Minnesotans For Sustainability©

Sustainable: A society that balances the environment, other life forms, and human interactions over an indefinite time period.

A Synopsis

Limits to Growth, The 30-Year Update

Donella Meadows, Jorgen Randers, Dennis Meadows*

2004

The signs are everywhere around us:

- Sea level has risen 10-20 cm since 1900. Most non-polar glaciers are retreating, and the extent and thickness of Arctic sea ice is decreasing in summer.

- In 1998 more than 45 percent of the globe's people had to live on incomes averaging $2 a day or less. Meanwhile, the richest onefifth of the world's population has 85 percent of the global GNP. And the gap between rich and poor, is widening.

- In 2002, the Food and Agriculture Organization of the UN estimated that 75 percent of the world's oceanic fisheries were fished at or beyond capacity. The North Atlantic cod fishery, fished sustainably for hundreds of years, has collapsed, and the species may have been pushed to biological extinction.

- The first global assessment of soil loss, based on studies of hundreds of experts, found that 38 percent, or nearly 1.4 billion acres, of currently used agricultural land has been degraded.

- Fifty-four nations experienced declines in per capita GDP for more than a decade during the period 1990-2001.

These are symptoms of a world in overshoot, where we are drawing on the world's resources faster than they can be restored, and we are releasing wastes and pollutants faster than the Earth can absorb them or render them harmless. They are leading us toward global environmental and economic collapse —but there may still be time to address these problems and soften their impact.

We've been warned before. More than 30 years ago, a book called *The Limits to Growth* created an international sensation. Commissioned by the Club of Rome, an international group of businessmen, statesmen, and scientists, *The Limits to Growth* was compiled by a team of experts from the U.S. and several foreign countries. Using system dynamics theory and a computer model called "World3," the book presented and analyzed 12 scenarios that showed different possible patterns —and environmental outcomes— of world development over two centuries from 1900 to 2100.

The World3 scenarios showed how population growth and natural resource use interacted to impose limits to industrial growth, a novel and even controversial idea at the time. In 1972, however, the world's population and economy were still comfortably within the planet's carrying capacity. The team found that there was still room to grow safely while we could examine longer-term options.

In 1992, this was no longer true. On the 20th anniversary of the publication of *Limits to Growth*, the team updated *Limits* in a book called *Beyond the Limits*. Already in the 1990s there was compelling evidence that humanity was moving deeper into unsustainable territory. *Beyond the Limits* argued that in many areas we had "overshot" our limits, or expanded our demands on the planet's resources and sinks beyond what could be sustained over time.1 The main challenge identified in *Beyond the Limits* was how to move the world back into sustainable territory.

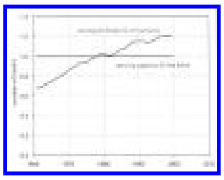
> 1. To overshoot means to go too far, to grow so large so quickly that limits are exceeded. When an overshoot occurs, it induces stresses that begin to slow and stop growth. The three causes of overshoot are always the same, at any scale from personal to planetary. First, there is growth, acceleration, rapid change. Second, there is some form of limit or barrier, beyond which the moving system may not safely go. Third, there is a delay or mistake in the perceptions and the responses that try to keep the system within its limits. The delays can arise from inattention, faulty data, a false theory about how the system responds, deliberate efforts to mislead, or from momentum that prevents the system from being stopped quickly.

The 30-Year Update

Now in a new study, *Limits to Growth: The 30-Year Update*, the authors have produced a comprehensive update to the original Limits, in which they conclude that humanity is dangerously in a state of overshoot.

While the past 30 years has shown some progress, including new technologies, new institutions, and a new awareness of environmental problems, the authors are far more pessimistic than they were in 1972. Humanity has squandered the opportunity to correct our current course over the last 30 years, they conclude, and much must change if the world is to avoid the serious consequences of overshoot in the 21st century.

Ecological Footprint versus Carrying Capacity



(Click image to enlarge)

This graph shows the number of Earths required to provide the resources used by humanity and to absorb their emissions for each year since 1960. This human demand is compared with the available supply: our one planet Earth. Human demand exceeds nature's supply from the 1980s onward, over-shooting it by some 20 percent in 1999. (Source: M. Wackernagel *et al.*)

When *The Limits to Growth* was first published in 1972, most economists, along with many industrialists, politicians, and Third World advocates raised their voices in outrage at the suggestion that population growth and material consumption need to be reduced by deliberate means. Over the years, *Limits* was attacked by many who didn't understand or misrepresented its assertions, dismissing it as Malthusian hyperbole. But nothing that has happened in the last 30 years has invalidated the book's warnings.

On the contrary, as noted energy economist Matthew Simmons recently wrote, "The most amazing aspect of the book is how accurate many of the basic trend extrapolations ... still are some 30 years later." For example, the gap between rich and poor has only grown wider in the past three decades. Thirty years ago, it seemed unimaginable that humanity could expand its numbers and economy enough to alter the Earth's natural systems. But experience with the global climate system and the stratospheric ozone layer have proved them wrong.

All the environmental and economic problems discussed in *Limits to Growth* have been treated at length before. There are hundreds of books on deforestation, global climate change, dwindling oil supplies, and species extinction. Since *The Limits to Growth* was first published 30 years ago, these problems have been the focus of conferences, scientific research, and media scrutiny.

What makes *Limits to Growth: The 30-Year Update* unique, however, is that it presents the underlying economic structure that leads to these problems. Moreover, *Limits* is a valuable reference and compilation of data. The authors include 80 tables and graphs that give a comprehensive, coherent view of many problems. The book will undoubtedly be used as a text in many courses at the college level, as its two earlier versions have been.

World 3

The World3 computer model is complex, but its basic structure is not difficult to understand. It is based in system dynamics —a method for studying the world that deals with understanding how complex systems change over time. Internal feedback loops within the structure of the system influence the entire system behavior.

World3 keeps track of stocks such as population, industrial capital, persistent pollution, and cultivated lands. In the model, those stocks change through flows such as births and deaths; investment and depreciation; pollution generation and pollution assimilation; land erosion, land development, and land removed for urban and industrial uses.

The model accounts for positive and negative feedback loops that can radically affect the outcome of various scenarios. It also develops nonlinear relationships. For example, as more land is made arable, what's left is drier, or steeper, or has thinner soils. The cost of coping with these problems dramatically raises the cost of developing the land —a nonlinear relationship.

Feedback loops and nonlinear relationships make the World3 dynamically complex, ***but the model is still a simplification of reality***. World3 does not distinguish among different geographic parts of the world, nor does it represent separately the rich and poor. It keeps track of only two aggregate pollutants, which move through and affect the environment in ways that are typical of the hundreds of pollutants the economy actually emits. It omits the causes and consequences of violence. And there is no military capital or corruption explicitly represented in World3. Incorporating those many distinctions, however, would not necessarily make the model better. And it would make it very much harder to comprehend.

This probably makes the World3 highly optimistic. It has no military sector to drain capital and resources from the productive economy. It has no wars to kill people, destroy capital, waste lands, or generate pollution. It has no ethnic strife, no corruption, no floods, earthquakes, nuclear accidents, or AIDS epidemics. The model represents the uppermost possibilities for the "real" world.

Readers who want to reproduce the World 3 scenarios of the book can do so themselves, because the authors have prepared interactive World 3 CDs. To order disks, please see back of title page. [See below]

The authors developed World3 to understand the broad sweep of the future —the possible behavior patterns, through which the human economy will interact with the carrying capacity of the planet over the coming century.

World3's core question is, How may the expanding global population and materials economy interact with and adapt to the earth's limited carrying capacity over the coming decade? The model does not make predictions, but rather is a tool to understand the broad sweeps and the behavioral tendencies of the system.

Technology Markets

The most common criticisms of the original World3 model were that it underestimated the power of technology and that it did not represent adequately the adaptive resilience of the free market. Impressive —and even sufficient— technological advance is conceivable, but only as a consequence of determined societal decisions and willingness to follow up such decisions with action and money.

Technological advance and the market are reflected in the model in many ways. The authors assume in World3 that markets function to allocate limited investment capital among competing needs, essentially without delay. Some technical improvements are built into the model, such as birth control, resource substitution, and the green revolution in agriculture. But even with the most effective technologies and the greatest economic resilience that seems possible, if those are the only changes, the model tends to generate scenarios of collapse.

One reason technology and markets are unlikely to prevent overshoot and collapse is that technology and markets are merely tools to serve goals of society as a whole. If society's implicit goals are to exploit nature, enrich the elites, and ignore the long term, then society will develop technologies and markets that destroy the environment, widen the gap between rich and poor, and optimize for short-term gain. ***In short, society develops technologies and markets that hasten a collapse instead of preventing it.***

The second reason for the vulnerability of technology is that adjustment mechanisms have costs. The costs of technology and the market are reckoned in resources, energy, money, labor, and capital.

The Driving Force: Exponential Growth

For more than a century, the world has been experiencing exponential growth in a number of areas, including population and industrial production. Positive feedback loops can reinforce and sustain exponential growth. In 1650, the world's population had a doubling time of 240 years. By 1900, the doubling time was 100 years. When *The Limits to Growth* was published in 1972, there were under 4 billion people in the world. Today, there are more than 6 billion, and in 2000 we added the equivalent of nine New York cities.

Doubling times: A quantity growing according to a pure exponential growth equation doubles in a constant time period. There is a simple relationship between the rate of growth in percentage terms and the time it will take a quantity to double.

Growth Rate (% per year)	**Approximate Doubling Times** (years)
0.1	720
0.5	144
1.0	72
2.0	36
3.0	24
4.0	18
5.0	14
6.0	12
7.0	10
10.0	7

Another area of exponential growth has been the world economy. From 1930 to 2000, the money value of world industrial output grew by a factor of 14 —an average doubling time of 19 years. If population had been constant over that period, the material standard of living would have grown by a factor of 14 as well. Because of population growth, however, the average per capita output increased by only a factor of five.

Moreover, in the current system, economic growth generally occurs in the already rich countries and flows disproportionately to the richest people within those countries. Thus, according to the United Nations Development Program, the 20 percent of the world's people who lived in the wealthiest nations had 30 times the per capita income of the 20 percent who lived in the poorest nations. By 1995 the average income ratio between the richest and poorest 20 percent had increased from 30:1 to 82:1.

Only eight percent of the world's people own a car. Hundreds of millions of people live in inadequate houses or have no shelter at all —much less refrigerators or television sets. Social arrangements common in many cultures systematically reward the privileged, and it is easier for rich populations to save, invest, and multiply their capital.

The Limits

Limits to growth include both the material and energy that are extracted from the Earth, and the capacity of the planet to absorb the pollutants that are generated as those materials and energy are used. Streams of material and energy flow from the planetary sources through the economic system to the planetary sinks where wastes and pollutants end up. There are limits, however, to the rates at which sources can produce these materials and energy without harm to people, the economy, or the earth's processes of regeneration and regulation.

Resources can be renewable, like agricultural soils, or nonrenewable, like the world's oil resources. Both have their limits. The most obvious limit on food production is land. Millions of acres of cultivated
land are being degraded by processes such as soil erosion and salinization, while the cultivated area remains roughly constant. Higher yields have compensated somewhat for this loss, but yields cannot be expected to increase indefinitely. Per capita grain production peaked in 1985 and has been trending down slowly ever since. Exponential growth has moved the world from land abundance to land scarcity. Within the last 35 years, the limits, especially of areas with the best soils, have been approached.

Another limit to food production is water. In many countries, both developing and developed, current water use is often not sustainable. In an increasing number of the world's watersheds, limits have already been reached. In the U.S. the Midwestern Ogallala aquifer in Kansas is overdrawn by 12 cubic kilometers each year. Its depletion has so far caused 2.46 million acres of farmland to be taken out of cultivation. In an increasing number of the world's watersheds, limits have already, indisputably, been exceeded. In some of the poorest and richest economies, per capita water withdrawals are going down because of environmental problems, rising costs, or scarcity.

Another renewable resource is forests, which moderate climate, control floods, and harbor species, from rattan vines to dyes and sources of medicine. But today, only one-fifth of the planet's original forest cover remains in large tracts of undisturbed natural forests. Although forest cover in temperate areas is stable, tropical forest area is plummeting.

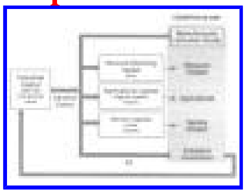
From 1990 to 2000, the FAO reports that more than 370 million acres of forest cover —an area the size of Mexico— was converted to other uses. At the same time that forests decline, demand for forest products is growing. If-the loss of 49 million acres per year, typical in the 1990s, continues to increase at 2 percent per year, the unprotected forest will be gone before the end of the century.

Nonrenewable Resources

A prime example of a nonrenewable resource is fossil fuels, whose limits should be obvious, although many people, including distinguished economists, are in denial over this elementary fact. More than 80 percent of year 2000 commercial energy use comes from nonrenewable fossil fuels —oil, natural gas, and coal. The underground stocks of fossil fuels are going continuously and inexorably down. Between 1970 and 2000, even though billions of barrels of oil and trillions of cubic feet of natural gas were burned, the ratio of known reserves to production actually rose, due to the discovery of new reserves and reappraisal of old ones.

Nonetheless the stock of reserves is finite and nonrenewable. Moreover, fossil fuels use is limited by the planet's capacity to absorb their byproducts after burning, such as the greenhouse gas carbon dioxide. Fossil fuels may be limited by both supply and sinks. Peak gas production will certainly occur in the next 50 years; the peak for oil production will occur much sooner, probably within the next decade. Energy efficiency and renewables offer the best prospect for a sustainable future.

Flows of Physical Capital in the Economy of World3



It is important to distinguish between money and the real things money stands for. This figure shows how the economy is represented in World3. The emphasis is on the physical economy, the real things to which the earth's limits apply, not the monetary economy, which is a social invention not constrained by the physical laws of the planet.

Industrial capital refers here to actual hardware —the machines and factories that produce manufactures products.

The production and allocation of industrial output are central to the behavior of the simulated economy in World3. The amount of industrial capital determines how much industrial output can be produced each year. This output is allocated among five sectors in a way that depends on the goals and needs of the population. Some industrial capital is consumed; some goes to the resource sector to secure raw materials. Some goes to agriculture to develop land and raise land yield. Some is invested in social services, and the rest is invested in industry to offset depreciation and raise the industrial capital stock further.

Materials are another finite resource. If population rises, and if those people are to have housing, health services, education, cars, refrigerators, and televisions, they will need steel, concrete, copper, aluminum, plastic, and many other materials.

But if an eventual nine billion people on earth all consumed materials at the rate of the average American, world steel production would need to rise by a factor of five, copper by a factor of eight, and aluminum by a factor of nine. From source to sink, the processing, fabricating, handling, and use of materials leaves a trail of pollution.

Such materials flows are neither possible nor necessary. Fortunately, growth in materials consumption has slowed, and the prospects for further slowing are good. The possibilities for recycling, greater efficiency, increased product lifetime, and source reduction in the world of materials are exciting. On a global scale, however, they have not yet reduced the vast materials flow through the economy. At best, they have slowed its rate of growth.

Another fundamental limit to growth is sinks —the capacity of the planet to absorb the pollution and waste resulting from human economic activity. The most intractable wastes are nuclear wastes, hazardous wastes (like human synthesized chemicals), and greenhouse gases. They are chemically the hardest to sequester or detoxify, and economically and politically the most difficult to regulate.

Current atmospheric concentrations of carbon dioxide and methane are far higher than they have been in 160,000 years. It may take decades for the consequences of climate change to be revealed in melting ice, rising seas, changing currents, greater storms, shifting rainfall, and migrating insects, birds or mammals. It is also plausible that climate may change rapidly.

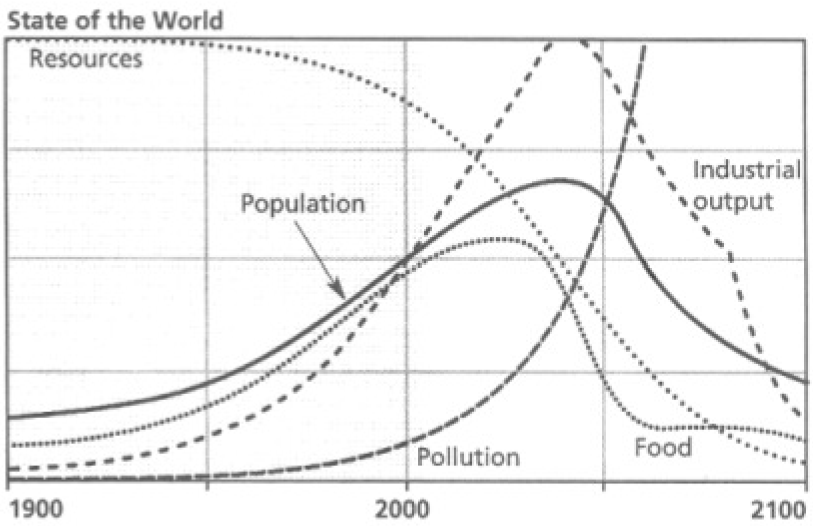
The Scenarios

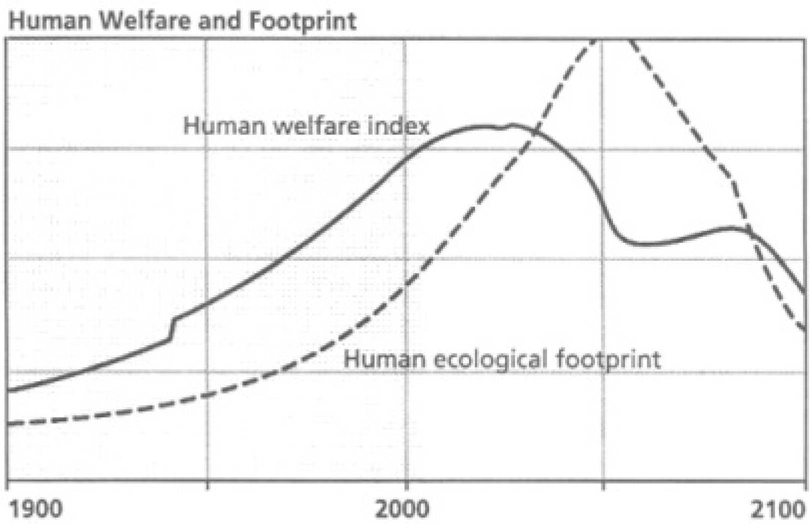
Using the World3 computer model, *Limits to Growth: The 30-Year Update* presents 10 different scenarios for the future, through the year 2100. In each scenario a few numbers are changed to test different estimates of "real world" parameters, or to incorporate optimistic predictions about the development of technology, or to see what happens if the world chooses different policies, ethics, or goals. Most of the scenarios presented in *Limits* result in overshoot and collapse —through depletion of resources, food shortages, industrial decline, or some combination of these or other factors.

Under the "business as usual scenario," world society proceeds in a traditional manner without major deviation from the policies pursued during most of the 20th century. In this scenario, society proceeds as long as possible without major policy change. Population rises to more than seven billion by 2030. But a few decades into the 21st century, growth of the economy stops and reverses abruptly.

As natural resources become harder to obtain, capital is diverted to extracting more of them. This leaves less capital for investment in industrial output. The result is industrial decline, which forces declines in the service and agricultural sectors. About the year 2030, population peaks and begins to decrease as the death rate is driven upward by lack of food and health services.

Scenario 2: More Abundant Nonrenewable Resources





This table postulates that advances in resource extraction technologies are capable of postponing the onset of increasing extraction costs. Industry can grow 20 years longer. Population peaks at 8 billion in 2040, at much higher consumption levels. But pollution levels soar (outside the graph!), depressing land yields and requiring huge investments in agricultural recovery. The population finally declines because of food shortages and negative health effects from pollution.

A similar scenario assumes that the world's endowment of natural resources doubles, and further postulates that advances in resource extraction technologies are capable of postponing the onset of increasing extraction costs. Under this scenario industry can grow 20 years longer. But pollution levels soar, depressing land yields and requiring huge investments in agricultural recovery. The population finally declines because of food shortages and negative health effects from pollution.

Other scenarios address the problems of pollution and food shortages by assuming more effective pollution control technologies, land enhancement (an increase in the food yield per unit of land), and protections against soil erosion.

Even a scenario with these features however, results in overshoot and collapse. After 2070 the costs of the various technologies, plus the rising costs of obtaining nonrenewable resources from increasingly depleted mines, demand more capital than the economy can provide. The result is rather abrupt decline.

If to this scenario one adds reductions in the amount of nonrenewable resources needed per unit of industrial output (resource efficiency technology), in combination all these features permit a fairly large and prosperous world, until the bliss starts declining in response to the accumulated cost of the technologies.

This technology program comes online too late to avoid a gradual decline in human welfare throughout the century. By the end of the 21st century, a stable population of less than eight billion people is living in a high-tech, low pollution world with a human welfare index roughly equal to that of the world of 2000.

But industrial output begins to decline around 2040 because the rising expense of protecting the population from starvation, pollution, erosion, and resource shortage cuts into the capital available for growth. Ultimately this simulated world fails to sustain its living standards as technology, social services, and new investment simultaneously become too expensive.

Transitions to a Sustainable World

The world can respond in three ways to signals that resource use and pollution emissions have gone beyond their sustainable limits. One way is to disguise, deny, or confuse the signals. Generally this takes the form of efforts to shift costs to those who are far away in space and time. An example would be to buy air conditioners for relief from a warming climate, or to ship toxic wastes for disposal in a distant region.

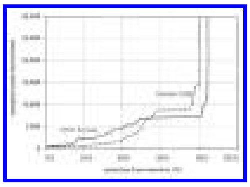
A second way is to alleviate the pressures from limits by employing technical or economic fixes. For example, reducing the amount of pollution generated per mile of driving or per kilowatt of electricity generated. These approaches, however, will not eliminate the *causes* of these pressures. The third way is to work on the underlying causes, to recognize that the socioeconomic system has overshot its limits, is headed toward collapse, and therefore seek to change the structure of the system. World3 can be used to test some of the simplest changes that might result from a society that decides to back down from overshoot and pursue goals more satisfying and sustainable than perpetual material growth.

Scenario 7 supposes that after 2002, all couples decide to limit their family size to two children and have access to effective birth control technologies. Because of age structure momentum, the population continues to grow for another generation. But the slower population growth permits industrial output to rise faster, until it is stopped by rising pollution.

Under this scenario, world population peaks at 7.5 billion in 2040. A globally effective, two children policy introduced in 2002 reduces the peak population less than 10 percent. Because of slower population growth, consumer goods per capita, food per capita, and life expectancy are all higher than in the scenario where the world's endowment of natural resources was doubled.

But industrial output peaks in 2040 and declines. The larger capital plant emits more pollution, which has negative effects on agricultural production. To sustain food production, capital must be diverted to the agricultural sector. Later on, after 2050, pollution levels are sufficiently high to have negative impacts on life expectancies.

Nonlinear Costs of Pollution Abatement



The air pollutant NO_x can be removed from emissions to a significant degree at a low cost, but at some level of required abatement the cost of further removal rises precipitously. The marginal cost curve for NO_x removal is calculated for 2010 for OECD Europe and the former USSR in euros per ton. (Source: J. R. Alcamo et al.)

But what if the world's people decide to moderate not only their demand for children, but also their material lifestyles? What if they set a goal for themselves of an adequate but not excessive standard of living?

If the model society both adopts a desired family size of two children and sets a fixed goal for industrial output per capita, it can extend somewhat the "golden age" of fairly high human welfare between 2020 and 2040 in the previous scenario. But pollution increasingly stresses agricultural resources. Per capita food production declines, eventually bringing down life expectancy and population.

These changes cause a considerable rise in consumer goods and services per capita in the first decade after the year 2002. In fact, they rise higher and faster than they did in the previous run, where industrial growth was not curtailed. But this economy is not quite stabilized. It has an ecological footprint above the sustainable level, and it is forced into a long decline after 2040.

The world of Scenario 8 manages to support more than seven billion people at an adequate standard of living for almost 30 years, from 2010 to 2040, but during that time the environment and soils steadily deteriorate. To remain sustainable, the world in this scenario needs to lower its ecological footprint to a level below the carrying capacity of the global environment.

Scenario 9: World Seeks Stable Population and Stable Industrial Output per Person, and Adds Pollution, Resource and Agricultural Technologies from 2002. Moving in this direction, in another scenario the world seeks stable population and stable industrial output per person, and adds pollution, resource and agricultural technologies starting in 2002.

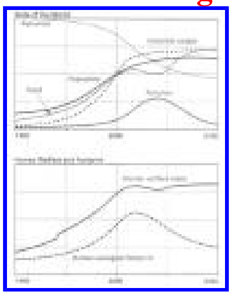
In this scenario, population and industrial output are limited as in the previous run, and in addition technologies are added to abate pollution, conserve resources, increase land yield, and protect agricultural land. The resulting society is sustainable: Nearly eight billion people live with high human welfare and a continuously declining ecological footprint.

Under this scenario, the world decides on an average family size of two children and sets modest limits for material production, as in the previous scenario. Further, starting in 2002 it begins to develop, invest in, and employ the technologies that increase the efficiency of resource use, decrease pollution emissions per unit of industrial output, control land erosion, and increase land yields until food per capita reaches its desired level.

The society of this scenario manages to begin reducing its total burden on the environment before the year 2020; from that point the total ecological footprint of humanity is actually declining. The system brings itself down below its limits, avoids an uncontrolled collapse, maintains its standard of living, and holds itself very close to equilibrium.

In a final scenario, the sustainability policies of the previous scenario are introduced 20 years earlier, in 1982. Moving toward sustainability 20 years sooner would have meant a lower final population, less pollution, more nonrenewable resources, and a slightly higher average welfare for all. Under this scenario, population levels off just above six billion instead of eight billion. Pollution peaks at a much lower level and 20 years sooner, and interferes less with agriculture than it did in the previous scenario. Life expectancy surpasses 80 years and remains high. Life expectancy, food per capita, services per capita, and consumer goods per capita all end up at higher levels than they did in the previous scenario.

Scenario 9: World Seeks Stable Population and Stable Industrial Output per Person, and Adds Pollution, Resource, and Agricultural technologies from 2002



In this scenario population and industrial output are limited, and in addition technologies are added to abate pollution, conserve resources, increase land yield, and protect agricultural land. The resulting society is sustainable: Nearly 8 billion people live with high human welfare and a continuously declining ecological footprint.

Two general insights from this effort are valid and relevant. The first insight is the realization that waiting to introduce fundamental change reduces the options for humanity's long-term future. The second insight is that the model world's goal for industrial goods per capita, even with all the ameliorative technologies, cannot be sustained for the resulting population of more than seven billion.

The final four scenarios also suggest some general conclusions:

- A global transition to a sustainable society is probably possible without reductions in either population or industrial output.

- A transition to sustainability will require an active decision to reduce the human ecological footprint.

- There are many choices that can be made about numbers of people, living standards, technological investment, and allocations among industrial goods, services, food, and other material needs.

- There are many trade-offs between the number of people the earth can sustain and the material level at which each person can be supported.

- The longer the world takes to reduce its ecological footprint and move toward sustainability, the lower the population and material standard that will be ultimately supportable.

- The higher the targets for population and material standard of living are set, the greater the risk of exceeding and eroding its limits.

The Sustainable Society

In 1987, the World Commission on Environment and Development put the idea of sustainability into these words:

> A sustainable society is one that "meets the needs of the present without compromising the ability of future generations to meet their own needs."

From a systems point of view, a sustainable society is one that has in place informational, social, and institutional mechanisms to keep in check the positive feedback loops that cause exponential population and capital growth. This means that birthrates roughly equal death rates, and investment rates roughly equal depreciation rates, unless or until technical change and social decisions justify a considered, limited change in the levels of population or capital.

Such a society, with a sustainable ecological footprint, would be almost unimaginably different from the one in which most people now live. Before we can elaborate on what sustainability could be, we need to start with what it need not be.

Sustainability does not mean zero growth. Rather, a sustainable society would be interested in qualitative development, not physical expansion. It would use material growth as a considered tool, not a perpetual mandate. Neither for nor against growth, it would begin to discriminate among kinds of growth and purposes for growth. It would ask what the growth is for, and who would benefit, and what it would cost, and how long it would last, and whether the growth could be accommodated by the sources and sinks of the earth.

A sustainable society would also not paralyze into permanence the current inequitable patterns of distribution. For both practical and moral reasons, a sustainable society must provide sufficiency and security for all. A sustainable society would not be a society of despondency and stagnation, unemployment and bankruptcy that current systems experience when their growth is interrupted. A deliberate transition of sustainability would take place slowly enough, and with enough forewarning, so that people and businesses could find their places in the new economy.

A sustainable world would also not be a rigid one, with population or production or

anything else held pathologically constant. One of the strangest assumptions of present-day mental models is the idea that a world of moderation must be one of strict, centralized government control. A sustainable world would need rules, laws, standards, boundaries, social agreements and social constraints, of course, but rules for sustainability would be put into place not to destroy freedoms, but to create freedoms or protect them.

Some people think that a sustainable society would have to stop using nonrenewable resources. But that is an over-rigid interpretation of what it means to be sustainable. Certainly a sustainable society would use nonrenewable gifts from the earth's crust more thoughtfully and efficiently.

Suggested Guidelines

The authors do suggest a few general guidelines for what sustainability would look like, and what steps we should take to get there:

- Extend the planning horizon. Base the choice among current options much more on their long-term costs and benefits.

- Improve the signals. Learn more about the real welfare of human population and the real impact on the world ecosystem of human activity.

- Speed up response time. Look actively for signals that indicate when the environment or society is stressed. Decide in advance what to do if problems appear.

- Minimize the use of nonrenewable resources.

- Prevent the erosion of renewable resources.

- Use all resources with maximum efficiency.

- Slow and eventually stop exponential growth of population and physical capital.

The necessity of taking the industrial world to its next stage of evolution is not a disaster —it is an amazing opportunity. How to seize the opportunity, how to bring into being a world that is not only sustainable, functional, and equitable but also deeply desirable is a question of leadership and ethics and vision and courage, properties not of computer models but of the human heart and soul.

Donella Meadows, who died unexpectedly in 2001, was a systems analyst and adjunct professor of Environmental Studies at Dartmouth College. She wrote the nationally syndicated newspaper column "The Global Citizen."

Jorgen Randers is professor and former President of the Norwegian School of Management. He is also former Deputy Director General of World Wildlife Fund International. He lives in Oslo, Norway.

Dennis Meadows has served on the faculties and directed research centers at MIT, Dartmouth College, and the University of New Hampshire. He is President of the Laboratory for Interactive Learning. He lives in Durham, New Hampshire.

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