An Examination of What Causes Pollution and Resource Depletion

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Abstract

What is it that drives humans to pollute and deplete resources to the extent they do? Extensive pollution and resource depletion are problems unique to humans. Besides specific health and survivability issues resulting from pollution and resource depletion, populations have crashed to the point of extirpation in the past, in part due to societal stress induced by anthropogenic resource depletion. While no other population has achieved the degree of technological complexity that exists today, the underlying, fundamental needs of all societies are the same: clean resources, available in the quantities needed to allow survival. When those resources are at risk, the population is threatened. Proactively addressing this threat is a fundamental policy issue.

Instead of seeking specific solutions to individual issues of pollution and resource depletion, this paper aims for a broad view, to understand the underlying forces that drive these two problems. With this understanding would come the insight to design policy to proactively mitigate or ideally stop pollution and resource depletion, and hopefully avoid societal trauma.

Chapter 1

The System Generating Pollution and Resource Depletion

The first section of Chapter 1 explains the proposed system that generates pollution and resource depletion. The second section is a discussion of the parts of that system.

Pollution and Resource Depletion Trends

Human-caused pollution is now wide-spread and long-lasting. Heavy metals such as chromium, mercury, and lead, chemicals such as PCBs, dioxins, pesticides and fertilizers, gaseous pollutants such as CO_2, SO_2, NO_2 and CH_4 are toxic and are now spread throughout the earth's air, waters and soils (EPA, 2008; UNEP, 2008; MEA, 2008; IPCC, 2008; Global 2000 Report, 2008; Conklin, 2007)

There is a long history of literature concerning the effect humans have on the earth. Quintus Septimus Florence Tertillianus wrote in 200 A.D.: "We are burdensome to the world" regarding the changes effected by human development including the, loss of natural landscape and of species diversity (Holland, 1993). George Perkins Marsh wrote with concern about the effects of human impact on the natural world (Marsh, 1864). Thomas Malthus (Malthus, 1798) started a conversation that continues today concerning the possibility that the human population is growing faster than the resources it needs to survive. More recently, biologists Rachel Carson (1962), Aldo Leopold (1966), Paul Ehrlich (1971), Garrett Hardin (1993), Jared Diamond (1999, 2005); economist Herman Daly (1989); and demographer Joel Cohen (1995) have written about their observations of environmental problems and what they mean for human health.

Examples of resource depletion include declining levels of clean water in rivers, lakes and aquifers, loss of farmland soil from wind and water erosion, a decrease of clean air in major cities of the world, and a loss of species due to severe depletion and extinction (UNEP, 2008; IUCN, 2008; Davis, 1991). For example, Figure 1 plots historic catches of cod off Newfoundland. The decline in the catch around 1992 is due to overharvesting that had been taking place since about 1950 (MEA, 2008).

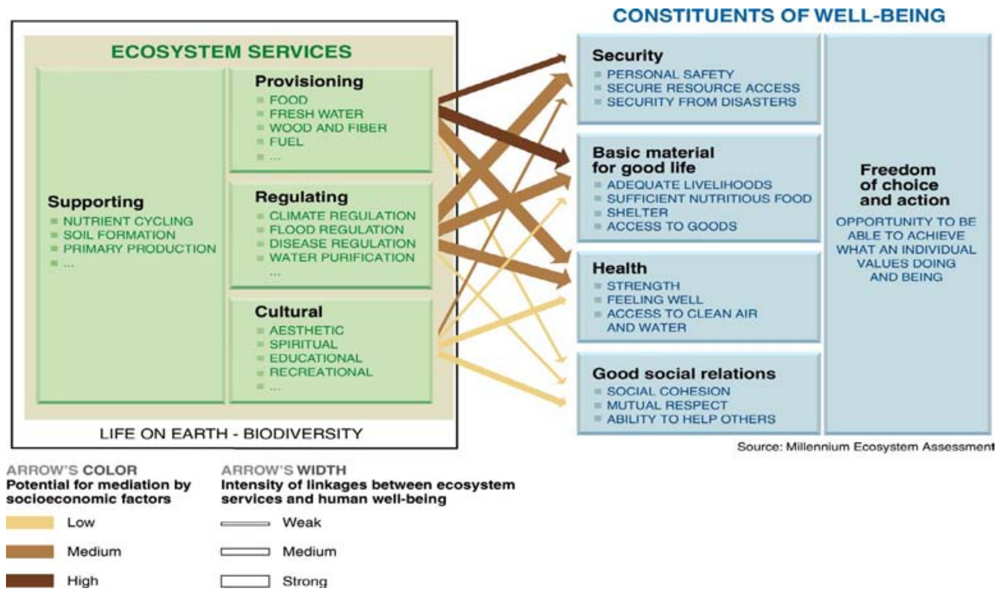
In some instances pollution problems have been ameliorated through conscious efforts. For example, Lake Erie is cleaner than it was 30 years ago (Burns, 1985) and the Cayahoga river is cleaner than when it last caught fire in 1969 (Ohio History Central, 2008). Public reaction to these and other polluted waters helped prompt the Clean Water Act and the Great Lakes Water Quality Agreement, generating remediation efforts.

The late economist Julian Simon and statistician Bjorn Lomborg are two who have been skeptical of the problems posed by pollution and resource depletion. Simon was optimistic about people's ability to use technology to avoid significant problems and to continue increasing standards of living (Simon, 2000; 1986). Lomborg believes that the environmental state of the earth is not as bad as others make it out to be (Lomborg, 2001).

Figure 1. Graph of the number of tons of cod caught off Eastern Newfoundland from 1850 to 2002 (MEA, 2008).

In spite of those who do not see long-term consequences of these problems and in spite of local improvements in environmental quality, pollution and depletion of resources are deleterious to human well-being, and globally the problems are increasing (IPCC, 2008, MEA, 2008, UNEP, 2008). Like other organisms, human health is reliant on a healthy environment (Figure 2). Every form of pollution is toxic to humans in some way, and depletion of the resources humans need threatens their health and their ability to survive. If public policy is intended to improve the common good of a population, and if that common good is to be considered for the long-term, pollution and resource depletion are issues that need addressing.

Figure 2. A diagram showing the connections between ecosystem services and human well-being (MEA, 2008).



The Importance of Population Dynamics

Consistently, connections have been made between pollution and resource depletion and the size of the human population. Thomas Malthus saw population growth as a terminal problem – that people would eventually consume food faster than the land could provide, and suffer as a result (Malthus, 1798). Marston Bates and Julian Huxley wrote in 1962 on their perceptions of how humans fit into the larger biotic systems of earth, and concern for how people were adversely affecting those systems (Osborn, 1962, p. 18-27, 222-233). Donella Meadows, Dennis Meadows and Jorgen Randers wrote about how population growth and human consumption may lead to societal crisis (Meadows, 1972; 1992).

Underlying the connection between population size and the problems of pollution and resource depletion are the dynamics that drive population growth. Fundamental population growth dynamics apply to all organisms, but humans bring an additional input to the system, the unique ability to manipulate resources to a complex level, creating technology. This ability changes the dynamic and the final outcome of the system, as is explained below.

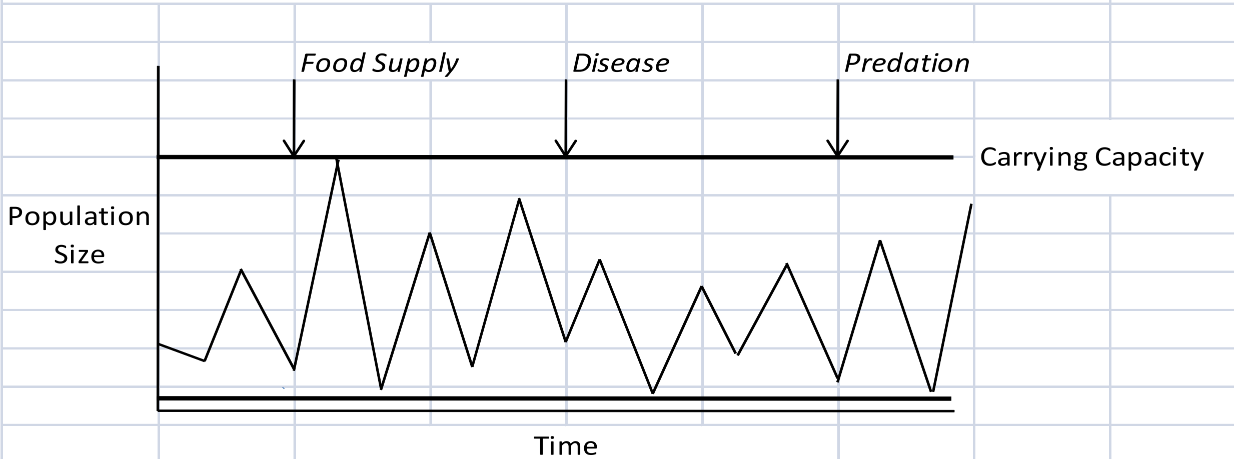
Population Limiting Factors

For the purposes of this paper two basic aspects that regulate the growth of species' populations and their overall size are important: the concepts of limiting factors and of carrying capacity.

There are three categories of environment-based variables that together are called 'limiting factors' or 'environmental resistance' that control the size of non-human populations. These categories are: food supply, disease, and predation. (Pielou, 1974, p. 45-61; Emlen, 1984, p. 46-50; Gould, 1996, p. 1129-1133) Each of the limiting factors is present to some degree in any population. Together the combined effects of the limiting factors exert some degree of limit on the overall size of a given population of a species (Figure 3).

Over long periods of time, the limiting factors define a ceiling on the size of each population of a species. The size of a population will be at or lower than the upper limit (Gould, 1996, p. 1128-1129). The maximum number of individuals that can be supported by local resources is the carrying capacity, and it varies by location due to geographic variation (Emlen, p. 40; Gould, 1996, p. 1123). The carrying capacity of the population cannot increase unless some aspect of the limiting factors change.

Figure 3. Representative graph of a population, indicating constraints applied by limiting factors that define the carrying capacity (based on Hedrick, 1984).



There is also a lower limit to a population's size. When the population drops below the lower limit, the species is extinct. Between the lower and upper limits, the population is extant and able to maintain itself indefinitely.

Human population dynamics

Just like other organisms, humans are biological beings that need to consume natural resources to survive, and humans are subject to disease (Osborn, 1962, p. 10). The system of limiting factors and carrying capacity described above applies to human populations as well as non-human.

The difference between humans and most other species is that humans are unique in their ability to highly manipulate natural resources to influence their environment. The product of this manipulation is technology. The intent of human technology development is to benefit society by creating products that improve living standards for people (Sarewitz, 1996, p. 6-8; Ruttan, 2001, p. 61, 79-85; Holdren, 2008, p. 424). Under the broad meaning of 'improving living standards' are such aspects as enhancements in production, markets and trade, maintenance of national and personal security, and improvements of education, health care and environmental conditions (Holdren, 2008, p. 424). Technology directed towards improving living standards therefore has the effect of decreasing the impacts of limiting factors on people. Two examples are the development of medical technology which mitigates the negative impact of disease on people, and the development of agriculture which provides people with a large and consistent food supply.

By decreasing the impacts of limiting factors on people, technology increases the carrying capacity, and allows the human population size to increase beyond the upper limit that would be imposed without technology. In this way, technology may be called an 'expanding factor.'

What generates technological evolution?

If the above observation that technology drives the human population to increase above the natural carrying capacity is correct, it begs a question: what is it that has allowed technology to keep evolving over a long period of time? From the initial technologies using wood, bone and stone tools developed 4 to 2.4 million years ago (Daumas, 1962, p. 18-35; Schick, 1993, p. 26) technology has evolved continuously to the point it is now, with plastics, internal combustion, complex medical technology and space flight. Technology is expensive to produce; it takes a lot of research time and money to design a functional technology, and even then, many new technologies turn out to be ineffective and non-productive. Something in the system prompts technology to keep evolving. What is it?

Ester Boserup, a Danish economist, believed that a large population prompts technology development. She wrote that a large population develops stress, and that resolve for such stress was in many cases accomplished by manipulating resources in a new way, in other words, technology (Boserup, 1981). One of Boserup's theories is that the development of agriculture was the result of this process as regional populations sought resolve for stresses induced by size. Boserup also believed that technologies other than agriculture were prompted by a large population.

Summary of technology and human population dynamic

Fundamental population growth dynamics involving limiting factors and carrying capacity apply to all organisms. The human population is affected by the same dynamics, but humans are unique in applying technology to the system to diminish the impact of limiting factors. Therefore, technology drives the population to grow beyond the natural carrying capacity, and a large population drives technology evolution.

Supporting discussion

Technology...

One useful definition of technology comes from historian of science Ruth Schwartz Cowan: "We use the word technology to denote those things that people have created so that they can exploit or manipulate the natural environment in which they are living." (Cowan, 1997, p. 2) Physicist Arnold Pacey incorporates cultural, technical and organizational aspects of society when he defines technology as "the application of scientific and other knowledge to practical tasks by ordered systems that involve people and organization, living things and machines." (Pacey, 1983, p. 6)

Many organisms other than humans generate technology. Bird nests, beaver lodges and dams, sea-otters' use of rocks as anvils, caddisfly larva cases, bald-faced hornet nests and leaf-cutter ant agriculture are examples of non-human technology (Singer, 1957, p. 1-14; Hoff, 2008). Most non-human technology is developed to create an area of safety for the organism (protection from environmental exposure and from predators) or to allow easier harvesting of food. In this way, non-human technology is developed to decrease the impact of the limiting factors of food supply and predation.

Non-human technology, when left unattended, is broken down relatively quickly by biological organisms and the weathering effects of wind, sun and water, leaving by-products easily absorbed and recycled by the local environment. For example, abandoned bird-nests fall apart into constituents of twigs, grass and feathers, and decompose into more basic elements. These elements are by-products of technology, but are not widely toxic to other organisms, and are absorbed by other local biological systems for their own use.

...and Human Technology

Human technology, similar to non-human technology, protects people from environmental exposure and predation, and provides a large and stable food supply. Examples include houses and agriculture. In addition, human technology has two other effects: it reduces the impact of the limiting factor of disease, and decreases per capita energy expenditure needed to live and be productive. Examples include antibiotics to decrease the impact of bacterial illness, and internal combustion engines, which allow for greater productivity with less human energy expenditure.

Much of human technology is not readily broken down by biological organisms after being used. Long-term persistence in the environment allows pollutants to travel long distances from their source (Eckley, 2001, p. 27-28). Plastics may take hundreds of years to decompose (UNEP, 2008). PCBs in the environment last a long time, and can travel by air and water long distances from where they were released (EPA, 2008). Other technologies that are long-term pollutants are the persistent organochlorines DDT, HCH, and CHL (Renzoni, 1994, p. 19). Some general categories of pollutants include chemical, radiological, heavy metal, plastic, gaseous, heat and light pollutants in soil, water and air. (EPA, 2008).

As well as the technology itself, some by-products from the production of technology are toxic, long-lasting and wide-spread. For example the fission of uranium for the centralized production of electricity results in the by-products plutonium-239 and plutonium-240, with half-lives of 24,000 years and 6,800 years, respectively (NRC, 2008).

Pollution

Pollution is, by definition, harmful. "2. the introduction of harmful substances or products into the environment" (Random House Webster's, 2001, p. 1498). Another view is that pollution is "...too much of something in the wrong place." (Speth, 2004, p. 43) A pollutant may be something that is non-toxic in a low quantity, but toxic at a higher level. Soil phosphorus is an example of that; necessary for plant growth, but harmful at relatively high levels. A pollutant may also be toxic in very small quantities, such as dioxin.

Pollutants may be introduced into the environment in three ways: purposeful release (such as a pesticide), release as a byproduct (exhaust emissions from internal combustion), or accidental release (an oil tanker spill) (Speth, 2004, p. 44).

The connection between a growing population, and pollution and resource depletion follows from the rationale that a growing population consumes more products, requiring more production. More production results in more by-products from the production process and more consumption of resources. By-products that negatively affect people are pollution. However, pollution is not just an issue of quantity. More people do result in more production and therefore more by-products, but toxicity of pollution is also an issue. Some pollutants are toxic, even in small quantities. Early human technology working stone, wood, bone and leather produced by-products that most likely were not highly toxic, but as technology development progressed, some by-products were not broken down quickly by biological action, and long-term pollution resulted.

The vast majority of human technologies generate at least one pollutant. As well, there does not seem to be a long-term pollutant that is not caused by human technology. There is a significant difference between ‘simple’ technological by-products, readily broken down by biological activity, and pollutants that are toxic and not readily broken down in the environment. The net effect on humans is what counts; if pollution and resource depletion occur, people are negatively impacted.

Resource Depletion

Every organism must absorb or consume some resource to maintain life. The line between consumption and over-consumption is determined by the limiting factor of food supply; a population of organisms can only consume what is available in its environment. Beyond that quantity, the population cannot consume.

Every organism but humans is effectively a hunter-gatherer, using resources in their natural state or modifying them minimally to create low level technology, such as nests and larva cases. Unlike all other organisms, humans are able to modify resources to a high degree, generating technology, allowing the harvest of resources past the point that they are available from the environment through hunting and gathering. For example, the development of internal combustion engines allows extensive mining of metal ore bodies, something not feasible by human labor alone.

Being able to consume resources past the point that they are naturally available from the environment implies that humans are able to deplete resources. Using pumps to draw water from an aquifer allows consumption of water at a rate faster than the aquifer recharges.

Human technology results in resource depletion in two ways. First, technology is often developed to extract resources from the environment at rates faster than the resources regenerate, such as pump technology to draw water from aquifers. Besides direct extraction, pollution may be considered a form of resource depletion, as it may make a resource unavailable for use. A polluted water supply is an example of that. Second, technology allows the human population to expand beyond the natural carrying capacity, meaning there is more demand for resources. For example, a large population requires more homes covering more land, leading to habitat loss and species extinction.

Examples of resources that are being depleted include water sources (UNDP, 2006), species of non-human animals (Iudicello, 1999; IUCN, 2008), and soil (Pimentel, 1995). Atmospheric pollution is effectively a depletion of air resources.

The Risk of Societal Collapse

In seeking to understand the phenomenon of social collapses, Tainter evaluated collapses in terms of political factors: "*A society has collapsed when it displays a rapid, significant loss of an established level of sociopolitical complexity*." (Tainter, 1988, p. 4) Tainter recognized several political changes that typify collapses, including diminished social stratification and economic specialization, a breakdown of central control by authorities, less communication and coordination within the population, and a rapid decrease in the size of the population.

Resource depletion has been a factor in societal crashes in the past. As Tainter pointed out, no society can maintain itself when the resource base it relies on is depleted. The full accounting for collapses very possibly involves several factors occurring simultaneously, such as a catastrophic event, class conflict, and social disruption, but resource depletion is often thought to be part of the combined influence (Tainter, 1988, p. 50).

Tainter and Diamond both question how a society that has grown to some level of complexity, understands its resource needs and has a skilled ability to fulfill them, could not see the problem of depletion coming and react to avoid being depleted (Tainter, 1988, p. 50-51; Diamond, 2005, p. 420-421). If the premises of this paper are correct, the answer to that question may lie in a societal assumption that technology can be relied on to resolve resource problems. If agriculture technology allowed the growth of more food than was normally available, following that assumption may lead to thinking that more technology was needed to alleviate declining harvests. If declines in production were the result of depleted soils, then additional technology may have only exacerbated the problem. This apparently happened to the Mayan civilization in Mesoamerica, which by about 900 A.D. had collapsed (Tainter, 1988, p. 8, 45-46).

In terms of resource depletion, technology may be inadequate in two ways. Technology may not be able to counter the depletion trend if it cannot address the problem effectively, or it may exacerbate the trend if it causes more depletion.

Sustainability

The term 'sustainable' bears consideration. A definition of sustainable frequently referred to comes from the 1987 report of the Brundtland Commission of the United Nations, which states that "sustainable development requires that societies meet human needs both by increasing productive potential and by ensuring equitable opportunities for all." (Brundtland, 1987, p. 44)

A recent paper notes that "…the notion of sustainable development has exhibited broad social appeal but has proven difficult to define in precise terms. Most definitions include concerns for development, equity, and environment." (Parris, 2003). The same authors state that "[d]efining sustainability is ultimately a social choice about what to develop, what to sustain, and for how long." (Parris, 2003) The appeal of the concept of sustainability may reflect the population's desire to understand and resolve issues that make the future uncertain, such as pollution and resource depletion.

In a similar way, the U.S. EPA notes that "[s]ustainable development is less of a program and more of a new multifaceted approach to managing our environmental, economic, and social resources for the long term." (EPA, 2008) Embedded in this statement is an implication of needing to create public policy that embraces sustainability.

Based on the premises from the first section of Chapter 1, the Brundtland's definition is problematic, in that the problems of pollution and resource depletion are not addressed. To 'meet human needs' and 'ensuring equitable opportunities for all' doesn't take into account the problems that result from 'increasing productive potential.'

In the context of population size and resource consumption, a definition for 'sustainable' that incorporates the concept of consumption over the long-term would be valuable. In terms of natural resource consumption for the purpose of survival, 'over-consumption' means consuming at a rate in excess of the rate of regeneration of that resource. Therefore, the concept of 'sustainable' consumption as it relates to organism survival over the long-term would be: consumption of the resources necessary to live, at a rate that doesn't exceed the regeneration of those resources.

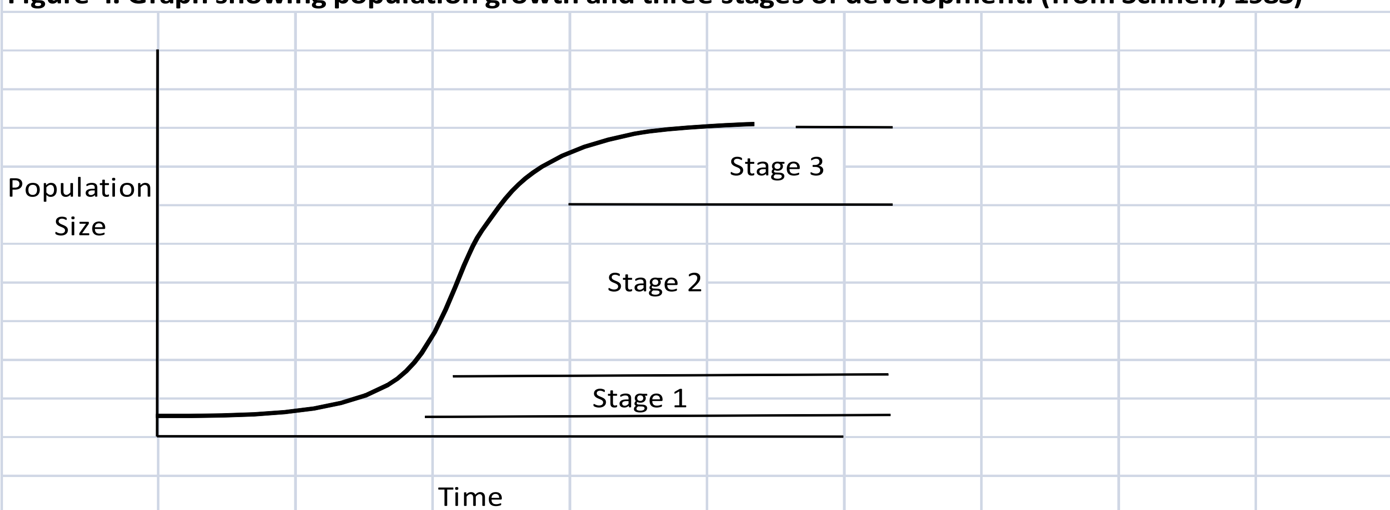
This definition of sustainable is connected to the population dynamics of limiting factors and carrying capacity. Sustainable means consuming resources only to the point of the natural carrying capacity of a region, without the expanding factor of technology. Consuming at this level would not create any pollution that is not resolvable by biological organisms in a short period of time, and resources would not be depleted.

This definition of sustainable implies the long-term, effectively forever. If survival over the long-term is not desired, consumption in a non-sustainable manner is an option, by consuming resources at a rate faster than they are regenerated. By definition, this implies depletion of resources.

Demographic transition

The phenomenon of demographic transition in human populations has been documented regionally (Schnell, 1983, p.94-111). Figure 4 is a graph of population growth over time that shows the stereotypical pattern of demographic transition. A population in the first stage of the growth curve has no, or very low, technological development, high rates of mortality and fertility, a low or stable growth rate, and relatively low population density (Schnell, 1983, p. 107-111). . With technological development come benefits that decrease mortality, and the population enters the second or transitional stage, characterized by rapid growth. In the second stage, mortality declines while fertility remains high, the population growth rate increases from what it was without technology, and population density increases. When the level of fertility drops and approaches the rate of mortality, the population enters the third stage, typified by low rates of mortality and fertility, high technological development, high population density, and a low or static growth rate. The size of the population in stage three is also larger than in previous stages. When population growth over time is graphed, the demographic transition is shown as an S-shaped curve (Figure 4).

Figure 4. Graph showing population growth and three stages of development. (from Schnell, 1983)



In the demographic transition, the influence on the population in the second stage that increases the rate of growth and increases the size of the population is the effect of technology acting to decrease mortality (Schnell, 1983, p. 108-110; Overbeek, 1976, p. 8). For example, medical technology may be developed to counter disease, and agriculture technology may be developed to increase the food supply. The third stage of the transition, characterized by a decrease in fertility, may be the result of a population realizing that it does not need to maintain a high birth rate to provide the workforce needed for the population, and opting to have fewer children per couple.

A UN paper on population (UN World Population, 2008) projects a range for the world population in 2050, from 7.8 billion people to 10.8 billion, these estimates assuming some degree of fertility decline in developing countries. This implies a demographic transition, although it is not certain that a demographic transition pattern will be evident in the global population as it has been regionally (Cohen, 1995, p. 79-88; Schnell, 1983, 111-116).

Chapter 2 – Policy Analysis

If the premises discussed in Chapter 1 are correct, the policy significance is hard to overstate. The premises explain that the problems of pollution and resource depletion are caused by technology and a large population, a concept at odds with current public policy that is oriented towards advancing technology to solve social problems and having a growing population (Bush, 1945; Holden, 2008; Weinberg, 1967, p. 1-2).

The problems of pollution and resource depletion are not indications of a system that is 'broken' or needs 'fixing.' Rather, the application of complex technology and a population larger than the original carrying capacity into the same system that all organisms occupy changes the dynamics of that system, and generates the problems of pollution and resource depletion.

Given these observations, alternative policy options are called for. The remainder of this paper will follow a method of alternative policy analysis developed by Eugene Bardach

(Bardach, 2000). His evaluation process involves eight steps, used to develop alternative policy options and assess their viability.

A System of Analysis

Bardach's evaluation process involves eight steps:

1. Define the problem

2. Assemble some evidence

3. Construct alternative policies

4. Select criteria to assess the policies

5. Project the outcomes

6. Confront the trade-offs

7. Decide on a policy

8. Tell the story/Conclusion (Bardach, 2000, p. xiv)

Application of Bardach's eight steps

1. Define the Problem

If the premises of Chapter 1 are correct, pollution and resource depletion result from technology and a large population. Technology and a large population are themselves the result of public policy derived from a short-term, reductionist perspective. Any one of those three steps in the process could be seen as the policy problem. However, the impact on society comes directly from pollution and scarcity of resources. Neither a short-term reductionist policy, or technology, or the size of the population would matter if by-products of technology decomposed quickly, and resources were consumed at or below the rate of regeneration. The bottom line for humans is the negative effect that pollution and resource depletion are having, and will continue to have, on our species.

At a certain point the releases of by-products into the environment go from being short-term and local problems to long-term and wide-spread. Short-term and local by-products and resource depletion result from technologies based on minimally modified resources, and the manufacture, use and abandonment of those technologies does not result in harmful effects on society. Examples include technologies made by non-humans, and human technologies of stone, wood, bone and leather. When by-products become toxic and long-lasting the environment is affected in ways that compromise the health and survivability of society. The point that technology development went from benign to deleterious is difficult to pin down. It may be the case that the complexity of the production process of a particular technology indicates how toxic the by-products are; the more complex, the more toxic the by-products. However, that doesn't really hold up to scrutiny. The simple act of burning coal releases mercury and sulfur into the atmosphere, pollutants that cause long-lasting and wide-spread problems. There doesn't seem to be a single, obvious line to draw, either in time or the history of technology development, where technologies produce benign by-products on one side, and toxic by-products on the other.

A corollary to this last point is that the creation of additional technology that produces non-toxic by-products is not a bad thing, while the creation of additional technology that produces toxic by-products makes the situation worse. For example, once stone tools had been developed, more stone tools did not result in harmful by-products, but once PCBs had been produced, the release of more PCBs into the environment resulted in a more polluted, toxic environment.

The same concept applies to resource consumption. Consuming resources at or below the rate of regeneration is not harmful to society. As soon as resources are consumed faster than they regenerate, a risk of insufficiency exists, threatening society.

This concept is important in the development and analysis of alternative policies. The line where the population is put at risk is drawn where deleterious by-products of technology are not quickly broken down by the environment, and where the long-term rate of consumption of resources is faster than the resources are regenerated. Any public policy that stimulates by-product generation and resource consumption short of that line means that the population is not harmed by the technology. Policy that stimulates by-product generation and resource consumption beyond that line means that the population is put at risk by the technology. In the worst case scenario, the population would suffer a collapse, due in part by resource depletion. Once pollution stocks exist, and once resource stocks are depleted below their normally available level, stopping the production of pollution and the consumption of resources only serves to not make the situation worse; the situation isn't fully resolved until the existing stock of pollution is gone and resource stocks have regenerated back to their normal level. Once pollution and resource depletion exist, society is at some level of risk.

In an effort to gain a broad view of the problems of pollution and resource depletion and how these problems are generated, the term 'pollution' used here includes all types of human pollution, and 'resource depletion' includes all resources consumed by humans. Within these categories are many individual forms of pollution and resource depletion. For example, pollutants include atmospheric pollutants CO, CO_2, SO_2, NO_2 and CH_2; heavy metals chromium, lead, cadmium and zinc that pollute air, water and soil; chemicals in the PCB family, organic herbicides and pesticides; and radiological products. The common threads linking these pollutants are that they are produced by humans, that they have deleterious effects on human life, that they are long-lasting and in many cases can spread widely once they are released into the environment.

Depleted resources include: water in lakes, rivers and aquifers; soil and land-based resources such as trees and plants; atmosphere; and species of other animals. The common threads connecting these resources are that they are consumed by humans at a rate faster than they can regenerate naturally, and that they are necessary for healthy human life.

Each of these pollutants and resources are quantified differently, and are valuable to humans for different reasons. For the purposes of this paper, increases or decreases of specific pollution or resources are not as relevant as the overall impact of all pollutants, and the overall level of resources.

In a similar way, there are regional differences in amounts of pollution and resource depletion. Again, this paper seeks to gain a broad view of what humans are generating, so is concerned with global levels of pollutants and resources.

2. Assemble Some Evidence

Unfortunately, evidence abounds for pollution and resource depletion. There are numerous scientific articles and books written about and documenting pollution. Examples of these include the *Millennium Ecosystem Assessment* (MEA, 2008), the *Intergovernmental Panel on Climate Change report from the United Nations* (IPCC, 2008), *The Global 2000 Report to the President: Entering the Twenty-first Century* (Barney, 1982), *Sourcebook on the Environment* (Hammond, 1978), and *The State of the Nation's Ecosystems* (The Heinz Center, 2002).

In the U.S, concern for conserving the nation's natural lands led to the formation of the U.S. Forest Service and the U.S. National Parks Service by the 1860s (Barrow, 1995, p. 8). Public concern about pollution prompted formation of the Environmental Protection Agency of the U.S. government in 1970 (EPA, 2008).

Some notable environmental red flags in recent U.S. history include the Cuyahoga River catching fire in 1969 (Ohio History Central, 2008), the use of Love Canal, NY as a chemical waste dumpsite (Levine, 1982, p. 7), and the polluted state of Lake Erie (Burns, 1985). According to the EPA, there are tens of thousands of hazardous waste sites classified for Superfund attention (EPA, 2008). Probably the largest and most public of current pollution issues is global warming, presumably caused by the release of green house gases from fossil fuel consumption.

3. Construct Alternative Policies

Designing alternative policies requires having a goal. In this case, the goal is to reduce or eliminate pollution and resource depletion. The more pollution and resource depletion are decreased, the more long-term common good for people is increased by providing healthy resources necessary to sustain life and avoiding the likelihood of a population crash due to depleted resources and population stress. Designing a policy that reduces pollution generation to below the rate that the environment breaks it down and resource consumption to below the rate that resources regenerate would be optimal, as that would eliminate risk to the population from pollution and resource depletion.

If the premises proposed in Chapter 1 are correct, the most expeditious means to reduce pollution and resource depletion would be to stop using all technology that generates pollution and drives the population to a size that depletes resources. This would stop pollution from being produced and stop consumption of resources at rates faster than they regenerate.

Is this policy realistic? No. Given human nature and reliance the human population now has on technology, stopping all technology use and stopping human reproduction to these levels is far-fetched, no matter how ideal the outcome.

What that means for alternative policy design is that options must be sought between the two extremes of eliminating all technology and population growth, and the current system of seeking technology development and population growth. What are those options, and what do they imply for achieving the goal?

Considering technology: there are two options: reduce the use of specific technologies, or keep existing technologies but reduce the overall level of their use.

Looking at the first of those two options, it makes sense to reduce the use of technologies that produce the most egregious pollution. However, that immediately implies the need for qualitative assessments of all pollutants and comparing them against each other. Is it possible to compare air-borne lead to mercury in water and air to heavy metals in soils? If viable comparisons can be made, is it possible to selectively reduce particular pollutants? This is a difficult task, given the interwoven nature of the world of production. Stopping the use of one technology would inevitably decrease the use of other technologies dependent on the first, in ways that would be difficult to predict. Issues of unequal and questionable impact seem inevitable.

Looking at the second of the options, the level of use of all existing technologies could be reduced. This would effectively put a ceiling on existing pollution production; if the ceiling was set low enough, pollution stocks would be stable at existing levels (if the rate of pollution release equaled the rate of pollution decomposition by the environment) or even decrease (if the rate of pollution release was less than the rate of pollution decomposition).

One way to set a ceiling on technology use is to limit energy consumption. Most technologies require energy for their manufacture and use, so a cap on energy consumption would limit pollution generation. This may be a way to evenly distribute the impact of reducing technology use based on the common denominator of energy use.

An example of applied policy that sets a ceiling on the amount of pollution emitted is the ‘cap and trade’ system. This system regulates the total amount of a pollutant released (sets the ‘cap’), distributes or sells vouchers or permits that allow pollution emitters to release their proportional amount of pollutant, and sanctions selling of those permits within the group of polluters (‘trade’). Those polluters who have or develop ways to pollute less therefore have excess permits that are of value on the market, and may be sold to polluters who generate more pollution (EPA, 2008).

An example of an effective cap and trade system is the Acid Rain Program enacted under the Clean Air Act of 1990. In response to acid rain caused by high levels of sulfur dioxide and nitrous oxides, the program set a permanent cap on emissions, and enacted a voucher trading system. The program has been very effective in reducing the level of SO2 and NOX emissions; in 1996, SO2 emissions were more than 6.3 million tons less than in 1990, and NOX emissions were 3.3 million tons less than 1990. These results are better than the original goals of the program, and in fact acid deposition in the East and Midwest has decreased (EPA, 2008).

Beyond the CAA of 1990, there are other systems to cap and trade allowances to emit greenhouse gases. In Europe, the European Union Emission Trading Scheme initiated in 2005 aims to control the emissions of CO2, in working with 11,500 energy- intensive polluters

(European Commission, 2008). In the private sector in the U.S, the Chicago Climate Exchange operates a cap and trade system for six greenhouse gasses. CCE's goals are to build a costs-effective, transparent, and private market for the application of environmentally beneficial trading of greenhouse gas allowances (Chicago Climate Exchange, 2008).

Considering population growth: the right to reproduce is a policy that is in many ways inviolable. Most current societies have assumed that the decision to reproduce is a right given to individuals and not to the state. There have been instances of state-controlled reproduction, such as China's one-child policy initiated in 1979 and India's compulsory sterilization program of 1976 (Gulhati, 1977; Zhang, 2007), but for the most part such programs are considered draconian and are exceptional in recent years. State policies that control reproduction and therefore population size are effectively off the table.

The public good cost to this policy of open reproduction rights is huge. As demographer Ronald Lee pointed out, every person born has an assumed right to public goods such as air, water, climate, public parks and the ozone layer (Lee, 1991, p. 316). As a result, the right to reproduce increases consumption by the right of the born to consume – and therefore pollute and over-consume – these public goods. These are the public goods that would most benefit from being able to craft public policy to manage the size of the population. Lee calls free and open access to reproduction the "second tragedy of the commons" (Lee, 1991, p. 317) in reference to Garrett Hardin's article "The Tragedy of the Commons" (Hardin, 1968).

There are voluntary constraints to population growth in developed countries. In the demographic transition of a developing population, the third stage, characterized by a decrease in fertility, is thought to be the result of understanding that maintaining a high fertility rate is not necessary once the mortality rate had declined (Schnell, 1983, p. 100). Associated with this understanding is an assumption that with a reduced need for high fertility, women in a population are able to pursue educational and professional endeavors; raising children becomes a choice rather than a necessity (United Nations 2008).

Ideally, population size would be manageable. Realistically, a state-generated policy to control reproduction is not likely, regardless of the long-term benefit. This is an extremely difficult area to regulate through applied policy. Any policy other than 'laissez-faire' that exists now is therefore not included in the alternatives offered here.

To this point, we have three policy alternatives to consider: the status quo, stop selective technologies, and apply a cap on all energy use in the world. There is one more option to consider: conservation.

Conservation implies using fewer resources than are consumed presently. Conservation could be voluntary on the part of users, or conservation could be a function of state mandate. The most effective application of conservation might be voluntary acceptance by the population, as that would assure buy-in.

The state has the ability to affect consumption by applying taxes, fees, subsidies, tradable permits, and refundable deposits to the act of polluting and consuming resources (Bailey, 1998). When this is done with the aim to decrease pollution, the state is effectively putting an economic value on resources of air, soil, water and species diversity that are now open-access. By needing to pay for consumption, polluters respond by conserving on the consumption of the now-valuable resources.

There are two areas in the consumption spectrum that conservation measures would have an effect. First, any wasteful consumption would tend to be decreased. For example, if pressure to conserve electricity use was applied, un-needed lights would be turned off.

The second area conservation would find influence is in pressuring consumers to rethink the value of a resource in the first place, and therefore rethink consumption. Consumption that is less vital to survival would be questioned, and possibly decreased. For example, when gasoline prices increase, bicycle ridership may increase, as people see that driving a car is not necessary.

Conservation would also have the effect of decreasing both pollution and resource depletion at the same time. The fewer resources demanded, the less production technology is used, and the fewer resources consumed. In theory, a conservation policy could have a huge impact on pollution and resource depletion.

Within the policy of conservation is the concept of 'green' technology. Green technology is designing products in environmentally friendly ways, by aiming to consume resources optimally and to prevent waste (Hundal, 2002, p. 2). More broadly, green engineering "…is a systems-level approach to product and process design where environmental attributes are treated as primary objectives or opportunities, rather than as simple constraints, and emphasizes the legitimacy of environmental objectives as consistent with the overall requirements of product quality and economy." (Billatos, 1997, p. 3) Green technology slows the rate of pollution generation and resource depletion. Examples of green technology are ones that replace more polluting or consumptive technology, such as photovoltaic electricity in place of coal burning power plants, and light-emitting diodes in place of incandescent lights.

4. Select the Criteria

Three criteria are used to gauge the effectiveness of the outcomes of the alternative policies. The first of the criteria is clear – if pollution and resource depletion decrease as a function of new policy, the policy has been effective. The alternative that reduces pollution generation below the rate that it is broken down and reduces resource consumption below the rate of regeneration generates the optimal outcome.

The second of the criteria is the political palatability of the alternative policy. The reality of human nature is that regardless of how beneficial a policy may be for a population in the long-term, short-term acceptability defines whether or not it may be accepted.

The third of the criteria is whether the alternative policy has a beneficial long-term effect on the health and survivability of the population, or not. Each of the three aspects within this criterion is important. The long-term effect of pollution and resource depletion on a population doesn't always show up immediately after a technology is implemented, even though the impact is happening. For example, the impact of CO_2 emissions from fossil fuel combustion was not evident until fossil fuel consumption had been going on for a long time. In the short-term, the population was better off by the technology of fossil fuel consumption, but the long-term impact has proved to be negative.

The second aspect of the third criterion is the health of the population. Both pollution and resource depletion can cause illness and suffering. PCBs, lead and mercury are examples of pollutants that are shown to be toxic to humans (Eckley, 2001). By their presence in the environment, humans ingest them and suffer the consequences that result. The scarcity of resources necessary for human life results in suffering and sometimes death. For example, the difficulty of accessing clean water in parts of India is making life difficult for the people living there (Sengupta, 2006).

The third aspect of the third criterion is the survivability of the population. Resource depletion is one factor that likely contributed to population collapses in the past (Tainter, 1988; Diamond, 2005). Resources can be depleted both by physical scarcity, and by being polluted and therefore inaccessible for human consumption. Water wells over-drawn to the point of depletion cause stress, potentially to the point of disallowing life.

5. Project the outcomes

Projected outcomes (Figure 5) provide an indication of the effectiveness of alternative policies in reaching the goal of reducing pollution and resource depletion.

Alternative 1 – keeping the current policy of promoting technology and a large population.

Consistent with the premises of Chapter 1, continuation of the current policies of encouraging technology evolution and population growth will result in increased pollution and resource depletion. This path would be the most politically acceptable policy of those proposed by being the most likely to provide short-term benefits. However, the long-term risk of societal harm in terms of population health and the potential for societal crash due to resource stress is large (Diamond, 2005, p. 313; Meadows, 1992, p. 2; Tainter, 1988, p. 44; Schnell, 1982, p. 119-121).

Alternative 2 – placing a cap on all energy use.

Placing a cap on the consumption of energy would have the effect of decreasing the production of pollution by limiting the amount of technology production. Energy use is necessary for manufacturing and application of most, if not all, technology, so energy use limits imply widespread impact. Acceptance and effectiveness of this option would depend on the level of the cap. However, this policy has the potential to provide great long-term benefits to the population. The lower the cap is set, the less pollution and resource depletion are generated. Any cap would be better than none, but a low cap would result in less pollution and resource depletion.

Figure 5. Outcomes Chart

Alternatives	Criteria		
	Change in Pollution and Resource Depletion	Political Viability	Long-term Outlook for Society
1. Existing Policy - Develop Technology and Promote Population Growth	Continued increase	Very good - this policy is what is now expected and desired	Grim - reliance on technology implies a large population, open to a crash
2. Place a Cap on all Energy Use	Depends on the level of the cap - the lower the cap, the less pollution and resource depletion	A range of low to good, depending on level of the cap, acceptance by the public, and direct impact on life-style	Good - the lower the cap, the better the long-term outlook
3. Stop Use of Selective Technologies	It depends on the technologies stopped, but there would be continued pollution and resource depletion	A range of low to good, depending on how people accept the change in quality of life	Not good, unless many technologies are stopped or reduced
4. Conservation Policy	Potentially a large decrease in pollution and resource depletion levels, depending on degree of conservation	The more pain involved, the more resistance to any conservation method, no matter what form it takes	Potentially, very good, depending on how effective the conservation efforts are

<u>Alternative 3 – stopping the use of selected technologies.</u>

Stopping the use of selective technologies is inherently difficult for needing to make choices about what technologies to stop, and understanding the ramifications of the choices. In theory, this policy would allow identifying the most egregious pollutants and stopping the technologies that produce them, but in reality technologies and their related pollutants and resource needs are interconnected in ways that are difficult to separate. Stopping the use of one technology would affect the use of another in ways that would be difficult to predict. The initial impact may be positive in terms of curtailing the production of pollutants and consumption of resources, but there would likely be reactions to use other technologies and resources to compensate for the controlled ones, which could have the effect of not limiting pollution overall.

This option is effectively what has been applied, with some positive effects. For example, in the U.S. estimates of emissions of particulate matter and carbon monoxide show a decrease since 1940 and a decrease in sulfur oxides and ozone since 1970 largely as a result of the impact of federal legislation creating the Clean Air Acts and regulations by the EPA (Bailey, 1998, p. 6).

However, this type of policy has proven to be only partially effective, in part because it is reactive. Legislation to stop or slow the release of a pollutant comes after the deleterious effects from a pollutant become evident. For example, in the U.S. tetra-ethyl lead had been added to gasoline since about the 1920s, but only when the negative health effects of ingesting airborne lead became known did the EPA restrict lead as a gasoline additive (EPA, 2008).

Another problem with this policy is that it is politically viable only on certain technologies. For example, consumption of gasoline causes atmospheric pollution, but application of a stiff gas tax to stop or slow gas consumption would be so unpopular, no politician dares attempt it.

It is also the case that earlier pollution control measures cost less and were more effective than recent attempts at control. The benefit/cost ratio appears to have decreased from the 1970s to the 1990s, as costs of air pollution control have gone up, and marginal benefits have remained steady (Bailey, 1998, p. 7).

Recent activity in technological development

Beginning about forty years ago as developed countries became aware of some of the environmental problems around them, there have been significant attempts to develop technology to resolve those problems. Currently, there is a strong emphasis on developing technologies that produce less pollution or consume fewer resources relative to other technologies, or actively work to decrease pollution. This type of technology is called ‘green’ technology, ‘green’ engineering or ‘environmentally conscious manufacturing’ (Billatos, 1997, p. 3).

Green technology

Green technology is technology that uses fewer resources and/or results in less resource consumption in its application compared to another technology, but that generates an equivalent benefit as the comparative technology. The development and application of green technology is intended to alleviate some of the environmental problems evident in society today. Green technology either replaces an existing technology, or is specifically developed to remediate a problem of pollution or resource depletion (Billatos, 1997, 3-7).

There are many examples of green technology. In the area of power generation, there are photovoltaic panels and wind turbines that convert sunlight and wind to electricity, generating fewer greenhouse gasses than coal or oil combustion in the process. For residential and commercial buildings there are low-flow plumbing fixtures that decrease water use, geothermal heat pumps that can heat and cool buildings, light-emitting diodes and compact fluorescent light bulbs that consume much less electricity than standard incandescent bulbs, roof shingles made of recycled plastic and wood dust, and electrochromatic glass that darkens automatically to reduce sunlight passage. For personal transportation, there are electric and hybrid cars that use little or no gasoline. For cleaning up toxic waste, there are technologies that use iron nanoparticles to oxidize organic pollutants, and the technologies of bio- and phyto-remediation, which use microbes and plants to break down or absorb pollutants.

An example of an area where green technology has grown in influence is building construction, and the generation of the Leadership in Energy and Environmental Design (LEED) rating system. The U.S. Green Building Council developed the standards of the LEED system to promote energy and resource conservation and high indoor environmental quality. LEED is a certification system that assesses the overall environmental performance of a building project as important; the five performance areas of the standards include sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality. Use of the LEED rating system is expanding; local, state and federal governments have adopted the standards for public building projects, and LEED projects are taking place in 41 countries (USGBC, 2008).

Life cycle assessment

Evaluating one technology relative to another technology is important to be able to determine the environmental impacts. The practice of life cycle assessment (LCA) is a structured way to do so.

Live cycle assessment is a method used to assess the environmental impact of the production of goods from “cradle to grave.” According to the Society of Environmental Toxicology and Chemistry, a life-cycle assessment is “a process to evaluate the resource consumption and environmental burdens associated with a product, process, package, or activity.” (Fava, 1993, p. 1) A life-cycle assessment accounts for the energy and resources consumed throughout the entire life of an item, from resource harvesting through disposal, including pollutants released into the environment. Life-cycle assessment is meant to be a tool that allows industries, governmental agencies and public interest organizations to understand the impact of every step in the life of a product, and thereby reduce environmental impact (Fava, 1993, p. xxiii).

LCAs are used to evaluate different segments of the life cycles of products. An LCA can be from ‘cradle to grave,’ by examining the energy and material flows from the harvesting of resources through the disposal of the product (EPA, 2008). A ‘cradle to gate’ LCA stops short of the end of the life of the product, and assesses energy and material flows through the point that the product leaves the manufacturing plant. An LCA of biodiesel described its assessment of the fuel as being from ‘source to tank’ (Hu, 2008).

There are four phases of a life cycle assessment: the goal and scope definition, the life cycle inventory analysis, the life cycle impact assessment, and the life cycle interpretation (UNEP, 2008). The first phase defines the product being assessed, and sets the boundaries of the assessment; the boundaries define what aspects of the product are being assessed. The second phase identifies the steps in the production process, and quantifies the aspects being assessed in each of those steps of the life cycle. The third phase assesses the impact the quantified aspects of the product have on the environment. The fourth phase uses the information from the previous steps to compare products within the LCA, or to compare the information to other LCA studies (UNEP, 2005; Wimmer, 2004).

An LCA can be comparative, by assessing two different products to determine how their different production processes compare environmentally. An example of this is Hu’s comparison of conventional diesel fuel to soybean-based biodiesel (Hu, 2008). LCAs can also be of a single product, with the intent to understand how the assessed product impacts the environment in terms of an existing problem. An assessment of the application of nitrogen fertilizer for corn production and its impact on green house gas production is an example of this (Kim, 2008).

While the concept of life cycle assessment is a logical way to determine the environmental impact of the production of items, and while numerous LCAs have been performed, there are problems in their implementation. A recent article pointed out 15 major problem areas in the four phases of the LCA process. Examples of the identified problems include boundary selection and social/economic impacts in the goal and scope definition phase, the proper allocation of environmental impacts to the appropriate process within a complex production facility in the life cycle inventory phase, the impact category and methodology selection within the life cycle impact phase, and weighting and valuation within the life cycle interpretation phase. Throughout all phases are problems of data quality and availability (Reap, 2008). In an assessment including a supply chain for a product, data may be too expensive, time consuming or impossible to gather (Hundal, 2002, p. 32).

On the basis of the identified problems, Reap questions the value of LCAs, and notes that to be effective, awareness of the problems should be addressed in future designs of LCA studies, to be able to avoid the shortcomings and improve the process.

Limitations of technology

If the premises of Chapter 1 are correct, the observation that human technology generates pollution implies that even green technology is limited in its ability to stop pollution generation. Life cycle assessment may prompt changes in a production process that results in less environmental degradation than a previous process, but any technology that generates pollution at a rate faster than it is broken down in the environment is adding to the problem. For example, electric cars require batteries for storage of electricity to run motors that drive the car; the batteries themselves often contain toxic materials, and the manufacture and disposal of some batteries can be problematic for the hazardous materials involved. As well as batteries, the manufacture and recycling of steel and plastics for the car bodies is associated with pollution, and the electricity that recharges batteries is today at least in part generated from polluting sources such as coal, oil and nuclear (Billatos, 1997, 182-185).

If the premises of this paper are correct, applying technological development with the intent to reduce particular by-products can only be effective in reducing the rate of production of pollution relative to other technologies, and only to a certain point. To bring the rate of pollution generation down to or below the rate that it is broken down by the environment would require a shift to 'low' technologies that generate no long-term pollution in their chain of development and application.

Alternative 4 – conservation

There are several aspects to consider within the conservation policy. From the minimum amount of resources humans need to survive (food, air, water) anything beyond that may be considered luxurious. The population now consumes much more than the bare minimum, so the question is, what is really needed to consume, to live comfortably? For example, the U.S. population is about 4.5 percent of the world total (Census Bureau, 2008), but in 2005 accounted for 21.8 percent of the world energy consumption (DOE, 2008). That implies the U.S. population may be able to cut back on energy consumption and still live comfortably.

Application of the conservation policy has a range of potential outcomes. One extreme is that people could ignore the pain of the cost incurred by the mechanism imposed to prompt conservation and keep consuming at the same or a greater rate as now. At the other extreme, people could respond to the costs incurred by reducing consumption to the bare minimum needed to survive. Between these extremes are variations on the conservation/consumption continuum. The more any conservation policy is applied the lower the rates of pollution and resource depletion. If the conservation policy outcome resulted in enough of a reduction in consumption, it is possible the rate of consumption would be less than the rate of resource regeneration.

Related to this last point is the issue of efficiency. Efficiency relates to consumption per capita, but does not relate to overall consumption. Resource depletion is only a function of the total volume of withdrawals from the resource stock. A change to a more efficient consumption rate may still mean withdrawals are greater than regeneration.

Finally, conservation is only directly beneficial when the long-term rate of consumption is higher than the rate of resource regeneration. If the rate of consumption is lower than the rate of resource regeneration, the system is sustainable – withdrawals and regeneration could continue indefinitely. It is only when the rate of consumption exceeds the rate of regeneration that conservation is valuable.

The degree of effectiveness of incremental policies

Alternative policies 2, 3 and 4 impact pollution and resource depletion incrementally, by reducing energy consumption, limiting particular technologies, and applying conservation measures more or less depending on the specific policy design. The overall impact of any policy would depend on the aggressiveness of the policy. For example, applying an aggressive limit on the amount of global energy consumed would have the effect of severely limiting the application of technology, and therefore the amount of pollution released.

The aggressiveness of the policy defines the impact on the population. Any policy that slows the rates of pollution generation and resource consumption from what they are now would help, in that less pollution and less resource depletion are better than more. However, the population will be optimally served by a policy that decreases the rate of pollution generation below the rate of pollution decomposition and decreases the rate of resource consumption below the rate of resource regeneration. It is only at or below this line that the population is at the minimal risk of ill-health or a collapse from environmental degradation.

Optimal outcome of alternative policies

Many authors have estimated the global carrying capacity of the human population on earth. Cohen lists 66 of those estimates, and reviews 8 of them closely (Cohen, 1995, p. 212-236, p. 402-418). The range of these estimates runs from less than .5 billion people to 10^{16} – 10^{18} people. These estimates are based on different assumptions, such as the length of time considered, the amount of technology applied, the amount of food required by individuals, life-style requirements, and physical space requirements.

When considering policy design, one way to approach a numbers-based estimate of a population that could live without producing pollution or resource depletion is to look back in time to just before humans started to pollute, and see what the population was then. That size population, using the technology available at that point, would be the optimal number.

If the industrial revolution is the point where long-term pollution and resource depletion began, looking to the pre-industrial revolution population may be instructive. An average of Cohen’s estimates for the size of the population for 1700 gives a population size of 644 million people (Cohen, 1995, p. 400). However, this number is immediately problematic; the industrial revolution began first in England, but other countries were not necessarily at their maximum non-polluting carrying capacity in 1700, implying an optimal global population size of about 644 million would be low.

Based on the premises of this paper, the number of people that constitutes the carrying capacity is not as important as the maximum size of the population that can live without polluting or depleting resources. Once pollution and resource depletion are introduced, the population is faced with new stresses that threaten its health and longevity. The line between a society with no pollution or resource depletion and a society living with pollution and resource depletion relates directly to the concept of sustainability mentioned earlier. Sustainable means maintaining the health and viability of the population indefinitely. Policy-wise, avoiding pollution and resource depletion would be desirable if the long-term health of the population is desired.

6. Confront the trade-offs between outcomes

To fully assess the trade-offs between alternative policy outcomes, both the short- and the long-term dynamics of the two policies need to be assessed.

In the short-term, the first policy generates more and more benefit to humans as additional technology is developed to relieve limiting factor impact. Relief from limiting factor impact is expressed different ways, such as improved standard of living, increased development, and improved quality of life. However, this additional technology results in more pollution, a larger population, and increased resource depletion. In the long-term, pollutants build up in the environment to a level of having detrimental effects on people and resources are depleted to the level of being inaccessible. Both situations harm the population. While there is a direct correlation between development of technology and the benefits accrued to people in the short-term, in the long-term there is an inverse correlation, as pollution generated by technology negatively impacts people's health.

The between the benefits of technology in the short-term and the liabilities of pollution and resource depletion in the long-term also play out in alternatives 2, 3 and 4 in the Outcomes table (Figure 5). Pollution and resource depletion happen on a continuum; more technology development results in more pollution and resource depletion. The second alternative would have an effect of decreasing pollution and resource depletion to the degree that energy use is capped; the lower the cap, the less pollution and resource depletion is generated. The same holds true for alternative 3, although it is much more difficult to foresee the effect on pollution and resource depletion without knowing precisely how each specific technology affects others, and the related pollutants each generates. Alternative 4 embraces many different types of action, but broadly, the more conservation that takes place, the less pollution and resource depletion occur.

The tradeoffs in policies 2, 3 and 4 are between the value of a sustainable society, and the short-term benefits that over-consumption bring. Consuming at a rate greater than the rate of regeneration gives society a higher quality of life in the short-term, but at the risk of poor health and societal collapse in the long-term. Consuming less – at a rate lower than the rate of resource regeneration – allows a lower quality of life, but a society not hindered by the impacts of a degraded environment.

7. Decide on a policy

Policy-making: for the short- or long-term?

If the intent of public policy is to create the most common good for the most people, the first consideration for policy-makers is about time-frame: is the common good to be considered in the short-term, or the long-term? Is it assumed that public policy effects are to extend for 5 years? For 100 years? For 500 years? What about an indefinite time period – could policy be designed to benefit humans forever?

The important distinction between 'short-term' and 'long-term' is not a specific number of years, but the intent of the policy. Designing policy for the short-term means considering policies that solve immediate-need issues, in ways that only consider the immediate effects of policy actions. Designing policy for the long-term means thinking about immediate impacts but also about the long-term ramifications of policy actions. Long-term policy-makers would not make a decision that remedies an immediate need, while imposing a harmful situation in the future. The distinction between short- and long-term is important. Deciding to orient policy to either direction directs all subsequent policy decisions to the short- or the long-term.

Short-term policy leads to long-term problems

Technology has generated short-term benefits for the human population. For example, providing a generous food supply, plumbed water and medicinal drugs to prevent disease can be seen as good. However, seeking solutions for the immediate may outweigh assessing the long-term problems that could result. The development and use of pesticides is an example: the immediate desire for pest control overwhelmed considering the long-term consequences of pesticides in the environment. Another example is crop irrigation: the immediate need for water led to well technology that allows consuming water faster than the aquifers recharge, resulting in aquifer depletion.

Pollution and resource depletion are long-term problems. Pollution that results from human technology often lasts a long time before breaking down. By remaining toxic for a long time, such pollution can become wide-spread.

For a technological development to have a positive long-term benefit to society, it would have to produce no detrimental by-products and would have to utilize resources that are limitless. If a technology produced no detrimental by-products, then the use of that technology would not be polluting. This holy grail of technologies is often sought in the arena of energy generation: an energy source that does not create any pollutants. To date, there has been some pollutant associated with most human technologies, energy source or otherwise. The only human technologies that do not produce pollutants are those that minimally modify natural resources, such as stone and wood tools.

To date, there are no limitless resources. The earth's atmosphere and the oceans are resources that seemed limitless at first, but are proving finite in the long-run. Solar energy is one resource that is unique, in that its source is from beyond the earth, and it is supplied to the planet on a continual basis without cost. The limitations for humans come in the sporadic availability of sunlight due to diurnal, geographic and cloud-based variability, and in the need to convert solar energy into a form that is usable for humans. Except for direct heating by solar energy, for example to dry crops and to passively heat buildings, solar energy needs to be converted to another form to be useful to humans (Kruger, 2006, p. 145). For example, converting solar energy to electricity can be performed in different ways, including solar thermal and solar electric technologies, but the production of any conversion technology and the technology to transport electricity requires energy and resource expenditure, which imply limits to the use of solar energy.

Some factors complicating a policy decision

One factor making it difficult to rationalize the options in the outcome chart is the assumption that technological advancement is justified to resolve societal problems (Bush, 1945; Holdren, 2008). Acting on that assumption has resulted in our population being dependent for survival on technology. Voicing resistance to technological evolution would be politically difficult, as people are accustomed to relying on technology for problem solution.

Once the policy decision to use technology to provide relief from limiting factors is applied, it is hard to change policies. Developing technology drives the population to grow; a population supported by technology would suffer a crash if technology was removed.

Given that humans have the ability to create technology it is difficult to imagine that they would not do so. In situations that threaten survival, the obvious reaction is to use available tools that help in immediate ways, and not question the long-term ramification. The problem is that people are incredibly effective at developing technology, which results in more pollution and resource depletion, and a large population.

At the moment, the problems of pollution and resource depletion are not inflicting a severe cost on those causing the problem. People have died for scarcity of resources in Rwanda (Diamond, 2005, p. 311-328) and are suffering and dying for lack of water (Sengupta, 2006; UNDP, 2006) and people are becoming ill from pollution (Selin, 2006), but the populations responsible for the majority of pollution and resource depletion are not paying severely or losing significant population as a result of the problems.

What this means is that there is room for different factions in the policy arena to maintain different assumptions of what is 'right' without direct feedback. For example, some people have faith that social problems can be resolved by technology. This group would probably take issue with the premises that technology and a large population are responsible for pollution and resource depletion and that more technology will result in more pollution. Some people think that aggressive resource consumption is helpful for society by continuing production growth; others think reducing resource consumption is healthier.

Each perspective can voice their assumptions, with no definitive proof or fallout from taking a stance. In fact, those believing in technology have examples from history working for them; previous technological development has slowed disease, extended life spans and provided more food for the population. However, history also points out that resource depletion was probably a significant factor causing societal failure in the past (Tainter, 1988; Diamond, 2005).

Making a policy choice

Assuming the premises of this paper are correct, it is an understatement to say that choosing a policy that can benefit the human population for the long-term is a difficult proposition. Implicit in the idea that technology and a large population result in pollution and resource depletion is the notion that to deal with those problems, society will have to live with less technology and have a smaller population. Less technology implies lowering the population's short-term quality of life by removing the elements that make life easier, but improving the long-term quality of life by reducing the illness and suffering caused by pollution and resource depletion, and making the population viable for the long-term.

For the short-term, the optimal policy is alternative 1 of the Outcome chart. We would hopefully keep improving our living standards, while creating more pollution and resource depletion problems.

For the long-term, the optimal policy is to reduce technology to the point that pollution generation and resource depletion cease. By doing so, the environmental problems that cause harm to society and that put it at risk of collapse are eliminated. Any policy that goes part-way towards that long-term optimum will help slow the rate of environmental degradation, and perhaps slow the rate that society approaches a crisis, but will not solve the problems.

Another issue concerning the difficulty of applying policy that focuses on the long-term health of the population is the ability to legislate the policy over the global population. There are now close to 200 different countries, each with autonomous populations and governing bodies, with many cultural and political differences between them. To come to a global agreement on the application of a policy that would to some degree limit technology, energy use and resource consumption would be extremely difficult. While this paper has no solution to propose for this conundrum, the difficulty of policy application does not diminish the importance of the recognizing the system that generates pollution and resource depletion.

An example of effective long-term policy

In his book *Collapse*, Jared Diamond discusses three societies that have sustained themselves through the long-term, one of which provides an especially clear illustration of long-term policies (Diamond, 2005, p. 286-293). Tikopia is a small island in the South Pacific Ocean, located north and east of Australia. It is isolated from other land and from the ability to import life-sustaining goods. To support the population of about 1,115 people, inhabitants must rely on resources that can be grown and harvested on the island. The island has been populated since 900 BC and has survived since then by the application of long-term policies.

Survivability is a very real issue for the inhabitants of Tikopia. They recognize that the resources they need to live are limited to their island and could be depleted by mis-management or over-population. Choices of what foods to grow and store, what to harvest from the sea, and how to survive dry seasons and cyclones are incorporated into their management system.

Besides food supply, Tikopians recognize the need to limit their population size and not outstrip the capacity of their island to support them. The methods of population control used by Tikopians include contraception, abortion, infanticide, suicide and celibacy. In the past, inter-clan warfare also limited population size. Clan chiefs are responsible for exhorting the population to limit births. By western standards, Tikopians may exert harsh controls on population growth, but they recognize the consequences of overpopulating their island and depleting its resources.

As a case study, Tikopia is a microcosm of the planet. Resources are finite on both 1.8 square mile Tikopia and the earth, and choices need to be made for how to manage those resources if long-term survival is the goal. Mis-management leads to destruction of the population, as resources become unavailable.

Conclusion

If the goal of public policy is to generate long-term health of the population, a pertinent question to ask is: how do we maintain our population without polluting or depleting resources? If the premises of this paper are correct, the answer to that question is driven by long-term public vision, and would result in a population that the earth could support forever without polluting or depleting resources.

The premises of this paper are extremely simple, with complex social ramifications. We are just like every other organism on earth in needing to consume resources to survive. We are unique in being able to develop technology that allows manipulation of resources to access the resources we seek to survive. This technology allows our population to grow beyond the natural carrying capacity of the earth, at the cost of pollution and resource depletion.

There is an underlying tension in our present policy. We use technology to diminish the effects of the limiting factors of disease and food supply, increase the lifespan of people, and develop ways to make people's lives easier. This increases the quality of life of the population.

At the same time, we are creating pollution and depleting essential resources, by-products of our policy that diminish the long-term health and survivability of the population.

The Millennium Ecosystem Assessment observed the same tension. It points out that human well-being has improved over the past 50 years: the world's population has grown, life expectancy has increased and infant mortality has decreased in much of the world, famines have declined in frequency and the problem of hunger is not of the same magnitude as it used to be. However,

"... [a]s human populations and individual well-being have increased, so has the consumption of ecosystem services, leading to increasing demands on ecosystems to provide for people. The use of ecosystem services has also changed in its nature, in large part due to research and technology development, allowing for more-efficient use and production of services such as clean water and food and for partial substitutes to be developed for other services, such as for some fibers and for some cultural services. However, the parallel increased efficiency of use of many ecosystem services has been offset by increases in the absolute amounts of consumption of services, giving rise to serious concerns about the sustainability of their supply." (MEA, 2008)

Malthus, Hardin, the Ehrlichs, the Meadows and Osborn all wrote of this tension. We cannot have high tech and high population simultaneous with low pollution and low resource consumption. The assumption of a reductionist, short-term perspective prompts technology and population growth, and results in pollution and resource depletion.

In spite of the difficulty, policy-makers may want to consider the possibility that the premises proposed here explain what drives humans to pollute and deplete resources to the extent they do. If these premises are correct, we either manage our long-term policy, or it may be managed for us in a catastrophic manner.

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