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Population in Relation to Nuclear Energy Potentials

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We shall follow the organization proposed for papers in this section. Accordingly, we begin with existing levels of utilization of nuclear energy for peacetime purposes. We next examine the likelihood that increased utilization of nuclear resources can help to support growing populations over the next twenty-five years at rising levels of living.

The first part of this framework is easily handled. In brief, existing peacetime use of nuclear energy is inconsequential in any of the regions of the world. Significant military applications are obvious but beyond our discussion. The use of radioisotopes for observation, measurement, and other scientific purposes in agriculture, industry, and medicine is also well-known. Such use is pointing the way to important advances which may ultimately be instrumental in promoting mortality declines both directly through improved controls over disease and indirectly through advances in food and industrial technology.

At this point we may well note that present low levels of utilization are not caused by a lack of source materials for nuclear fuels, nor is it likely that future development will be restricted in this way. Careful studies of the distribution of the principal fissionable materials, uranium and thorium, indicate their widespread distribution in the earth's accessible crust and the fact that they constitute a sizable reserve despite their rather low concentration.[1] Of more fundamental importance for the long run is the established ability to obtain artificial fissile substances such as plutonium from a nuclear reaction; and the development of a breeder

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reactor, designed to produce more nuclear fuel than it actually consumes.

Unfortunately, uranium 235, the isotope most readily producing fission, is only one part in 140 in natural uranium. Whether we can eventually utilize all or a good fraction of the uranium in natural uranium, or only seven-tenths of one percent of it is the critical question in determining whether our supply of nuclear fuel is ample or restricted.[2]

The remainder of this brief paper will focus upon atomic power and upon the possibility of new chemicals, structural materials, and related products which might be developed as a result of nuclear energy research. Any such development remains almost wholly for the future. Atomic power exists, but present levels of utilization are either absolute zero or insignificant everywhere. In the United States power is being derived from various nuclear energy installations but nowhere in appreciable amounts. The Soviet Union has indicated that it is putting a 5,000 kilowatt reactor into operation. Power from a few nuclear stations elsewhere is similarly limited.

From present knowledge we realize that the construction of atomic power plants in the future in any part of the world is technically possible. But possibility and probability must be kept distinct, and the development of any world wide network of stations in the decades just ahead seems unlikely. The substantial optimism in some quarters over the sweeping advances in industrial and human productivity which are claimed as derivatives from the introduction of atomic power into areas of limited economic development is certainly not based on any full-scale operating experience. Nevertheless, where the cultural context is favorable and motivation is strong, as in the United States and the Soviet Union, nuclear development will not be determined simply by economic factors. In both countries the goal of full-fledged atomic power development is pronounced. Nuclear products have become symbols in the complex political process of attracting adherents from among the economically less developed nations. Nuclear research is likely to go forward whether atomic power proves to be justified or not in economic terms. Russia is currently providing heavy subsidization for its program, and the United States is similarly underwriting a good part of the cost of research and development in that country. Alfonso Tammaro, assistant general manager for research and industrial development for the United States Atomic Energy Commission indicated in July that several hundred million dollars are going to be spent in research and development in the next five years, with nearly an additional billion dollars likely to go into the construction of prototype plants and pilot models before 1964.[3]

Broad segments of the American public have already accepted atomic power as a fact of life. Leaders of several major industries have in the last two years given public expression to their tremendous confidence in the potentialities of atomic power and have pushed vigorously for nuclear development by private industry. Perhaps this reflects the broad swing of reaction from earlier pessimism. Perhaps it represents a desire not to lose out on a new field with assumed wide opportunities. Whatever the complex causes behind it, the fact that a tremendous confidence in, and drive toward the commercial application of atomic power exists,measurably increases the likelihood of successful development just as apathy and indifference hinder promotion in such a region as Central America. One immediate consequence is that a number of major American businesses are investing relatively large amounts of money in exploratory pure research on nuclear energy, money which yields no immediate profits to the firms involved. Thus, hard economic facts, which we shall consider next, may yield biased answers if the human context is ignored.

One of the most important economic generalizations is this: the capital cost of an atomic power plant will probably exceed that of a comparable steam station based on coal or oil. Barring further innovation, any nuclear station will require the turbine generator which is part of a conventional steam station so that there will be no opportunity for savings here. What is substituted for is the usual boiler in which coal or oil is burned. It is replaced with a considerably more expensive combination of reactor and heat exchanger. Additional costs for chemical and metallurgical facilities will probably continue in the immediate future.

Even if the necessity for a heat exchanger is eliminated by successful developmen of the experimental boiling water reactor, now under consideration, the requisite capital investment can still be expected to exceed that for a comparable coal-steam plant. Perhaps the most optimistic prediction of such investment cost for a light water-moderated boiling reactor to come from a representative of a major industrial corporation is that of Mr. Francis K. McCune, general manager of the Atomic Products Division of the General Electric Company.[4] According to his data, a nuclear plant of 300,000 kilowatt capacity utilizing a boiling reactor would require an investment of $243/kw. This figure includes the nuclear fuel inventory. In a comparable coal station the investment would be $160/kw. The kilowatt-hour cost for the nuclear station when operating at a plant utilization factor of 80 percent is estimated at 6.7 mills against a comparable kilowatt-hour cost of 6.9 mills for a coal station with the same utilization factor.[5]

Mr. McCune presents further data for a graphite-moderated, water-cooled moderator. A competitive kilowatt-hour cost of 6.8 mills is estimated. This depends, however, on employing a reactor with the unusually large capacity of 700,000 kilowatts and operate at a plant utilization factor of 85 percent. It also involves highly optimistic assumptions about a number of underlying factors such as interest rates, depreciation, fuel costs, and reprocessing expenses. In addition to these two types of reactors, the Unite States Atomic Energy Commission intends to support the development of the pressurized-water reactor, the fast breeder reactor, and the homogeneous reactor. Indications are that these reactors will require a greater capital outlay than comparable conventional units.

There are two points in the estimates above which we judge to have particular significance for the utilization of atomic power in regions which look toward extensive economic development as a means of supporting increased populations or raising levels of living or both. These are the extremely large size of plant and the unusually high plant utilization factor which have been assumed in order to produce a competitive cost figure. Such levels do not seem realistic for areas where limited capital is a restrict ing factor and where the market for power is largely undeveloped.

Let us review briefly the reasons for such a conclusion. We know that economic development in general, and atomic power development in particular, require substantial amounts of capital. Lack of necessary capital is a formidable obstacle, particularly so to the regions which show the lowest levels of living and the least consumption per capita of non-human power. The initial investment of $73,000,000 required for a boiling reactor or of $194,000,000 required for a graphite reactor of the size discussed is hardly negligible in itself and yet at any given time must compete with many other types of capital investment needs in any given region. Beyond this, a plant with a capacity of 700,000 kilowatts, or even of 300,000 kilowatts, is meaningless unless there is a market for its output. This implies the need for a very sizable stock of power-using equipment and facilities. For most underdeveloped regions this means in turn a substantial investment in industrial and household equipment and machinery which are power operated.[6]

Strictly from an economic viewpoint there are few parts of the globe outside the major industrial nations where extremely large nuclear reactors can now be rationally located and operated.[7] Power-using equipment and machinery simply are not available in anything like adequate amounts and, because of the size of the investment required to achieve such levels, are not likely to become available in the near future. In regions where rationalized agriculture and industrialization are to be undertaken or speeded up, and where capital is sharply restricted, it is a more reasonable course to construct a limited amount of power capacity initially, say on the order of 10,000 to 50,000 kilowatts, and to apportion the remaining available capital in some balanced distribution among industrial plants, equipment and machinery, agriculture, transportation, housing, education, population control, and so on. Yet such balanced development produces the kind of situation in which a nuclear station tends to be uneconomic. A station of optimum size cannot be built because of lack of demand for power. And for a relatively small nuclear plant the cost of power to the consumer would be high because of the need to spread large initial investment costs over a relatively few kilowatt hours produced. Moreover, it is rare that a plant utilization factor of 80 percent or more can be achieved, especially where part of the power is consumed by households with the result that peak capacity must exceed average kilowatt-hour use throughout the day. United States steam plants typically operate at only a 50 percent plant factor. If this level of utilization is substituted for the higher figures in Mr. McCune's estimates, kilowatt-hour costs rise by roughly four to five mills. Such costs become about 11 to 12 mills instead of 6.7 and 6.8 mills.[8]

In addition, there are serious problems of acquiring skilled personnel to man the programs; of developing a whole series of auxillary engineering activities needed to support a major nuclear energy installation; and so on. These are costly items, especially where money must be borrowed. Both capital cost and interest rates in underdeveloped areas are well above United States levels. If, as we believe, more capital is required per kilowatt for a nuclear station than for a steam station, then such regions will be penalized additionally for nuclear development. For an assumed situation not greatly different from that presented by Mr. McCune, we have shown that a difference of three percent in the interest rate on borrowed capital between regions (a difference which is less than that between the average of the major industrialized and non-industrialized nations) can result in an increase of 2.5 mills in the cost of a kilowatt hour of electricity.[9] It is in fact to the principal industrialized nations, like the United States and the Soviet Union, that atomic power is likely to be most meaningful. These already have to varying extents the capital needed or can get it at lowest cost. They have the best supply of needed scientists, engineers, and technicians. They are capable of absorbing large blocs of additional power. And they are most strongly motivated politically to move ahead with an atomic program.[10]

We conclude that by 1975 it is not likely that atomic power will have made a major contribution toward supporting expanding populations at rising per capita levels or living. By itself it can hardly serve as an open sesame to rapid industrialization. And if employed in small quantities, perhaps under subsidy, it may well fail to promote a rate of technological growth sufficiently rapid to keep ahead of the rate of population growth in densely populated regions of demographic types one through three.

Especially in the midst of a recurring wave of optimism about the potentialities of atomic power, we believe these things need to be said. But they are not the whole story and alone they undoubtedly understate the significance of atomic power.

We have no way of knowing the new production processes and products which may develop as dividends of a nuclear energy program. Noting the somewhat parallel instance of the automotive revolution (most meaningful again to the western nations), we would be hard-shelled pessimists to deny the strong possibility that the development of new chemicals, alloys, and metals and the use of atomic power in new production processes can have far-reaching and unanticipated effects. Specifically, such occurrences may produce savings and additional revenues which can counterbalance the costly operations involved in producing atomic power alone. In underdeveloped regions it may become possible to combine atomic power production with other major development projects such as irrigation and the desalting of brackish water in such a way as to afford an attack on several obstacles to industrialization at one time. Capital savings may be achieved in particular phases of an industrialization program.[11] Or we may find that an atomic power plant can be used for purposes for which conventional oil and steam stations are unsuited. Unanticipated consequences of such character may even force a reassessment of our previous conclusion that atomic power will prove of greater significance to major industrialized nations than to underdeveloped regions. At present there are no facts available either to support or to deny such possibilities nor to indicate when or where new applications may produce revolutionary changes.

Footnotes

1. J. R. Menke, "Nuclear Fission as a Source of Power," Econometrica: 15-4 (October 1947), pp. 321-324.

2. Joint Committee on Atomic Energy, Report of the Subcommittee on Research and Development on the Five-Year Reactor Development Program Proposed by the Atomic Energy Commission (Washington: Government Printing Office, 1954), p. 20

3. The Evening Bulletin (Providence, Rhode Island), July 22, 1954, p.3, col. 1.

4. Presented to a meeting arranged by the Atomic Industrial Forum, Inc., in Washington in May 1954. Published in A Forum Report: Nuclear Reactor Development (New York: Atomic Industrial Forum, Inc., 1954).

5. Mr. McCune's data appear in Appendix A to this paper.

6. A.J. Brown, Applied Economics (London: George Allen and Unwin, Ltd., 1947.

7. "Atomic Energy — Its Future in Power Production", Chemical Engineering: 53-10 (October 1946), pp. 125-133.

8. Based on independent calculations by the authors set forth in Walter Isard and Vincent Whitney, Atomic Power: An Economic and Social Analysis (Philadelphia: The Blakiston Company, 1952), chapter 2.

9. Ibid., p. 64.

10. Ibid., chapter 9.

11. Cf. Sam H. Schurr and Jacob Marschak (directors), Economic Aspects of Atomic Power (Princeton: Princeton University Press, 1950), pp. 267-270.

Appendix A

Below are presented the date of Mr. Francis K. McCune referred to on page 4 of this paper. These are reproduced from A Forum Report: Nuclear Reactor Development (New York: Atomic Industrial Forum, Inc., 1954), pp. 64-65, where they appear as Figures 2, 3, and 4.

Figure 1. Plant Data (for a boiling reactor plant and a steam plant based on coal).

	Boiling Reactor Plant	Coal Plant
Electrical Output (net capability)	300 m w	300 m w
Plant Utilization Factor	0.8	0.8
Steam Temperature	450°F(sat.)	1000°F
Pressure	421 psia	1450 psia
Net Plant Thermal Efficiency	24%	35%
Heat Generated	1250 m w	857 m w

Figure 2. Total Investment.

	Boiling Reactor Plant	Coal Plant
Physical Plant	$195/kw	$140/kw
Land	2	2
Engineering	15	11
Start Up	14	7
Nuclear Fuel Inventory	17	
	$243/kw	$160/kw

Figure 3. Cost of Electricity

	Boiling Reactor Plant	Coal Plant
Fixed Charges	4.65 mills/kwhr	3.0 mills/kwhr
Operating Cost	.70	.5
Fuel	1.35	3.4*
Total	6.7 mills/kwhr	6.9 mills/kwhr

* Coal at 35c/million BTU