What Is Ecological Scarcity?

Ecological scarcity is an all-embracing concept that encompasses all the various limits to growth and costs attached to continued growth that were mentioned above. As we have seen, it includes not only Malthusian scarcity of food but also impending shortages of mineral resources, biospheric or ecosystemic limitations on human activity, and limits to the human capacity to use technology to expand resource supplies ahead of exponentially increasing demands (or to bear the costs of doing so). We have seen diminishing returns, which have overtaken not only agricultural production but every other economic activity as well; the limits to the efficiency of pollution control and of energy conversion, the need to mine ever-thinner ores to get the same useful quantity of metals, the need to pour ever-more money and energy into the maintenance of the basic technological infrastructure, and so on. Instead of being able to do ever more with ever less or to substitute one resource for another indefinitely, as economists often claim is possible, we shall have to spend more money, energy, and social effort to obtain the same quantity, or even a diminished quantity, of useful output. Furthermore, most proposed technological solutions to the problems of growth call for more materials (often materials of a very particular and scarce type), create more pollution (or demand more technological solutions to control it), require more energy, and absorb more human resources. Thus the costs of coping with each additional increment of growth rise inexorably and exponentially.

We have also seen that, in general, all sectors are interacting and interdependent, so that on the one hand, the combination of sectoral micro-problems creates an almost overwhelming macro-problem, while on the other hand, the solutions to the macro-problem (as well as those to most of the separate micro-problems) depend on the questionable availability of a host of factors that may be in least supply. Thus problems exacerbate each other. Also, the solution to one micro-problem is often inconsistent with the solution to other micro-problems or is dependent on the solution of still another problem, which depends in turn on the solution to a third problem, and so on. Nothing less than a coordinated strategy that takes into account the full ensemble of problems and their interactions can hope to succeed.

Thus, stating that ecological scarcity will one day bring growth to a halt is much more than merely asserting that the earth is finite and that growth must therefore cease some day in the future. Ecological scarcity is indeed ultimately grounded on the physical scarcity inherent in the earth's finitude, but it is manifested primarily by the multitude of interacting and interdependent limits to growth that will prevent us from ever testing the finitude of the biosphere and its resources. In fact, as we shall see, ecological scarcity has already begun to restrain growth.

The overall course of industrial civilization as it responds to ecological scarcity is illustrated graphically in Figure 3-3 by the familiar sigmoid or logistic growth curve. In the period between A and B, the ecological and other resources necessary for growth are present in abundance (at least potentially), and splendid and accelerating growth ensues, as it has during the last 300 years or more. Eventually, however, resources are no longer abundant enough to support further growth, and technological ingenuity can no longer postpone the day of reckoning. At this point of inflection (Q, deceleration begins; in the narrow transition zone (B to D), which is approximately one doubling period wide about the point of inflection, considerable further growth due to momentum occurs, but the ecological abundance that fueled accelerating growth begins to disappear, and the first warning signs of ecological scarcity are quickly succeeded by various negative feedback pressures that start to choke off further growth. Beyond the brief transition period these pressures build up quite rapidly, and deceleration continues until equilibrium (E) is attained. The zone of transition is therefore the most critical section of the growth curve. The entire changeover from accelerating to decelerating growth occurs in a very brief time, especially compared to the seemingly infinite period of growth that precedes it, during which the very idea of limits or scarcity, except as temporary challenges to
ingenuity, seems ludicrous.

FIGURE 3-3 Growth curve of industrial civilization: A, steady state (beginning of accelerating growth); B, end of unrestrained growth (beginning of transition period); C, point of inflection (beginning of deceleration); D, end of transition period; E, terminal steady state.

Thus ecological scarcity becomes evident only once the curve is within the transition zone. This being the case, the mere fact that so many aspects of ecological scarcity have been discussed and debated at great length should be ample evidence that industrial civilization is near or past the point of inflection and confronts the prospect of deceleration to a steady state. Yet, in fact, the controversy continues. As we noted in the Introduction, the time factor is the crux of the debate over the limits to growth, so let us examine in greater detail the question of how far away industrial civilization is from the proximate and ultimate limits to growth.

How Far Away Is Ecological Scarcity?

The evidence is overwhelming that we have entered the transition zone. People can impressionistically observe rising pollution problems, not only in industrial nations but in many over-crowded and over-urbanized developing countries. These were the first signs of thermodynamic bills coming due. Since then, specialists have observed degradation of all three of the biological systems on which the world's economy depends: croplands, forests, and grasslands.

Croplands provide feed, food, and many raw materials that industry uses. Forests provide fuel, lumber, paper, and many other products. Grasslands are the source of meat, milk, leather, and wool. As of 1986, 11% of the earth's land was cropland, 31% was forest, and 25% was pasture. The rest of the earth's land surface had little biological activity; it either was desert or was paved over for human use. Since 1981, the amount of land reclaimed for crops has been offset by an equal amount no longer suitable for agriculture or paved over. The amount of grassland worldwide has declined, as overgrazing turns it into pasture. Forests have been shrinking for centuries and, in the 1980s, at a rapidly accelerating rate. The combined area of the three biologically productive areas has been shrinking since the 1980s, whereas the earth's biological wastelands (deserts and paved areas) have been expanding.

Worse, productivity in two of the earth's three biologically productive areas is also down. Throughout the Northern hemisphere, where forest growth rates are measured, trees are growing more slowly. In
many areas, whole species of trees and even local forests are dying from acid rain, ozone, and other stresses. Grassland destruction is occurring on every continent, as grazing exceeds the carrying capacity of the land. Even in the United States, a majority of the grassland is in fair to poor condition. As grassland deteriorates, soil erosion accelerates and the capacity to carry livestock is reduced further; eventually, the area turns into a desert. Livestock growers then seek grain from cropland for their animals, putting increased pressure on farmers, whose production of food per capita has not kept up with the increase in human population since 1988.

According to Stanford University biologist Peter Vitousek, humans now appropriate 40% of the land's net primary biological product. Net primary biological product is the amount of energy that primary producers capture via photosynthesis, less the energy they use in their own growth and reproduction. In other words, 40% of the earth's land-based photosynthetic product either is used by humans or has been lost as a result of the alteration of ecosystems by human activity. This means several things. First, as the human impact on the environment increases, other species will find it more difficult to survive. Eventually they will not survive, and human life-support systems will begin to unravel. Second, "eventually" is not so far off. Let us assume a constant level of per capita resource consumption. Then if 5 billion human beings appropriate 40% of the land's NPP, 10 billion human beings will appropriate 80%; before the population got to the projected 14 billion by 2100, humans would have consumed the entire, world's net primary biological product, which is impossible. Indeed, even 80% is ecologically impossible; humans cannot survive without the survival of ecosystems made up of other species, most of which would be dead by that point.

As the example of the lily pond makes clear, time is running out. Just as demand for various biological products is increasing to keep up with human population growth and appetites, the carrying capacity of the earth is decreasing with the depletion and degradation of resources (Figure 3-4). Indeed, most ecologists would argue that the carrying capacity has already been exceeded whenever one can observe dangerous levels of pollution, serious ecological degradation, or widespread disturbance of natural

![Figure 3-4](image)

**FIGURE 3-4 Growth versus carrying capacity. If growth results in environmental degradation, the carrying capacity is progressively reduced.**

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balances, all of which are readily observable today. Thus, although precise forecasting is not possible, the available quantitative evidence rather strongly suggests that industrial civilization will be obliged to make an abrupt transition from full-speed-ahead growth to some kind of equilibrium or steady-state society in little more than one generation—and that the process of deceleration has already begun.

The Historical Significance of Ecological Scarcity

The essential meaning of ecological scarcity is that humanity's political, economic, and social life must once again become thoroughly rooted in the physical realities of the biosphere. Scarcity and physical necessity have not been abolished; after a brief historical interlude of apparently endless abundance, they have returned stronger than ever. Because of ecological scarcity, many things that we now take as axiomatic will be inverted in the near future. For example, during the growth era, capital and labor were the critical factors in the economic process; henceforth, land and resources (that is, nature) will be critical. In addition, because the United States, Europe, and Japan—the so-called "haves"—are now living to some extent beyond their ecological means, they may turn into ecological and economic "have nots," while some current "have nots" who are comparatively resource-rich will suddenly become the new "haves." (This transformation is already under way.) All the institutions and values that characterize industrial societies and are predicated on continuous growth will be confronted with ruthless reality tests and revolutionary challenges. Above all, the sudden coming of ecological scarcity means that our generation is faced with an epochal political task. The transition is under way regardless of our wishes in the matter, so our only proper course is to learn how to adapt humanely to the exigencies of ecological scarcity and guide the transition to equilibrium in the direction of a desirable steady-state society.

The great danger from the sudden emergence of ecological scarcity is that we will not respond to its challenges in time. We have already seen that time is probably our scarcest resource; the sheer momentum of growth, the long time constants built into the biosphere, and above all, social response rates that for various reasons lag behind events (and are in any event governed by the factor in least supply) all predispose the world system and most of its subsystems to overshoot (exceed) the level that would be sustainable over the long term. But the inevitable consequence of overshoot is collapse. The trend depicted in Figure 3-4 cannot continue in the real world, for environmental demand can never long exceed the carrying capacity. Figure 3-5 represents the three basic real-world possibilities: (a) smooth convergence on the optimal equilibrium level (which is, as noted above, unlikely); (b) overshoot and collapse with eventual convergence on a relatively high equilibrium level; and (c) overshoot and collapse to a significantly lower than optimal equilibrium level because the carrying capacity has been drastically eroded by the destructiveness associated with the overshoot.
FIGURE 3-5 (Left) Three scenarios for the transition from growth to maturity: (a) smooth transition to equilibrium with minimal erosion of carrying capacity; (b) overshoot with substantial erosion of carrying capacity; (c) overshoot with drastic erosion of carrying capacity.

Because the earth's carrying capacity is clearly being depleted and degraded, we are speeding rapidly toward the outcome depicted in Figure 3-5(c), which is highly undesirable for at least three reasons: The suffering and misery created by a large overshoot of the carrying capacity will be enormous. Any large overshoot seems certain to erode the carrying capacity so severely that the surviving civilization will have rather limited material possibilities. And the opportunity to build the basic technological and social infrastructure of a high-level, steady-state society may be irretrievably lost. That is, unless the remaining supplies of non-renewable resources are carefully husbanded and used to make a planned transition to a high-technology steady state, only steady states comparatively poor in material terms will be achievable with the depleted resources left following overshoot and collapse. Thus, although ecological scarcity means that there is no option other than the steady-state society in which people and their demands are in balance with the environment and its resources, the current generation does have a significant say in the type and basic quality of the steady state that will be achieved. The basic policy options are presented graphically in Figure 3-6.

FIGURE 3-6 The ecological history of the world—past, present, and future: I, direct transition to high-level steady state; II, belated transition to somewhat lower-level steady state; III, reversion to pre-modern agrarian way of life.

Throughout most of recorded history, the human race has existed in rough equilibrium with its resource base. Growth occurred, if at all, at an infinitesimal pace; even the population of relatively dynamic Europe grew at much less than 1% a year between A. D. 600 and 1600. But then, very suddenly, the Industrial Revolution rocketed the scale of economic activity upward. With the arrival of ecological scarcity, the rocket cannot continue to rise. The first policy option (transition I in Figure 3-6) is an immediate and direct transition to a steady-state civilization relatively affluent in material terms (however frugal it might seem to many now living in the richest countries). If this option is not taken, overshoot must occasion a fall to a significantly lower steady-state level than could have been achieved by carefully planned and timely action (transition II), or even to a level tantamount to a reversion to the
traditional premodern agrarian way of life (transition III), so that the entire Industrial Revolution from start to finish will appear as a brief and anomalous spike in humanity's otherwise flat ecological trace, a transitory epoch a few centuries in duration, when it momentarily seemed possible to abolish scarcity. In short, we stand at a genuine crossroads. Ecological scarcity is not completely new in history, but the crisis we confront is largely unprecedented. That is, it is not a simple repetition of the classic Malthusian apocalypse on a larger scale, in which nothing has changed but the numbers of people, the ruthlessness of the checks, and therefore the greater potential for misery once the day of reckoning comes. The wars, plagues, and famines that have toppled previous civilizations are overshadowed by horrible checks Malthus never dreamt of (such as large-scale ecological ruin and global radiation poisoning), for these checks are threats to the very existence of the species. On the other hand, we also possess technical resources that previous civilizations lacked when they encountered the challenges of ecological scarcity. Thus in our case a successful response is possible: We can create a reasonably affluent post-industrial, steady-state civilization and avoid a traumatic fall into a version of preindustrial civilization.

This imposing task devolves upon the current generation, and there is no time to lose. Already many trends, such as demographic momentum, cannot be reversed within any reasonable time without Draconian measures. Moreover, as we shall see in Part II, the way ahead is strewn with painful dilemmas. Indeed, nothing can be accomplished without the frustration of many deeply ingrained expectations and the exaction of genuine sacrifices. The epoch we have already entered is a turning point in the ecological history of the human race comparable to the Neolithic Revolution. It will inevitably involve racking political turmoil and an extraordinary reconstitution of the political paradigm that prevails throughout most of the modern world.

Alternative Technology

All forms of alternative, or "soft," technology share certain characteristics. First and foremost, they are closely adapted to natural cycles and processes, so pollution is minimized and as much of the work as possible is done by nature. Second, they are based primarily on renewable, "income" flows of matter and energy such as trees and solar radiation rather than on nonrenewable, "capital" stocks such as rare ores and fossil fuels. Third, the first two characteristics encourage the revival of some labor-intensive modes of production. Fourth, these three together imply the creation of a "low-throughput" economy, in which the per capita use of resources is minimized and long-term thermodynamic and social costs are not ignored for the sake of short-term benefits. Fifth, all of these seem to point to technologies that are smaller, simpler, less dependent on a specialized technical elite, and therefore more decentralized with respect both to location and to control of the means of production. Finally, among the possible social side effects of such alternative technologies are greater cultural diversity, reduced liability to misuse of technology by individuals and nations, and less overall anomie and alienation once individuals have greater control over their own lives than they do under the current technological dispensation.

Naturally, one way to achieve these goals would be to renounce modern science and technology entirely and revert to a low-technology, pre-modern agrarian society, but the proponents of alternative technology are not urging a return to some imaginary paradise of
pristine closeness to nature. They propose instead a creative blend of the most advanced modern science and technology with the best of the old, pre-Industrial Revolution "polytechnics". Yet at the same time, alternative technology is indeed profoundly anti-technological, for it is diametrically opposed to autonomous technological growth of the kind that has produced an ecological crisis. Perhaps technology has not exerted a determining influence on modern society, as some of its more extreme critics maintain, but it is quite evident that during the last 300 years, society has adapted to technology rather than vice versa. In seeking to reverse this situation and bring the technological process under full social control, alternative technology poses a challenge to the current order that is in the broadest sense primarily political, not scientific or technical. (Indeed, most of the essential components of a viable alternative technology, such as solar power, are already known or invented and merely require development; the process of changeover could therefore be quite fast, unlike the Industrial Revolution, which was retarded by the slow pace of invention.) Thus, although alternative technology is technically feasible and could be installed without unacceptable social costs, its adoption will require a revolutionary break with the values of the industrial era.

A major unanswered question is how high the material standard of living will be. Unfortunately, the answer depends largely on how many people there are. It is abundantly clear that "soft" technology is able to provide an ample sufficiency of material well-being to very large numbers of people. On the other hand, it cannot support the materialistic profligacy now enjoyed by the richest one-fifth of humanity. Humanity's affluent economies have emitted two-thirds of the greenhouse gases, three-fourths of the sulfur and nitrogen oxides, most of the world's hazardous wastes, and 90% of the world's chlorofluorocarbons. It is not possible under any scheme for the world to live like today's Americans, for before it could happen, the planet would be laid to waste. One rough estimate is that alternative technology could support a world population of about 1 billion people at the current standard of living of Norway or the Netherlands. Human resourcefulness may establish that this is a gross underestimate. But a world maintained in ecological balance with its resources by means of alternative technology will likely contain fewer people than it does now. And those people will have to be more frugal and contribute more physical labor for their affluence than does the richest one-fifth of humanity today.

-pp. 175-85; Ecology and the Politics of Scarcity Revisited; William Ophuls & A. Stephan Boyan