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This month's Museletter brings together two essays. The first, written for an exhibition on Nature and Sustainability in Istanbul, asks the big question 'what is sustainability' and how might we get there? The second is my response to a new Harvard study on rising global methane emissions and what it means for US energy policy.

Why Sustainability?

The following essay was written at the invitation of the curators, Çelenk Bafra and Paolo Colombo, for the catalog of the current special exhibit at the Istanbul Modern art gallery, Till It's Gone: An Exhibition on Nature and Sustainability. The exhibition features a "selection of artists who undertake conceptual research on nature and focus on ecological issues in their artistic practices," including pieces by (among many others) Joni Mitchell and Yoko Ono.

The essence of the term *sustainable* is simple enough: "that which can be maintained over time." We want our culture, our institutions, and our society to be durable rather than fragile. A society that is sustainable is built to last, while one that is unsustainable will fail sooner or later.

Of course, no society can be maintained forever: astronomers assure us that in several billion years the Sun will have heated to the point that Earth's oceans will have boiled away and life on our planet will have come to an end. Thus *sustainability* is a relative term. It seems reasonable to use previous civilizations as a yardstick; their lifetimes ranged from several hundred to several thousand years. A sustainable society, then, would be one capable of maintaining itself for many millennia.

The word *sustainable* is often used, in a general and vague way, merely to refer to consumer products reputed to be more environmentally benign than others. But sustainability has a life-or-death importance for us in an era of rapid population growth, resource depletion, widespread species extinctions, and catastrophic climate change. The term is key to understanding humanity's current ecological dilemma, and to finding a way toward a future in which we live happily within nature's limits.

The History of Sustainability

The essential concept of sustainability was implicit in the traditions of many ancient and indigenous peoples. For example, the *Gayanashagowa*, or Great Law of Peace of the Haudenosaunee (the Six Nations of the Iroquois Confederacy of North America) implored chiefs to consider the impact of their decisions on the seventh generation to come.

The first known European use of *sustainability* (German: *Nachhaltigkeit*) occurred in 1712 in the book *Sylvicultura Oeconomica* by German forester and scientist Hannss Carl von Carlowitz. Later, French and English foresters adopted the practice of planting trees as a path to "sustained yield forestry."

The term gained widespread usage after 1987, when the Brundtland Report of the World Commission of Environment and Development defined *sustainable development* as development that "meets the needs of the present generation without compromising the ability of future generations to meet their own needs." This simple definition of sustainability is still widely used; nevertheless it has been criticized for its failure to explicitly note the unsustainability of the use of non-renewable resources such as fossil fuels, and for its disregard of the problem of population growth.

Defining Sustainability

In an effort to help clarify the basic concept, I have formulated four axioms (self-evident truths) of sustainability, based on a survey of prior published definitions. These might be thought of as basic design criteria for building and managing a sustainable society.

1. Population growth and/or growth in the rates of consumption of resources cannot be sustained indefinitely.

Human population has grown for many centuries, and much more rapidly in the last few decades; this growth has obviously been sustained up to the present. How do we know that it cannot be sustained indefinitely? Simple arithmetic shows that even small rates of growth eventually add up to absurdly large—and plainly unsupportable—population sizes and rates of resource consumption. For example, a simple one percent rate of growth in the present human population (less than the actual current rate) results in a doubling of population every 70 years. Thus in 2090, the Earth would be home to 14.6 billion humans; in 2160, nearly 30 billion; and so on. By the year 3050, there would be one human per square meter of Earth's land surface (including mountains and deserts). Obviously, long before we get to that point the human population will have ceased to grow.

How big should our population be? Our economy? We should agree on science-based targets.

2. To be sustainable, the use of renewable resources must proceed at a rate that is less than or equal to the rate of natural replenishment.

Renewable resources are exhaustible. Forests can be over-cut, resulting in barren landscapes and shortages of wood (as occurred in many parts of Europe in past centuries); and fish can be over-harvested, resulting in the extinction or near-extinction of many species (as is occurring today globally). The first clue that harvesting of renewable resources is proceeding at a rate greater than that of natural replenishment would be the decline of the resource base (e.g., forests or fish are disappearing). However, a resource may be declining for reasons other than over-harvesting; for example, a forest that is not being logged may be decimated by disease.

Nevertheless, if the resource is declining, pursuit of the goal of sustainability requires that the rate of harvest be reduced, regardless of the cause of the resource decline. Sometimes harvests must drop dramatically, at a rate far greater than the rate of resource decline, so that the resource has time to recover. This has been the case with regard to commercial wild whale and fish species that have been over-harvested to the point of near-exhaustion, and have required complete harvest moratoria in order to re-establish themselves—though in cases where the remaining breeding population is too small even moratoria are not effective; the species simply cannot recover.

3. To be sustainable, the extraction of non-renewable resources must proceed at a rate that is declining, and the rate of decline must be greater than or equal to the rate of depletion.

No continuous rate of extraction of non-renewable resources (metals, minerals, or fossil fuels) is sustainable. However, if the rate of extraction is declining at a rate greater than or equal to the rate of depletion (defined as the amount being extracted and used per year as a percentage of the amount left to extract), this can be said to be a sustainable situation in that society's dependence on the resource will be reduced to insignificance before the resource is exhausted.

4. Sustainability requires that substances introduced into the environment from human activities be minimized and rendered harmless to biosphere functions.

The most serious forms of pollution in the modern world arise from the extraction, processing, and consumption of non-renewable resources such as fossil fuels. If (as outlined in Axiom 3) the consumption of non-renewable resources declines, pollution should also decline. However, where the consumption of non-renewable resources has been growing for some time and has resulted in levels of pollution that threaten basic biosphere functions, heroic measures are called for.

This is the situation with regard to atmospheric concentrations of greenhouse gases resulting from burning fossil fuels; it is also the case with regard to hormone-mimicking petrochemical pollution that inhibits reproduction in many vertebrate species. Merely to reduce fossil fuel consumption by the global depletion rate would not suffice to avert a climate catastrophe. Similarly, in the case of petrochemical pollution, merely to reduce the dispersion of plastics and other petrochemicals into the environment by the annual rate of depletion of oil and natural gas would not be enough to avert environmental harms on a scale potentially leading to the collapse of ecosystems.

All of these four axioms have to do with environmental sustainability. However, economists and political scientists might add two guidelines (they are too vague to be called axioms) to this list. Social sustainability requires that inequality in incomes, wealth, and political power not become overly great, as societies with sharp social divisions breed misery and contempt, and ultimately tend to succumb to revolutions. And financial sustainability requires that total debt (government as well as household and business debt) not increase far beyond levels that can be repaid).

Measuring Sustainability

How do we know if our society is sustainable or unsustainable? We can't just wait to see if it collapses; we need indicators to tell us how we are doing now, so that we can prevent future collapse.

Seeing the need for such indicators, Canadian ecologist William Rees in 1992 introduced the concept of the Ecological Footprint, defined as the amount of land and water area a human population would hypothetically need in order to provide the resources required to support itself and to absorb its wastes, given prevailing technology. Implicit in this accounting scheme is the recognition that, for humanity to achieve sustainability, the total world population's footprint must be less than the total land/water area of the Earth. That footprint is currently calculated by the Global Footprint Network as being about 30 percent larger than the planet—which is made possible only by drawing down resources at unsustainable rates.

More recently, Johan Rockström from the Stockholm Resilience Centre and Will Steffen from the Australian National University identified nine "planetary boundaries" that define a "safe operating space for humanity." Beyond these boundaries there is a risk of "irreversible and abrupt environmental change" that could make Earth less habitable. They attempted to quantify just how far these systems have been pushed already, and estimated how much further we can go before our survival is threatened; they concluded that three of these boundaries—climate change, biodiversity loss, and the biogeochemical flow boundary—appear already to have been crossed. Unfortunately, it is not necessary for all nine boundaries to be transgressed before global calamity threatens; all it takes is for one boundary to be breached far enough, long enough.

Post-Keynesian economists including Steve Keen have suggested that a nation's financial sustainability can be measured in terms of its debt-to-GDP ratio (that ratio hit a peak in 2008, which it has recently surpassed). Income inequality is commonly measured by the GINI index, which represents the income distribution within a nation (most nations are seeing a worsening of numbers in that regard).

What Would a Sustainable Society Look Like?

Is it possible to describe a sustainable society in more specific terms?

First, our hypothetical sustainable society would have a steady-state economy rather than one based on continual growth. It would be a conserver society rather than a consumer society. There would be far less advertising than we are accustomed to today, and products would be made to high standards, so they could be reused and repurposed indefinitely rather than being thrown away and replaced. All materials would be recycled or reused.

No fossil fuels would be used for energy; instead, all energy would come from renewable sources like solar, wind, geothermal, and biomass. Average global per capita energy consumption would be much lower than is currently the case in North America and Europe. Because no fossil fuels would be burned or turned into petrochemicals, air and water would be less polluted. Environmental toxins of any kind would be rare.

Biodiversity would be stable or slowly growing rather than diminishing. Forests would be increasing rather than shrinking. Bird populations would be healthy. The oceans would be clean and sea life would be flourishing.

People would have an intimate and interdependent relationship with the natural world, often spending time in nature. They would understand where their food comes from because more households would be participating in community gardens. People would know that while nature supplies resources for human benefit, humanity has the responsibility to keep its appetites within nature's long-term ability to provide.

Our sustainable society would also be one of relative equality, in which the highest and lowest members of society could still rub elbows. And it would be a society that relies minimally on debt.

How Do We Get There From Here?

Clearly, our imaginary sustainable society would work very differently from the nations of today's world. Fortunately, however, there are efforts under way to move us in the direction of sustainability.

The renewable energy industry has been growing dramatically in the past few years, with solar and wind power together increasing faster than any other energy source. Meanwhile climate activists are persuading large institutions such as universities to stop investing in fossil fuel companies. These two efforts—to force extractive industries to leave fossil fuels in the ground, and to replace fossil fuels with renewable alternative energy sources—represent today's most visible and important sustainability efforts. However, it is clear to most analysts that it will be difficult to fully replace the energy of fossil fuels with solar and wind power due to the intermittent nature of sunlight and wind resources. Thus, as we transition to an inevitable renewable energy future, it will also be important to reduce overall energy demand. Doing so will serve the interests of sustainability in other ways: all energy use entails environmental impacts, so the pursuit of sustainability will require highly industrialized nations to scale back energy usage in any case. The actual process of reducing energy usage while maintaining a high quality of life will require innovation and behavior adaptation throughout society—in agriculture, transportation, manufacturing, and the economy in general. Here are just a few examples, again highlighting efforts already underway.

If we are to have a conserver economy rather than a consumer economy, then extraction-dependent manufacturing sectors must shrink, while other sectors will have to be transformed so that they use renewable energy and recycled materials. The implications for jobs and investment are significant. The field of ecological economics has for years been exploring how this transition can be accomplished in a way that actually improves lives.

The "passive house" movement in Germany has pioneered techniques of building construction that yield structures using up to 90 percent less energy for heating, cooling, and lighting.

Green transport advocates around the world have been working to reduce consumption of oil through the replacement of internal-combustion vehicles with electric vehicles; through the promotion of walking and bicycling; and through investment in rail and public transit.

The local organic food movement aims to reduce the amount of transport energy in food systems. The market share of organic food—which requires no fossil fuel-based nitrogen fertilizers, pesticides, and herbicides—is growing by leaps and bounds. And advocates of regenerative agriculture hope to remove carbon from the atmosphere and store it in healthy topsoil.

Forest advocates note that climate remediation can also be accomplished through planting more trees, which would help protect the world's remaining biodiversity. Conservationists are also seeking to preserve and restore native forest, prairie, desert, and ocean ecosystems.

With regard to the financial and social dimensions of sustainability, debt and equity problems have become subjects of more widespread discussion throughout the world in the aftermath of the 2008 economic crisis and the Greek debt crisis. While solutions to these problems still seem to elude national governments, communities have quietly begun experimenting with the sharing economy, time banking, and alternative currencies.

It has been shown that high population growth rates can be brought down by raising the education levels of women, and by empowering women to take charge of their own reproductive lives.

These are all welcome and praiseworthy efforts. But they need to be appreciated in context: society has spent many decades on an unsustainable path; time, courage, and collective effort will be needed to transform unsustainable practices still embedded in nearly every aspect of our economy. We cannot know how long we have before the accumulating impacts of climate change, species extinctions, resource depletion, environmental pollution, debt, and inequality force changes upon us that none of us would want. The voices of sustainability-inspired artists, as well as those of conservationists, renewable energy advocates, and the rest, call not just for the moral improvement of society, but for a widespread awakening that might rescue us and countless other species from the consequences of more than a century of reckless, fossil fuel-based expansion.

We should listen as if our life depends on it.

The US: A Nation In Dire Need of Energy and Climate Policy

A new Harvard University study finds that world methane emissions have recently spiked, and that the US appears to be the site of most of the increase. Natural gas fracking is the apparent culprit. This finding should be (though I wouldn't bet on it) the final nail in the coffin of the "natural gas as bridge fuel to a clean energy future" argument.

The Obama administration has fixated on replacing coal with natural gas for electricity generation as a major pathway to meeting Paris COP 21 commitments for reduction in greenhouse gas emissions. Its strategy required the EPA to begin regulating CO2 as a pollutant (as the centerpiece of the "Clean Power Plan" or CPP). But industry fought the regulation all the way to the Supreme Court, which did something quite rare. It stepped in to block federal regulations going into effect until a lower court made a ruling, even though the lower court itself had denied a similar request. Now, following the death of Justice Antonin Scalia (who sided with the "conservative" majority halting implementation of the regulation), there appears to be the possibility for an eventual reprieve of CPP.

But what's the point? If natural gas from fracking harms the climate about as much as coal (higher methane emissions on one hand versus higher CO2 emissions on the other), then the entire strategy is revealed as ill-conceived and useless.

What is really needed is a national plan for a systemic energy transition, including policies, goals, and funding. Such a plan would break out the economy sector by sector, exploiting ways of radically reducing energy consumption over all while replacing oil, coal, and natural gas with renewable resources like solar, wind, biomass, hydro, and geothermal. The plan would have to take into account the vast magnitude of the undertaking by enlisting the entire population along in a visionary, multi-decade odyssey that will entail shared sacrifice as well as opportunity.

Since that effort appears to be currently impossible to mount for political reasons, policy makers have naturally fallen back on smaller projects that just might be achievable. The result is CPP—which, as we have just seen, is not just insufficient, but possibly a waste of effort altogether.

The most likely scenario going forward: environmental groups will lobby to save CPP, and if Democrats win in elections later this year, the regulation may just survive. A great deal of political capital will be spent on both sides, whatever the outcome. But the achievements could be largely symbolic in any case.

Half of US total natural gas supply now comes from fracked shale resources, and, as groundbreaking Post Carbon Institute analysis by David Hughes has shown, production from shale gas reservoirs is set to decline by the end of this decade for purely geological reasons. In fact, strong growth in overall US gas production has now halted, and most of the plays that figured in the recent shale gas boom are in steep decline. Tight oil production is falling, too.

In September 2014, at the U.N. Climate Summit, President Obama boasted that "Over the past eight years, the United States has reduced our total carbon pollution by more than any other nation on Earth." But as is now clear, the huge shift from coal to natural gas for electricity production has come with the largely-ignored spike in methane emissions—a far more potent greenhouse gas. (And even this ignores the reality that much of the coal that was displaced was simply shipped abroad while many of the goods we import were manufactured in coal-powered factories overseas.)

At the same time, the Obama administration took credit for soaring US oil and gas production resulting from the fracking frenzy, and cheered industry hype about energy independence and exports.

This is what served as energy and climate policy for the past eight years. Now hopes and dreams of energy abundance are about to be tested. Many analysts assume that current production declines are entirely due to low oil and gas prices, and that once the market is rebalanced, American oil and gas production levels will resume their ascent. If our analysis is correct, tight oil and shale gas production may never surpass 2015 levels and may instead plummet.

What happens then? How will policy makers distract the public from the evident fact that they have no long-range plan to deal with either energy supply or climate change?

No doubt they'll think of something.