CAN TECHNOLOGY SOLVE THE MATERIALS-NEEDS PROBLEM OF THE WORLD?

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As I search for the answer to this question I am reminded of the young engineer who, as he was pondering over an intricate problem of engineering, was asked, "Are you working on the solution to the problem or are you a part of the problem?" That is the question each of us may be asked as we are pondering over the issue of population pressure and the problems that relate thereto. We are part of the problem; this makes objectivity difficult.

I propose to demonstrate to you that technology can supply the materials-needs for the present population, and even for a higher population, for several hundred years, but that serious problems confront us in the next century even with the present population level. I shall also suggest what could be our potential food supply in the next thousand or several thousand years.

Some limitations we face in the near future.—Let us first consider some of the serious limitations, as well as some of the adequate resources, and some changes in materials that we can anticipate in the near future. Presently the rich ore deposits and fossil-fuel supplies are rapidly being depleted or nearing exhaustion. For several hundred years the energy resources of atomic and solar energy should

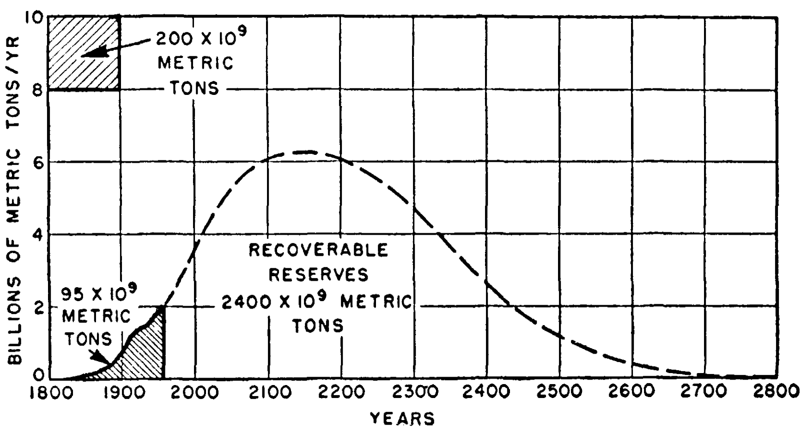

FIGURE 1. Ultimate world coal production (Brown, 1957).

be abundant. However, our technology will be considerably modified because of the limitations of the only available or reasonably priced metals. This may impose a serious limitation on our food and clothing supply. Most of our articles of clothing will be synthetic. Food can be plentiful if we are willing to modify our diet considerably and can work out effective methods of distribution. It is difficult to predict how long we can continue to supply food, fuel, and clothing because of our limited knowledge of such simple problems as the continued supply of phosphorus for fertilizer, or our ability to utilize solar power to concentrate atomic fuels (an extended use of water power) for this purpose.

These are some of the problems you must consider as you project your thinking into the future—beyond the next 100 years.

The rise of techology.—In 1850, 94 percent of the heavy work in this country was done by man and 6 percent by machines; in 1950 these percentages were reversed. This gives us a picture of the rise in technology in the United States in the last 100 years. This is quite significant because it does infer tremendous changes in our mode of living through technology. It is said today that 50 percent of the jobs in the country can be traced back to research laboratories where the discoveries are made which make it possible to develop technology (Meier, 1956).

This background becomes an important factor as we consider what our technological potential is and how we are making use of it in the country. Once we have the know-how and our citizenry is organized to make use of it, the question you will be concerned with is whether our technology will have materials to use—the natural resources, the fuels, and the materials to produce our machines, our food, our shelter, and our fuels.

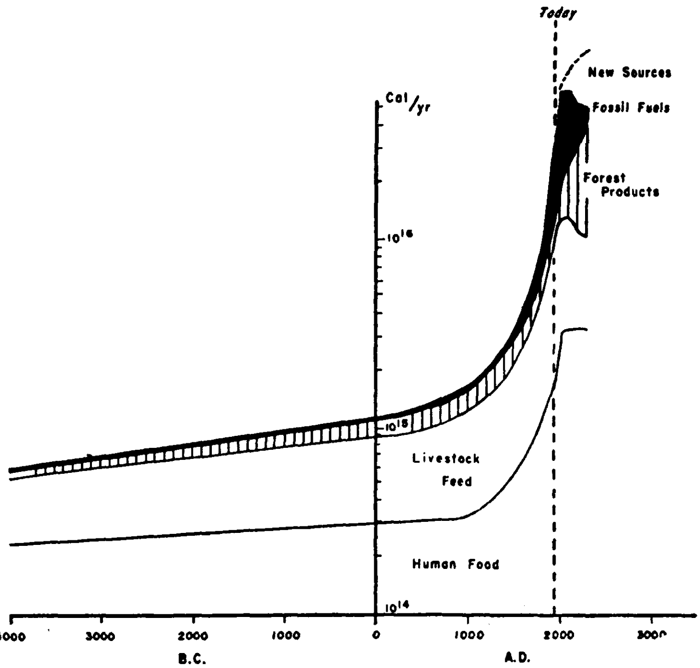

FIGURE 2. Energy use over historical time (Meier, 1956).

The fuel resources.—We have already consumed a tremendous amount of our world fuel supplies. In the United States very likely we have consumed more of our total natural resources in the past 50 years than did the whole world in the previous 50 centuries. There is a tremendous demand on our resources as a result of the increase in technology.

Figure 1 indicates that some place in the period around 2100 or 2200 A.D. we will go through the maximum consumption of fossil fuels.

If you are projecting your ideas about available resources beyond 1000 years, you realize we run into very serious resource problems. For example: We have about one-half of the world's coal supply in the United States and it is estimated that somewhere around 2200 we'll run through the peak of production in the United States. The rest of the world may continue to use coal for a longer period because they are not now using it as rapidly as we are. However, there is certainly a definite period within the next 1000 years when our rich fossil fuel supplies will be depleted (Brown, 1957; Hubbert, 1949).

The petroleum reserves.—The petroleum reserves are very difficult to predict. It is very likely that in about 50 years most of our rich petroleum supplies may be depleted. In several states in the United States we have gone through the peak of production already.

Efficiency in use of fuels.—Figure 2 gives pause for concern with reference to the raw materials that technology must make use of in producing food and clothing. For a long time there was very little change in the kinds and the amount of fuels including food and livestock food. But you see that since 1800 this increase has been tremendously dramatic and it continues to go up. That is a very disturbing fact to peoples of the world today.

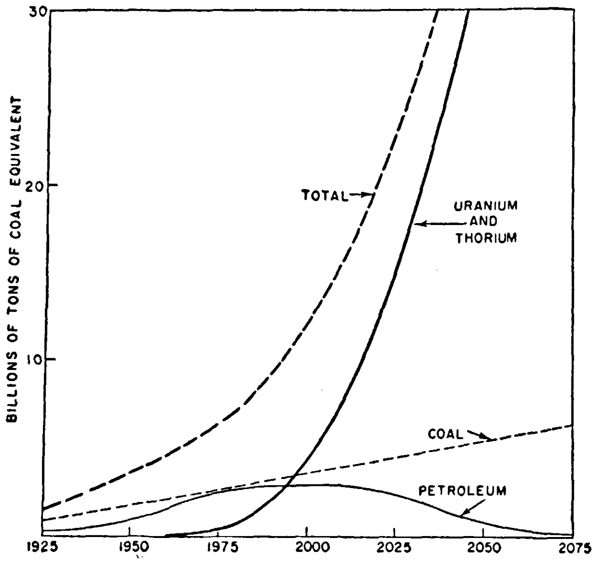

FIGURE 3. World energy consumption in the next century—a possible pattern (Brown, 1957).

Energy resources other than coal and oil.—If our fossil fuels are depleted, you may raise the question "What's the possibility of other energy sources?"

Of course, the best source, if we could use it effectively, is solar power. It is very likely that within the next 50 or 100 years we will make considerable progress in trapping solar energy; but until that comes about, we'll be using nuclear fuels. Figure 3 shows you about the time that atomic fuels will be used heavily. It is estimated that about 1970 atomic fuels will be in favorable competition with fossil fuels. And when the the cost curve for atomic fuels goes below that for fuels for steam power to make electricity, you will find a tremendous development of atomic fuels in place of coal and oil. When that comes about, the curve with reference to the rate of use of fossil fuels will change considerably. The use of atomic fuels will change considerably. The use of atomic fuels can extend the life of our fuel reserves by a factor of about twenty. If we can use the nuclear reactor using hydrogen and other light elements, we can extend fuel resources almost indefinitely.

The fuel problem is one that can be taken care of and we can have fuel supplies for a very long time.

The growth in the world's population.—Figure 4 gives the rate of increase in the population of the world.

In figure 5 we find the possible projections of the world's population to year 2000 and extrapolated to 3000 and 4000 (with uncertainties represented by the area between the branched extrapolations.)

When you compare graphs of the sort with the ones for fuel consumption, you can see they are almost superimposable.

Figure 6 shows the rapid increase in population of the United States.

Our natural resource reserves.—The really critical items as far as materials-needs are concerned are the ores as sources of metals. This is a fact most people do not recognize. They think in terms of food instead of in terms of metals to make the machinery help to raise and transport the food. This is the critical and startling part of the whole story.

The high grade iron ores in the United States will be exhausted in the next 100 years. The medium grade iron ores may last at the present rate of usage about 300 years.

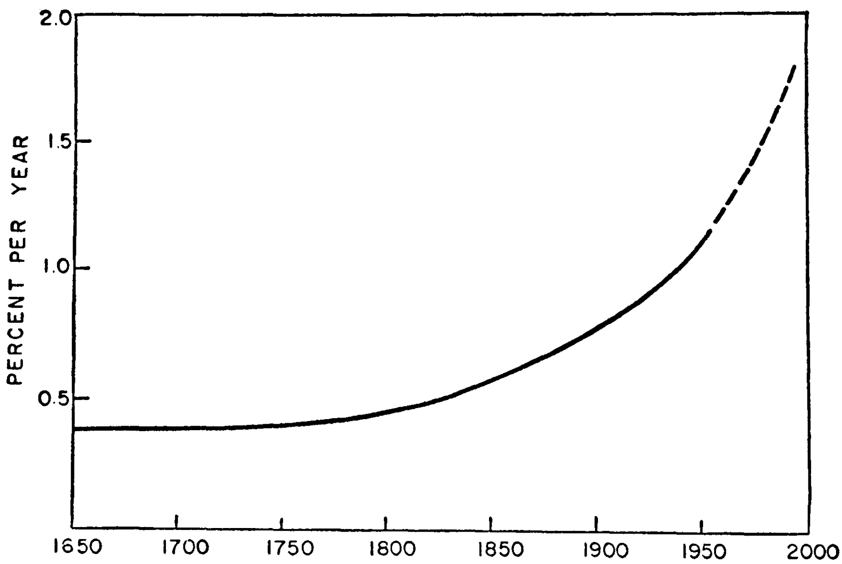

FIGURE 4. Annual rates of increase of world population (Brown, 1957).

Rich aluminum ores run about the same as iron in abundance. Rich oil reserves are limited. We import roughly half of our aluminum ores at the present time. It is true that ordinary clay contains 6 to 8 percent aluminum; if economical methods to extract it from clays can be developed, we have enough aluminum ore to last a long time; but it is very expensive to make metal from ores of low concentration. You can afford to do it for an expensive metal such as copper. We are now extracting copper from ores as lean as 0.3 percent (Brown, 1954). The magnesium reserves are much better than aluminum. We now extract all the magnesium we use from sea water. It can be extracted from brines which represent a very large reserve.

But here is the rough spot, iron and oil are our main materials for today's technology and these materials are severely limited.

How much food can the world produce?—Assuming fuel supplies and metals are available for manufacturing the machinery necessary for food production, table 1 gives some projections from Harrison Brown (Brown, 1957) with reference to amount of food that can be produced. This answers what technology can do for food production. More lands can be put in operation. Algae farms can be used. The productivity per acre can be increased. Brown's summation is that

TABLE 1

The World's Estimated Food Potential (after Brown)

Existing food production (given a base rating)	1.0
Production possible from existing land, using known conventional agricultural techniques	1.1
Production possible from existing cultivated land plus 1.3 billion new acres of tropic and northern soils	2.0
Production possible from existing land, using supplemental irrigation of 1 billion acres now under cultivation and complete irrigation of 200 million acres of desert and near-desert land	2.0
Production possible from all above sources	3.0
Production possible from above sources plus increased yields due to improved plant-breeding and selection and foreseeable improvements in agricultural techniques	6.0
Production possible from 100 million acres of algae farms	2.0
Production possible from all sources, including 1 billion acres of algae farms	25.0

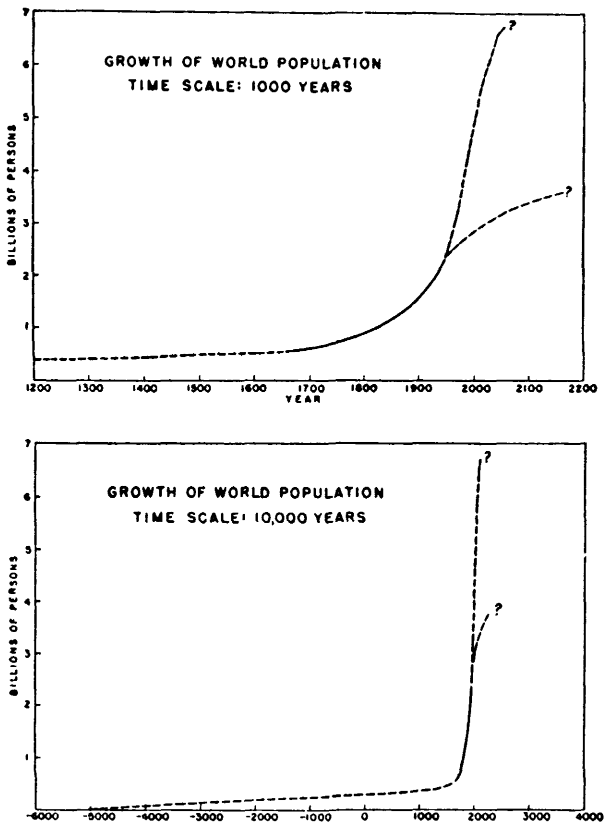

FIGURE 5. Growth of world population (Brown, 1954). Time scale: 1,000 years (top). Time scale: 10,000 years (bottom).

food production, utilizing all conceivable means, could be increased about 25-fold. Brown's estimate is simply what technology could do if we have adequate fuels, metals, and fertilizers. This 25-fold increase is simply the upper limit of what technology could ever achieve.

But what other problems must be faced?—If you think of the present world population of 2.5 billion to which sufficient food is not available (even in spite of great surpluses in some areas) because of major problems in distribution resulting in two-thirds of this mass of people going to bed hungry every night, you can prepare yourself to consider some of the great problems facing the world if the population doubles. We can expect many problems other than just raising the food. Furthermore, many of our foods may have to be changed radically. We may have hamburger sandwiches made of algae; "wheaties" made of sawdust fortified with enzymes (man doesn't have enzymes to split the cellulose to glucose); —a whole series of new developments of that sort are feasible. However, there are

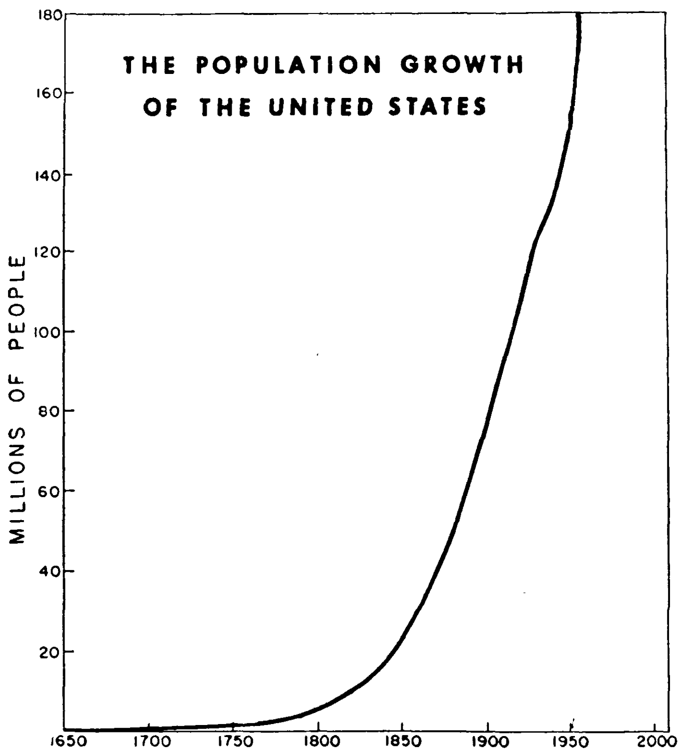

FIGURE 6. The population growth of the United States.

other limitations that must be considered when you think even of doubling let alone of quadrupling human populations. These limitations are not now necessarily in raw materials but rather they involve the human factor. Brown says, "If we are willing to be crowded together close enough and eat foods which bear little resemblance to the foods we get today and be deprived of simple and satisfying pleasures such as fireplaces, gardens, and lawns, a world population of 50 billion persons would not be out of the question.

"If we really put our minds to the problem, we could construct islands where people could live and algae forms could function, perhaps a 100 billion people might be possible.

"If we set strict limits to physical activity so calorie requirements could be reduced to an absolute minimum, perhaps as many as 200 billion persons could be possible. Again this is consistent with active data as far as technical requirements are concerned."

Solution to the human factor limitation.—McKelvey (1959) points up this problem in the following statements: "Resources of usable raw materials and energy may be increased to an unpredictable extent by the development and use of *ingenuity*. The most fundamental stimulus to ingenuity is the basic idealogy that challenges, encourages, and rewards individual initiative, gives freedom of thought, creates a desire for economic gain and a thirst for knowledge."

Summary.—The recent rapid development of technology in our own country is good evidence of the possibility for continued development and effectiveness of technology for the future.

All things considered, a factor of 25 seems to be the extreme upper limit which is conceivable for the future as far as food production is concerned; the world population might go to 200 billion but more likely 100 billion is the maximum possible limit.

The limiting factors for the next hundred are not the materials-needs factors alone but the social, political, and economic factors. These are the major ones for any increase in the world population.

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