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**Editor-in-Chief; John Roeder,**
**The Calhoun School**
**433 West End Avenue, New York City 10024**

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# The Meaning of Sustainability

by Albert A. Bartlett
Professor Emeritus, Department of Physics, University of Colorado at Boulder
Albert.Bartlett@Colorado.EDU

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## Background on Sustainability

In the 1960s and 1970s, it became apparent to many thoughtful individuals that global populations, rates of resource use and environmental degradation were all increasing so rapidly that these increases would soon encounter the limits imposed by the finite productivity of the global ecosphere and the geological availability of mineral and fossil fuel resources.

Perhaps most prominent among the publications that introduced the reality of limits in hard quantitative terms was the book *Limits to Growth* (1) which, in 1972, reported the results of computer simulations of the global economy that were carried out by a systems analysis group at MIT. The simulation recorded five parameters for the global economy (population, agricultural production, natural resources, industrial production and pollution) for the period of time from 1900 to 1970 and then projected the computer-generated values of these parameters for the period from 1970 to 2100. For a wide range of input assumptions, the projections predicted a major collapse of world population in the mid-twenty first century. The computed results seemed to show that sustainability of life as we know it may not be an option.

*Limits to Growth* evoked admiration from scientists and environmentalists who were comfortable with quantitative analysis. The study evoked consternation from less quantitative types who tend not to believe in limits. *Limits to Growth* precipitated immediate and urgent rebuttals from the global economic community which proclaimed that human ingenuity can overcome all shortages so that, in effect, there are no limits. (2, 3) The book *Limits to Growth* got people thinking about sustainability.

## The Definition of Sustainability

We must be clear on the meaning of sustainability before we make any more use the term. A very commonly used definition of sustainability is implied in the following definition of sustainable development which is found in the report of the Brundtland Commission of the United Nations (4):

> **Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.**

We must note two important things. First, "future generations" (plural) implies "for a very long time," where long means long compared to a human lifetime." Second, the arithmetic of steady growth shows that steady growth of populations or of rates of resource consumption for modest periods of time leads to sizes of these quantities that become so large as to be impossible. The combination of these two observations leads us to the First Law of Sustainability (5):

> **Population growth and/or growth in the rates of consumption of resources cannot be sustained.**

The First Law is based on arithmetic so it is absolute. Science is not democratic, so the First Law of Sustainability is not debatable; it can not be modified or repealed by professional societies, by congresses or by parliaments. The First Law implies that the term "Sustainable Growth" is an oxymoron. This is true when this term is used by an untutored person on the street, by an economics professor, or by the President of the United States. (6)

## The Brundtland Definition of Sustainability

The Brundtland definition of sustainability is appealing because it has both virtue and vagueness. It is virtuous to give the impression that one is thinking of the wellbeing of future generations, but the definition itself is vague; it gives no specifics or hints about the nature of a sustainable society or about how we must conduct our society in order to become sustainable. This vagueness of definition opens the door for people to use the term "sustainability" to mean anything they want it to mean. It's straight from Alice in Wonderland where Humpty Dumpty proclaims (7), "When I use a word, it means just what I choose it to mean, neither more nor less." With the freedom supplied by the vagueness, anyone can become an expert on sustainability.

Unfortunately, the Brundtland definition contains a flaw. It focuses first on the needs of the present, which have nothing to do with sustainability, and secondarily it mentions the needs of future generations which are vital for sustainability. This sets the stage for intergenerational conflict in which the present generation wins and future generations lose. We need to rephrase the Brundtland definition as follows:

> **Sustainable development is development that does not compromise the ability of future generations to meet their own needs.**

## Peak Petroleum Production and Global Climate Change

Today we face two major global threats to our way of life: the two threats are related and both are predictable consequences of a single cause; overpopulation. The first threat is the peaking of the production (tons per year) of fossil fuels, particularly petroleum. The second threat is the rapidly developing global climate change. As these threats develop, each will have a profound effect on life as we know it. To understand the first threat we need to know about the Hubbert Curve.

## The Hubbert Curve

Back in the 1950s the geophysicist M. King Hubbert noted that a couple of centuries ago the production (in tons per year) of a finite non-renewable resource, such as petroleum, was essentially zero. He reasoned that production would rise to one or more maxima after which it would decline back to zero in another century or two. No matter how erratic the production turns out to be, the curve of production (tons per year) vs. time (years) can be approximated by the Gaussian Error Curve which starts at zero, rises to a maximum and then returns to zero. The area under the curve from zero to infinity is equal to the ultimate size R of the recoverable resource measured in tons. This curve is known at the Hubbert Curve. The important parameter of the curve is the date of the maximum. In the case of petroleum production in the U.S., the peak occurred in 1971, just as Hubbert had predicted years earlier.

The mathematical exercise of fitting a Gaussian Curve to the world petroleum production data shows that if the world's ultimate recoverable quantity of conventional petroleum is 2000 billion barrels, then the peak of world petroleum production could be expected around the year 2004 and the peak moves to a later date at the rate of 5.5 days for every billion barrels that is added to the estimated world supply.(8), (9) In the case of world petroleum today (2012), there is debate among petroleum experts as to whether or not the world peak may have already passed. (10)

The passing of the world peak of petroleum production will be a major milestone for human life on Earth because it will mean that the tons per year of petroleum being produced world-wide will start to decline in its inevitable but erratic descent toward zero. At the same time the world population is projected to be increasing and the world per capita demand for petroleum can also be expected to be increasing. Supplies are decreasing but demand is increasing.

Almost all aspects of our industrial society depend on petroleum, so that, as Richard Heinberg has pointed out, peak petroleum will be quickly followed by Peak Everything. (11) In particular, modern agriculture is completely dependent on petroleum, so the peak of world petroleum production will be followed by the peak of world food production. We will then be facing the specter of declining world food production while at the same time the world population is expected to continue to grow. This is a recipe for famine and conflict.

## The Transition From Production Controlled by Demand to Production Controlled by Supply

Most discussions of sustainability, especially scientific discussions, tell repeatedly of experts who advocate major programs to increase supplies ("Drill baby, drill!") to meet the demands of growing populations. In this scenario, production is governed largely by demand. The more you need, the more you can have. But now, as the peak of global production of petroleum is near, the world is making the transition from the left side of the Hubbert Curve to the right side. On the left side the quantity produced each year is determined largely by demand while on the right side the quantity produced each year is falling so that the quantity produced will be governed mainly by the availability of supplies. As we pass the peak, Nature changes the game. On the left side of the peak, resource shortages are met by increasing production, so the cost of a barrel of petroleum tends over time to rise only slowly. On the right side of the peak, production (barrels per year) is constrained by the availability of supplies of petroleum so that shortages develop and prices rise rapidly.

The discipline of economics has long been accustomed to dealing with life on the rising left side of the Hubbert Curve for most critical resources. On the rising left side we have worked hard to increase resource production in order to meet the growing demand. The big question is, will economics be able to adapt to the completely changed conditions on the right side of the Hubbert Curve where production is determined, not by what we want, but rather by what is available? Will we continue to try to apply left side economics to the right side of the Hubbert Curve?

## Global Climate Change

With regard to the second major threat, global climate change, we can note that (12):

> **If any fraction of the observed global climate change can be attributed to the actions of humans, this is positive proof that the human population, living as we do, has already exceeded the carrying capacity of the Earth.**

This condition is unsustainable. This observation provides a direct identification of overpopulation as the main cause of global climate change. Strangely few, if any, of the experts on global climate change have spoken out to call public attention to the obvious and clear cause and effect connection between overpopulation and global climate change.

## The Cause and Effect Connection Between Overpopulation and Global Climate Change

To the first approximation, the magnitude of the effect of humans in producing global climate change is proportional to the product of the size of the global population P and the average per capita annual consumption of resources, A (tons per (person-year)). The product of P times A is the total annual consumption of resources (tons per year). Already this product appears to have exceeded the carrying capacity of the Earth and the world is briefly in overshoot.

**If we are serious about reducing the causes of global climate change,**
**we must reduce both P and A simultaneously and rapidly throughout the world.**

This defines the task before us. Reduction of P brings us in conflict with the business community that sees more people as more customers. Reduction of P brings us in conflict with various religious groups that oppose any reduction of births and that regard unrestricted reproduction as a basic human right. The reduction in A must be done equitably, recognizing that today (2012) the average annual per capita consumption of resources A, varies by one or two orders of magnitude between our well-to-do western societies and the world's poorest societies.

## The Problem Stated

The problem is apparent at once. Reducing either P or A is completely contrary to the foundations of our religious and economic systems. We are given the impression by "experts" that both P and A must increase continuously if we are to have a "healthy society." How small must P become to be sustainable? David Pimentel, a global agricultural scientist at Cornell University has estimated that a sustainable world population, living at the dietary level of the average American, is about 2 billion people. (13) The world population in late 2011 is estimated to have reached 7 billion people and was growing at the rate of approximately 1% per year! The annual increase of world population in 2012 is thus something like 70 million per year.

**Stopping population growth and stopping the growth of rates of consumption of resources are both necessary, but are not sufficient, conditions for sustainability.**

## The Insufficiency of Popular Prescriptions for Achieving Sustainability

Thousands of individuals and groups are working worldwide on hundreds of aspects of "sustainability." When you look at this work you quickly conclude that all of the usual sustainability prescriptions are valuable, but when you add them all up their sum is much less than what is needed. The reason? All of these efforts fail to address overpopulation! These usual sustainability endeavors include all manner of big research projects and thousands of smaller efforts such as promoting the use of more efficient light bulbs, more efficient automobiles, more efficient homes, expanding and improving the efficiency of the national electric power transmission grid, *etc.*

## Back to the Fundamentals: Malthus

Malthus observed some 200 years ago that population growth has the mathematical power to overcome the limited potential of increasing food supplies. By implication, the meaning of the message of Malthus is that, given sufficient time, population growth has the mathematical power to overcome or negate the limited advances that result from all of the technical achievements of our scientific and engineering establishments.

And if you're wondering where do you get the greatest reduction in greenhouse gas emissions per dollar spent, it is interesting to note that one probably gets more reduction per dollar spent if you spend that dollar on family planning as compared to spending them on any of the "engineering type" solutions that are so popular and widespread. It has been estimated that a dollar spent on family planning will yield about five or more times the reduction of the emission of global greenhouse gases than you get when that dollar is spent on engineering "solutions" that are aimed at reducing the emission of greenhouse gases. (14)

**Growth as the Centerpiece of Our Economy**

In our custom of taking care of ourselves before we think of the future, we are supported by the overwhelming devotion of our society to endless growth which is often called "Sustainable Growth." This oxymoronic concept is the centerpiece of our entire society, in which almost all leaders in our business, governing, and economic communities ignore or deny the existence of limits. The universality of the economic belief that there are no limits to growth gives the present generation reason to believe that there will always be plenty for future generations so that, as a consequence, we need not inconvenience ourselves now by accepting restrictions on our consumption or reductions in our population growth rates. As has been prominently asserted (15),

**The American way of life is not negotiable!**

**Nuclear Fission and Fusion**

In what follows I am assuming that there will be no major scientific or technological breakthroughs in the energy sector in the next century or so. I am uncertain about the role conventional nuclear fission power will play during the next hundred years. In the U.S. we have failed to provide the promised long-term storage for spent nuclear fuel and there seems to be little support in Washington, DC, to find an answer to the problems of what to do with the existing and predictable future quantities of high-level nuclear waste. Nevada has said that it does not want the Yucca Flats nuclear waste depository located in its borders. It could be expected that, if asked, the people in the other 49 states would say that they do not want the nuclear waste to be stored in their states, either. Unless some way can be found around this impasse, the future of nuclear power in the U.S. does not seem to be very bright. Yet if the lights don't come on when one turns on the switch, people will quickly develop strong support for electrical power from nuclear fission.

Conventional nuclear plants are extremely expensive to construct and to operate and they are very complex. They are subject to occasional accidents, which frequently turn out to be very serious. The finite nature of the supply of uranium suggests that nuclear power is not sustainable. So I don't include nuclear fission as a big player in my view of the distant future.

I have even less hope that there will be the successful development and widespread application of nuclear fusion within the next century or two. Fusion research has been continuing since the end of World War II with the hope that fusion will produce large quantities of low-cost electricity. Judging from the size of today's experimental fusion facilities, any plant using fusion to generate electricity will be very large, very complex and very expensive. Fusion still has a long way to go before it can be expected to meet the demands of the electricity market, which requires reliable electric power 24 hours a day and 365 days a year. The uncertainties are so large that I feel that it would be unwise to count on the widespread availability of fusion-generated electricity on any proposed timetable. Therefore, I leave fission and fusion out of the following discussion of sustainability.

## Sustainability of the Solar Society

In the long run, a century or more from now, if our society survives the catastrophic collapse predicted by *Limits to Growth*, the surviving society will be powered solely by solar energy, which includes wind, waterpower, and tidal energy. All of the easily available fossil fuels will have been used to the point where more extraction is uneconomic. Geothermal energy may provide a small fraction of the energy needed by the surviving society. This sounds pretty austere, but the solar society was anticipated with optimism by the famous American inventor Thomas A. Edison many years ago (16):

> **I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that.**

## Sustained Availability

But it is not all doom and gloom. The concept of "Sustained Availability" gives us some freedom to make limited use of fuel and mineral resources during the transition period between the present and the distant future.

Do you remember from calculus that the integral from zero to infinity of $\exp(-kt)$ is finite and has the value $1/k$. This mathematical fact has a useful consequence. Suppose that $P$ is the annual production of a resource in tons per year and that P varies with time according to the equation

$$P = P(0) \exp(-kt)$$

where $t$ is the time in years, $P(0)$ is the present rate of production and $k$ is the fractional change in $P$ per year.

$$k = -(dP/P)/dt$$

For a declining curve, $dP$ is negative. The graph of production in tons per year *vs.* time will be a declining exponential, of the same form as the decay curve for a sample of a radioactive material. The area under the complete curve of tons per year *vs.* years from zero (the present time) to infinity is the total amount of the resource (tons) that is consumed in all of the future. This can be set equal to the estimated size $R$ of the total remaining resource in tons to give a special value of $k$ for which the total resource consumption between now and infinity on the declining exponential curve is equal to the present size $R$ of the resource. In other words, a special value of $k$ can be found for the reserves of a resource so that the production of the resource declines steadily but $R$ lasts forever!

What is the particular value of the constant $k$ which will allow the resource to last forever? This can be answered by example. It has been stated that world petroleum will last 40 years at present rates of consumption. In this case the particular value of $k$ to make world petroleum last forever is ($k = 1/40 = 0.025$). So if the global use of petroleum is made to decline 2.5% per year the petroleum will last forever! This decay curve has a "half life" of 28 years.

It's important to note that:

> **At every point on the decaying production curve, the life expectancy of the then remaining resource will be 40 years at the then current rate of production.**

This has been called "Sustained Availability" (SA). The concept and the options available to a producing country that is following SA to divide production between domestic consumption and export were all examined in mathematical detail in 1986. (17)

More recently, and completely independent of this earlier work, the concept of SA, without the mathematics, has been reinvented and applied to world petroleum production. In the petroleum business, the present rate of production divided by the size of the estimated remaining resource $P(0)/R$ at a given time is called the "Depletion Rate." This is the fraction of the remaining resource that is produced this year; it is the reciprocal of the life expectancy of the resource "at present rates of consumption." World petroleum today (2012) is estimated to last about "40 years at present rates of consumption." The depletion rate is then 2.5% per year.

In 2004 the geologist Colin Campbell of Ireland and the physicist Kjell Aleklett of Uppsala University in Sweden proposed "The Uppsala Protocol" which called for oil producing countries to agree voluntarily to an accord (18):

> **No country shall produce oil at above its current Depletion Rate, such being defined as annual production as a percentage of the estimated amount left to produce.**

Thus, qualitatively Campbell and Aleklett independently re-invented the concept of Sustained Availability that had been published eighteen years earlier.

The concept of Sustained Availability (the Uppsala Protocol) can be applied to the finite reserves of any non-renewable fuel or mineral resource. The rate of decline, $k$, can be adjusted at any time based on new evaluations of the life expectancy of the resource "at present rates of consumption."

This is pretty good. We can use finite resources, such as petroleum, on declining curves in a way that allows future generations to access the resources just as the present generation does but in declining amounts each year. This path for resource production has the unique feature, noted above, that at every point on the declining exponential curve, the life expectancy of the then remaining petroleum at the then present rate of consumption will be 40 years!

We now have a "bridge" between our present society with its lavish use of non-renewable energy and the society of the future which will have to live pretty much exclusively on solar energy.

**Sustainability: Living Solely on Solar Energy**

Here are some scattered thoughts on the central challenge of sustainability: Living solely on solar energy. To understand the challenge of sustainability we might first ask what societies in this world today are closest to sustainability? I think we would have to answer that the most sustainable societies today are the primitive societies such as those in remote regions in Africa, Asia, Australia, *etc.* If our society crumbles, these primitive societies will probably go on living their hard and difficult lives being little touched by the collapse of the civilized world.

But as we strive for sustainability, our goal can't be to go back to a primitive way of life. People would simply not accept this. But there is an important lesson here; increasing the technological complexity of our society is probably not the path to follow if we want to move to a more sustainable society. So let's not go back thousands of years; let's look at things 200 years ago. The North American society of 200 years ago got along using mainly solar energy. First, and most important, the population was much, much smaller than today's population. Second, the society was an agrarian society with most of the population employed directly or indirectly in agriculture. Draft animals, windmills, and small amounts of water power provided essentially all of the non-human energy used on the farm. The draft animals provided most of the fertilizers that were used. We can see approximately this sort of living today in the Amish communities of western Pennsylvania and eastern Ohio. I suspect that the Amish communities are the closest to sustainability of any of today's American communities.

The Amish communities are mainly agrarian. The people are guided by religious beliefs: in general they use little or no electricity or petroleum and they use little in the way of engineering and technology. Their children are educated perhaps through the $8^{th}$ grade, which is sufficient for their agricultural work and for their interactions with the world around them. They are very successful in their agricultural pursuits. Their life is simple and austere and their communities contribute very little in the way of global warming gases. As individuals, they have a very small ecological footprint. On the other side of the sustainability ledger, they tend to have a high fertility rate, which is certainly unsustainable.

Now we can see the fundamental question of sustainability:

> **Can we transform our society to a solar-based society which will probably have to be mainly an agrarian society, while keeping and sharing throughout the world the benefits of modern medicine and technology?**

The first observation is that to do this we will have to have a much smaller population than the 7 billion plus that we have today (2012).

## Sustainability and Science, Engineering, and Technology

A major consequence of our much heralded science, engineering and technology has been to allow more people to live in regions that once supported only smaller populations. Ever since the age of hunters and gatherers, the population has grown slowly and humans have gradually invented science, engineering and technology to meet the needs of the growing populations. When the needs were not met, growing populations and civilizations were in trouble. Archaeologists today study the ruins of societies that failed and disappeared. A factor of the demise of these failed societies was the inability of the societies to provide sufficient food for their populations. The societies that persisted did so because they used science and technology to increase agricultural production and to allow urbanization and the rise of cities.

Science, engineering and technology have made today’s big cities possible, so that in 2012 something like 82% of Americans live in cities. All over the world people are leaving their poor but marginally sustainable rural agricultural life to crowd into the world’s massive and increasingly unmanageable cities.

Cities have near zero ecological productivity. In the ecological sense, our cities are deserts and wastelands! They are the human equivalent of the cattle feedlots (and other “high efficiency” facilities for the production of pigs and chickens) that one sees throughout America. In the feedlots the animals are confined: Petroleum is used to haul food to the animals and then more petroleum is used to haul away the waste products. So it is in our cities. The people are confined. Petroleum is used to haul in food and energy and to haul out waste. The human cities and the cattle feedlots are both made possible by science, engineering, technology and by abundant low-cost energy. By making cities possible, science, engineering and technology have supported and encouraged population growth, and the movement of people away from agriculture, which is the exactly the opposite of what is required for sustainability.

## Sustainability and Scientists, Engineers, and Technologists

As we contemplate how we should deal with the threat of global warming, it is distressing to read a statement by “a professor…who studies international climate policy…” saying that “The way we reduce emissions is through technology.” (19) Why is it that engineers, scientists and technologists almost never recommend stopping population growth as the solution to the problems of reducing global greenhouse gas emissions? Is this solution too obvious?

By ignoring overpopulation, scientists, engineers and technologists put society in a deep hole, yet they seem to forget the old adage:

**When you find yourself in a hole - stop digging!**

Throughout the world, our mega-technologists (albeit with a deep sense of responsibility and public service) recommend that we work hard to use science, engineering and technology to accommodate the growth of populations. Providing food for the expected population increase is presented as a great challenge, even though meeting the challenge will make the population problems worse. Here is a popular national newspaper columnist writing on the problems of overpopulation in the U.S. (20):

**The United States has its population challenges at home – building the infrastructure from schools to roads to food supply – for a predicted 100 million more people [in the U.S.] by 2040.**

The prevailing reaction of our leaders seems to be to speed up our digging. If we raise taxes and spend heavily and build the public infrastructure needed to accommodate the predicted population growth, then the people will appear. We have trapped ourselves in a self-fulfilling prediction.

**Can it be that scientists, engineers and technologists are impeding the movement of our society toward sustainability?**

Science, engineering and technology have made it possible for populations to grow so large that by our largeness we are threatening the global ecosphere. Is this what we want from our science and technology?

## The Role of Science, Engineering, and Technology in a Sustainable Society

There *is* a role for science, engineering, and technology in a sustainable society. This is because the sustainable society will operate from electricity with large amounts coming from solar cells and wind turbines, with smaller amounts coming from hydroelectric and geothermal sources. Science, engineering, and technology will be needed to improve the efficiency of the generation, transmission, and use of the electrical energy.

## Sustainability and Politics

We deplore the scientific illiteracy of members of Congress because many members don't understand the implications of the large scale of things created by our science, engineering and technology. Should the members of Congress be criticized for their scientific illiteracy because they don't recognize the problems that are developing so rapidly, or should we criticize ourselves for not recognizing that the overpopulation created by all of our actions has caused these predictable problems? Carl Sagan observed that (21):

> **We've arranged a global civilization in which most crucial elements – transportation, communications, and all other industries; agriculture, medicine, education, entertainment, protecting the environment; and even the key democratic institution of voting – profoundly depend on science and technology. We have also arranged things so that almost no one understands science and technology. This is a prescription for disaster. We might get away with it for a while, but sooner or later this combustible mixture of ignorance and power is going to blow up in our faces.**

## Sustainability and Geoengineering

One of the most alarming technological trends today is the eagerness with which technologists and many nonscientists, in the name of sustainability, are endorsing megaprojects of geoengineering that are intended to allow the continued growth of our growth-based society. For instance, we see proposals to mess with the Earth's atmosphere globally by a program of continuous injection of particulates in the upper atmosphere to scatter sunlight away from the Earth in order to reduce global warming. These technologists who offer geoengineering as a solution to the problem of global warming seem to ignore Eric Sevareid's Law (22):

> **The chief cause of problems is solutions.**

Has there been a comprehensive evaluation of the many problems that will result if we start a global project of injecting small particles into the upper atmosphere? And what about the problems that we don't anticipate in advance?

## Sustainability and Desertec

A megascale high-tech "environmentally friendly" project called Desertec is currently gaining support in Europe. It is proposed to cover large parts of the Sahara Desert in Africa with solar collectors which will be used to generate electricity that will then be sent to Europe via electrical transmission lines and cables under the Mediterranean. This might work in a peaceful world, but long lonely transmission lines are tempting targets for terrorists, as are undersea cables. (23)

People have forgotten that with the opening of the first World War almost 100 years ago, the first thing the British did was to send out naval raiding parties to destroy German undersea cables and remote relay stations that provided communications between Germany and its African colonies. At the same time the Germans were sending out naval raiding parties to attack and destroy British undersea cables and relay stations that kept Britain in communication with its world-wide empire. (24) Our mega-technologists today seem to forget that

> **Those who don't know history are destined to repeat it.** (25)

## Sustainability and Smart Growth

Planners sometimes promote "Smart Growth" as the solution to the problem of sustainability. Smart Growth applies to new developments which are built to accommodate growth. It calls for development on a human scale with places of work, shopping and recreation all being located within walking or bicycling distances from the residences. This is very pleasant indeed. But we must note that:

**Dumb growth destroys the environment.**
**Smart growth destroys the environment.**
**The difference is that smart growth**
**destroys the environment with good taste.**
**So it's like buying a ticket on the TITANIC.**
**If you're smart you go first class**
**If you're dumb you go steerage.**
**Either way the result is the same.**

## Sustainability and Localization

"Peak Petroleum" will cause rapid increases of transportation costs and thus make it more difficult to move fresh food half way around the world to the shelves in our supermarkets. Sustainability will require that the bulk of our food be produced locally near its point of consumption. We have the opposite of this in the world today in which items of food are transported to the wealthy countries from all parts of the world. World trade agreements will be reduced in importance because of a reduction of international trade.

## Sustainability and Education

Throughout the country, colleges and universities are introducing courses and educational programs in topics such as "Sustainability Studies." (26) It would be interesting to know how many, if any, of these programs stress the fundamental requirement of the First Law of Sustainability and point out that stopping population growth is a necessary (but not a sufficient) condition for sustainability.

Academic research proposals that contain the word "sustainability" abound and many receive generous support. But do these programs actually advance significantly the cause of sustainability or do they serve mainly to advance narrower goals? A simple test will answer this question for any particular program: Does the program acknowledge that overpopulation is the root cause of our present problems and then go on to address overpopulation in a significant way? If the answer is "No," then, no matter what the proponents of the program may say, the program is not likely to contribute in a significant way to the achievement of sustainability. There's more money and glamour in the high-tech research programs than there is in working to make family planning assistance available to all who want it so that population sizes can be reduced to sustainable levels.

## Sustainability and War

Modern warfare is extremely dependent on fossil fuels and minerals; hence, war can't be a part of a sustainable society. The world in 2012 seems to have a deep commitment to perpetual war. In today's wasteful and destructive environment of unceasing hostility we can have little or no hope of achieving global sustainability. In seeking to abolish war we must remember that overpopulation is a major factor that drives people to make war.

## The Gift That Keeps on Giving

Fertility reduction is the gift that keeps on giving. One avoided birth today will result in many more avoided births in the succession of future generations. The People's Republic of China has boasted that its (very coercive) "One child per family" policy has avoided over 300 million births (27) and that as a consequence, China claims that it has done more to reduce its emission of global greenhouse gases than any other country has done.

## What We Need to Do

As a start, here are twelve things that are urgent:

In our classrooms and in our lives as scientists,

1) We must acknowledge that overpopulation is the world's most serious and threatening problem and that this problem requires immediate and urgent attention.

2) We must teach about the arithmetic and consequences of growth as they apply to our present rates of consumption of resources and to our current national and global conditions of overpopulation.

3) We must seek to educate elected officials at all governmental levels about the severe present problems of overpopulation in our own local communities, in the United States and the world. We treasure our democracy but we must remember the words of Isaac Asimov (28): "Democracy cannot survive overpopulation."

4) We must break down the mental and other blocks that keep most of our environmental organizations, large and small, from addressing overpopulation on the local and national levels.

5) We need to get all of our mainline scientific associations and societies to act on the recognition that overpopulation is a threat to the stable societies. Science can thrive only in a stable society. The long-term survival of science is threatened by overpopulation.

6) We should seek to get the U.S. and other governments to support major programs of family planning in the U.S. and throughout the world. These programs should make high quality family

planning assistance available worldwide at no cost to all individuals who request it. The goal of the family planning program should be that "Every child is a wanted child." Rapid population decrease is essential to achieving sustainability.

7) We must expend great efforts worldwide in the education and emancipation of women, giving women freedom to make their own health, reproductive, economic and political decisions.

8) We should work to guide production of fossil fuels and mineral resources in accord with the concept of "Sustained Availability," (The Uppsala Protocol) thinking of it as a program of Equal Opportunity for Future Generations.

9) We must continue our efforts to use science and technology to greatly improve the efficiency with which we use energy and mineral resources within the framework of Sustained Availability.

10) We must continue research on the development of alternative fuels, being careful to see that these alternative fuels are not competing with the development of food supplies as is the case in 2012 with production of ethanol in the U.S.

11) We must encourage the transition from our present inefficient mega-agriculture (29) to localized agriculture that operates solely from solar power and from human and animal labor.

12) We must seek to re-orient science, technology and engineering away from their present roles that support population growth and redirect them to work for more modest, less glamorous and less complex roles that can improve the quality of life for human beings. The model might be that which is found in the book *Small is Beautiful* by E.F. Schumacher. (30)

As one can see, the creation of a sustainable society will be both difficult and challenging.

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(*Editor’s Note*: Al Bartlett is Professor Emeritus of Physics at the University of Colorado. This article is an expanded version of an invited paper that was presented at the Annual Summer Meeting of the American Association of Physics Teachers in Omaha, Nebraska on Monday, 1 August 2011, and covered in the Fall 2011 issue of this *Newsletter*.)
Albert.Bartlett@Colorado.EDU