It has been estimated that the few scattered, rural hydro stations comprised no more than 2 percent of the 1962 generation of electricity.\(^{34}\) Thermal station plant factor has been notoriously low and it has been assumed that there has been little change from the 1956 figure of 35 percent (upgraded by 5 percent for 1962).\(^{35}\) Only a 25 percent plant factor for rural hydro plants has been used, since these stations are characteristically poorly utilized.

Total Generation of Electricity 1962\(^{36}\) 6.09 BKWH

Thermal Capacity

\[
\frac{(6.09 \text{ BKWH}) \times 0.98}{8760 \times 0.40}
\]

= 1.71 MKW
Hydro Capacity

\[
\frac{(6.09 \text{ BKWH}) \times (0.02)}{(8760) \times (0.25)} = 0.06 \text{ MKW}
\]

Estimate of Total Installed Capacity 1.76 MKW

Percent of National Total

\[
\frac{1.76 \text{ MKW}}{82.4 \text{ MKW}} = 2.1 \text{ Percent}
\]

PART IX--THE MURMANSK REGION.

For this region the capacities of all hydro plants have been aggregated and for the one thermal plant, a capacity of 0.05 MKW has been assumed.

Hydro Capacity

\[
0.68 \text{ MKW}
\]

Thermal Capacity

\[
0.05 \text{ MKW}
\]

Estimate of Total Installed Capacity 0.73 MKW

Percent of National Total

\[
\frac{0.73 \text{ MKW}}{82.4 \text{ MKW}} = 0.9 \text{ Percent}
\]

REFERENCES:

1. Data from Elektricheskiye Stantsii, November 1963, p. 47.


4. Note: 65 percent plant factor just under national average, while the figure for hydro approximately the same.

5. Figure compiled from data in Narodnoye Khozyaystvo RSFSR v 1962 Godu, Statisticheskii Ezhegodnik, (Statistical Yearbook), Tsentral'noye Statisticheskoye Upravleniye pri Sovete Ministrov SSSR, Moskva, 1963, p. 78.

6. For explanation of the method, see Appendix A.

7. This figure corresponds to that obtained if one sums all the known hydro capacity in the region and then makes allowances for Volgograd not being at maximum efficiency, thereby lessening effective capacity. Sum total 5.7 MKW less Volgograd (rated at 2.5 MKW). Data from, Joint Hearings Before the Committee on Interior and Insular Affairs and the Committee on Public Works. United States Senate, Eighty-Fifth Congress Second Session, Water Resource Programs of the United States, Russia and (Red) China, United States Government Printing Office, Washington, D.C., 1958, pp. 203-11.

8. Note: In all cases - likely to be underestimated in view of rural capacity generating comparatively little power.


10. Elektricheskiye Stantsii, loc. cit. At this time (1962) the Votkinsk hydro plant (1.4 MKW) had not been completed and interconnected with the Ural Grid.

11. Figure from, Narodnoye Khozyaystvo RSFSR v 1962 Godu, loc. cit.

12. Result again complies with known capacity, Joint Hearings, loc. cit.

13. Figure from, Narodnoye Khozyaystvo SSSR v 1962 Godu, op. cit., p. 159.

14. See Chapter V.

15. Elektricheskiye Stantsii, loc. cit.

17. Note: hydro capacity was estimated at 1.8 MKW as of 1958, Joint Hearings, loc. cit.


19. See Chapter V.

20. Data on hydro capacity from, Joint Hearings, loc. cit.

21. This is somewhat under the national average since the thermal plants in the region are not deemed to have as high a plant factor as those in the industrialized areas of European Russia - e.g., Center, Urals, and Donbass.


27. Ibid.

28. For discussion see Chapter VI. Of Kazakhstan's 13,3 BKWH generation, 3 BKWH assumed generated within Central Asia region.


30. Ibid.


32. Figure result of deducting 3 BKWH of 1962 generation assigned to the Central Asian region.
33. The figure for hydro capacity includes the Ust-Kamenogorsk, Bukhtarma and Shulba plants; Joint Hearings. . ., loc. cit.


38. See, Joint Hearings. . ., loc. cit.
APPENDIX D
**TABLE I**

**TOTAL INSTALLED CAPACITY AND PRODUCTION OF ELECTRIC POWER**

**HYDROELECTRIC CAPACITY AND PRODUCTION OF ELECTRIC POWER**

**1913 AND BY YEAR 1921-1965**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Installed Capacity MKW</th>
<th>Total Generation MKWH</th>
<th>Hydro Capacity MKW</th>
<th>Hydro Production MKWH</th>
<th>Hydro Capacity as Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1913</td>
<td>1.098</td>
<td>1,945</td>
<td>.020</td>
<td>40</td>
<td>1.3%</td>
</tr>
<tr>
<td>1921</td>
<td>1.228</td>
<td>520</td>
<td>.018</td>
<td>10</td>
<td>1.6%</td>
</tr>
<tr>
<td>1922</td>
<td>1.247</td>
<td>775</td>
<td>.021</td>
<td>12</td>
<td>1.5%</td>
</tr>
<tr>
<td>1923</td>
<td>1.279</td>
<td>1,146</td>
<td>.026</td>
<td>20</td>
<td>1.6%</td>
</tr>
<tr>
<td>1924</td>
<td>1.308</td>
<td>1,562</td>
<td>.023</td>
<td>30</td>
<td>1.7%</td>
</tr>
<tr>
<td>1925</td>
<td>1.397</td>
<td>2,925</td>
<td>.035</td>
<td>40</td>
<td>1.8%</td>
</tr>
<tr>
<td>1926</td>
<td>1.586</td>
<td>3,508</td>
<td>.028</td>
<td>50</td>
<td>1.8%</td>
</tr>
<tr>
<td>1927</td>
<td>1.698</td>
<td>4,205</td>
<td>.035</td>
<td>286</td>
<td>6.0%</td>
</tr>
<tr>
<td>1928</td>
<td>1.905</td>
<td>9,007</td>
<td>.121</td>
<td>430</td>
<td>6.3%</td>
</tr>
<tr>
<td>1929</td>
<td>2.296</td>
<td>6,224</td>
<td>.126</td>
<td>462</td>
<td>5.4%</td>
</tr>
<tr>
<td>1930</td>
<td>2.875</td>
<td>8,368</td>
<td>.128</td>
<td>555</td>
<td>4.4%</td>
</tr>
<tr>
<td>1931</td>
<td>3.972</td>
<td>10,687</td>
<td>.130</td>
<td>592</td>
<td>3.2%</td>
</tr>
<tr>
<td>1932</td>
<td>4.677</td>
<td>13,542</td>
<td>.154</td>
<td>812</td>
<td>10.7%</td>
</tr>
<tr>
<td>1933</td>
<td>5.583</td>
<td>16,357</td>
<td>.140</td>
<td>1,250</td>
<td>10.8%</td>
</tr>
<tr>
<td>1934</td>
<td>6.315</td>
<td>21,011</td>
<td>.140</td>
<td>2,376</td>
<td>13.1%</td>
</tr>
<tr>
<td>1935</td>
<td>6.923</td>
<td>26,288</td>
<td>.136</td>
<td>3,076</td>
<td>13.7%</td>
</tr>
<tr>
<td>1936</td>
<td>7.529</td>
<td>32,837</td>
<td>.156</td>
<td>4,013</td>
<td>12.6%</td>
</tr>
<tr>
<td>1937</td>
<td>8.235</td>
<td>34,173</td>
<td>.169</td>
<td>4,814</td>
<td>12.7%</td>
</tr>
<tr>
<td>1938</td>
<td>8.441</td>
<td>39,366</td>
<td>.173</td>
<td>5,084</td>
<td>13.1%</td>
</tr>
<tr>
<td>1939</td>
<td>9.894</td>
<td>43,203</td>
<td>.185</td>
<td>4,705</td>
<td>13.0%</td>
</tr>
<tr>
<td>1940</td>
<td>11.193</td>
<td>48,309</td>
<td>.187</td>
<td>5,113</td>
<td>14.1%</td>
</tr>
<tr>
<td>1941</td>
<td>6.665</td>
<td>46,571</td>
<td>.252</td>
<td>4,841</td>
<td>11.2%</td>
</tr>
<tr>
<td>1942</td>
<td>11.124</td>
<td>43,257</td>
<td>.142</td>
<td>6,046</td>
<td>11.5%</td>
</tr>
<tr>
<td>1943</td>
<td>12.338</td>
<td>48,571</td>
<td>.185</td>
<td>7,283</td>
<td>13.5%</td>
</tr>
<tr>
<td>1947</td>
<td>13.677</td>
<td>56,491</td>
<td>.187</td>
<td>7,283</td>
<td>13.5%</td>
</tr>
<tr>
<td>1948</td>
<td>15.157</td>
<td>66,341</td>
<td>.219</td>
<td>9,369</td>
<td>14.4%</td>
</tr>
<tr>
<td>1949</td>
<td>17.149</td>
<td>78,257</td>
<td>.279</td>
<td>11,542</td>
<td>16.3%</td>
</tr>
<tr>
<td>1950</td>
<td>19.614</td>
<td>91,226</td>
<td>.316</td>
<td>12,691</td>
<td>11.3%</td>
</tr>
<tr>
<td>1951</td>
<td>22.117</td>
<td>104,022</td>
<td>.333</td>
<td>13,722</td>
<td>15.0%</td>
</tr>
<tr>
<td>1952</td>
<td>25.250</td>
<td>119,116</td>
<td>.314</td>
<td>14,908</td>
<td>11.1%</td>
</tr>
<tr>
<td>1953</td>
<td>28.602</td>
<td>134,325</td>
<td>.452</td>
<td>19,201</td>
<td>15.0%</td>
</tr>
<tr>
<td>1954</td>
<td>32.815</td>
<td>150,195</td>
<td>.513</td>
<td>18,561</td>
<td>15.6%</td>
</tr>
<tr>
<td>1955</td>
<td>37.236</td>
<td>170,225</td>
<td>.596</td>
<td>23,165</td>
<td>16.1%</td>
</tr>
<tr>
<td>1956</td>
<td>43.470</td>
<td>191,553</td>
<td>.849</td>
<td>28,984</td>
<td>19.5%</td>
</tr>
<tr>
<td>1957</td>
<td>48.397</td>
<td>209,688</td>
<td>10.040</td>
<td>39,429</td>
<td>20.7%</td>
</tr>
<tr>
<td>1958</td>
<td>53.682</td>
<td>235,351</td>
<td>10.856</td>
<td>46,487</td>
<td>20.2%</td>
</tr>
<tr>
<td>1959</td>
<td>59.142</td>
<td>264,020</td>
<td>12.580</td>
<td>47,560</td>
<td>21.2%</td>
</tr>
<tr>
<td>1960</td>
<td>66.721</td>
<td>292,274</td>
<td>14.781</td>
<td>50,913</td>
<td>22.1%</td>
</tr>
<tr>
<td>1961</td>
<td>74.098</td>
<td>327,611</td>
<td>16.366</td>
<td>59,122</td>
<td>22.0%</td>
</tr>
<tr>
<td>1962</td>
<td>82.461</td>
<td>369,275</td>
<td>18.622</td>
<td>71,944</td>
<td>22.5%</td>
</tr>
<tr>
<td>1963</td>
<td>93.050</td>
<td>412,418</td>
<td>20.830</td>
<td>75,859</td>
<td>22.3%</td>
</tr>
<tr>
<td>1964</td>
<td>103.000</td>
<td>512,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td>512,000 (planned)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>