Global Ecological Mega-Concerns
An Outline of the Causal Network

(A "Straw Man")

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Table of Contents

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1 Introduction

The ills and problems that beset the modern world are many and very complex. But in many ways these problems are not new. We find ourselves at the centre of a myriad of problems that previous societies have also faced. These problems include ecological damage, population overshoot, key resource depletion, excessively complex and unresponsive social institutions, large-scale social unrest, extremist ideologies of a religious, political or economic nature, and loss of respect for ruling elite. Those many societies that failed to resolve such problems ceased to exist, some leaving scant traces, the effect being relatively local in both space and time.

But in this modern world we face an additional problem. Modern society has become economically integrated globally in a fashion that has never before been seen, with the result that the impact of failure will also be global in scope, and will be measured on geological time scales. The rise of modern societies has changed the face of the Earth in ways that are somewhat regrettable. But the failure and collapse of modern societies may do much worse harm. There are at least four global trends that are massive in scale and that conspire to create the possibility of such drastic regrettable impacts:

- **After Peak Oil** – The study of Hubbert’s curve and the phenomenon of “Peak Oil” by CAS Hall, one of the leading lights in the field of Biophysical Economics, has made it clear that our modern society is fueled by, and enabled by, the immense amounts of oil and other fossil fuels that we have extracted and burned in the past 200 years. An economy is a biophysical system which, by the laws of thermodynamics, must consume a steady stream of high-quality energy to remain stable. So, a growing economy must consume growing amounts of high-quality energy. When the energy supply ceases to grow, and starts to decline, so must the economy. As the economy declines, so will food production, and so will the world population.
- **Population Overshoot** – The human population on the Earth, which in 1800 AD was held down to a carrying capacity of about one billion people due to limited flows of energy, has had that restriction lifted, slowly at first, and then ever more quickly, due to the exploitation of cheap and high-quality fossil fuels. The human population now has an ecological footprint of 1.6 Earths. When the oil ceases to flow, and when alternative energy sources are found to be inadequate to the task, the population of the Earth will start to fall.
- **Anthropogenic Climate Change** – The Earth’s ability to process the immense amounts of waste produced by seven billion people is severely overtaxed. With rising levels of greenhouse gasses in the atmosphere, global climatic systems are approaching unpredictable tipping points beyond which humankind will have lost the possibility of control or recovery. Think of a rocking chair that, when pushed too far, tips over backwards. The built-in tendency to return to normal resting position is gone, and it would be unable to ever return to that position. A tipping point is most probably a forever change.

- **<u>Biodiversity Loss</u>** – Global chemistry is changing. Global energy flows are changing. Global trophic networks are stressed and collapsing. Global biodiversity is rapidly decreasing as species go extinct, not to be recovered in less than geological time scales. As wild habitats are degraded the Earth is losing species at an almost unprecedented rate. This loss of biodiversity degrades the fabric of the trophic networks of the planet within which we evolved, and without which we cannot continue to live.

For most people in Western societies, the response to such claims of impending doom are disbelief and denial. They think back over the past few decades of their lives, and agree that things seem to be changing, but believe that it has not gotten that much worse. Or they recall the ecological apocalyptic movies and books they have enjoyed, and recast the arguments as another imaginative way to thrill ourselves and to make our lives less mundane. In any case, they tell themselves things are not so bad, and they get on with their lives.

But, if these global trends are real, and if there is something that we, the current cohort of people living on this Earth, can do to change the ultimate outcome, then we must try to stop the madness. There are thousands of scientists world-wide working to that end. In recent years there have been many publications in which the combined knowledge and work of these thousands of scientists has been synthesized into books. In these books the current state of the world, from an ecological perspective, is described in great detail. But, unfortunately such publications are having little impact. Few readers have the ability to see the big picture in the wealth of details available. We must find a way to present these trends graphically.

Modern societies, and the problems they exhibit, do not exist independent of the past, and the policy decisions our leaders can make now, and the effects we can bring about now, are greatly constrained by the global trends that have shaped our past and brought us to this present circumstance. We must understand from whence we came, and our direction of travel, if we are to steer towards a better future.

2 Purpose

The purpose of this exercise is to draw a map of the causality network showing the linkage between the significant trends in ecological, social and economic spheres of influence that have brought our global society to this present circumstance.

With this visual representation of the causal network the authors attempt to lay out the interconnecting ecological, social and economic mega-trends and mega-concerns that have brought us to this place, and map the causal connections between them. The goal is to encourage discussion and improve our general understanding of where we are, how we got here, and how we can possibly find a way to a desirable future.

3 Methodology

3.1 A “Straw Man”

This document, and the slides that go with it, form a “straw man” map of the causality network of global ecological mega-concerns, and the social and economic trends that play a significant role in that causal network. “Straw man” means it is known to be incomplete, and it probably contains some causal connections that are controversial or incorrect. When a straw man model is produced, the intention is to make it public, collect constructive criticism, and improve the model. We believe that every causal connection shown in the panels of this map is supportable by peer-reviewed science. Most can be supported by consensus science (i.e. the opinions of the majority of research scientists as presented in omnibus works and summaries). It is our intention and hope to ultimately improve the model by supporting each causal link with references to documents which represent credible peer-reviewed studies, or which represent the opinions of consensus science, where available. Such an intention cannot be easily fulfilled in a short time frame by a small number of people. It will require the broad participation of people with expertise in many branches of science.

3.2 Core Ecological Mega-Concerns

The impetus for this study was driven by three ecological mega-concerns:

- There are too many people on the Earth, and this can only end badly;
- The formerly robust global ecosystem is becoming fragile. There are too many species going extinct causing a severe loss of biodiversity with no possibility of recovery; and
- There are too many pollutants in the air, causing global warming, shifting climatic areas, and threatening to push the global climate systems past a tipping point with massive unknown consequences and no possibility of recovery.

These problems are interrelated, and each is potentially fatal to much or all of humanity.

3.3 Building a Causal Network of the Past and Present

A distinction can be made between proximate and distal causes. A proximate cause is an event close in time and space that has an immediate and local effect. A distal or ultimate cause is a cause that may be distant in time or space, but which, through the means of altering circumstances, and usually in combination with other ultimate causes, brings about a situation in which proximate causes create effects. Proximate causes are often easier to identify and manage. Distal causes are often difficult to identify, and have far-reaching effects in both time and space. It is usually possible to identify a web of causality between ultimate (distal) causes and current effects, trends, or concerns. It is our goal to identify the proximate and distal causes of humankind's current dilemma.

However, every ultimate cause has its own proximate and distal causes. The only true ultimate cause we know of, at the moment, is the Big Bang of several billion years ago. For the purposes of this study we define the ultimate causes as **those which arose at the dawn of the industrial age**, at approximately 1765. Of course, the industrial age had its roots in the Renaissance, which had its roots in middle eastern Islam, etc.

To find the ultimate causes of the three problems noted above, we started looking for the proximate causes of each of these problems, and found that we could not easily separate them into distinct cause-effect chains. Ultimately, based on the perspectives of biophysical economics, we discovered that the flow of energy and the attendant production of entropy was a thread that wound through all of the trends, whether social or ecological, and we revamped the story to highlight the deep causal forces of energy flows. We then set out to remap the most conspicuous and generally well-reasoned cause-effect relationships that have brought us to this modern dilemma, and formed them into a linked web of cause-effect relationships.

But, one cause can have many effects, and one effect can have many causes. What arises is a complex web or network of ecological, social and economic trends in a self-adjusting system of dynamic feedback mechanisms that are driving our modern societies, and the physical world along with them, to some kind of undesirable yet imminent climax.

3.4 About Time Lines

For reasons mentioned above and described in more detail under the description of Panel A below, we chose to consider 1765 as the moment in time when we start mapping causes. However, you will see relatively little discussion of time lines, because a causal network is a model of a complex dynamic system, and as such it is replete with many feedback mechanisms that loop as time passes. Positive feedback mechanisms cause exponential growth or exponential decline after perturbation. An example is unrestrained population growth. Negative feedback mechanisms cause a return towards an average state after perturbation. An example would be average global temperatures, which have strangely hovered close to the freezing point of water for eons. Just to be clear: positive feedback is BAD because it destroys stability, and negative feedback is GOOD because it engenders stability. But such feedback, whether positive or negative, is not an event but rather an ongoing process. For example, the rising agricultural industry causes the rising population. The rising population causes the rising agricultural industry. This mutual two-way causality forms a positive feedback loop that is driving the rise of the global population and the conversion of vast areas of formerly wild lands into farm land. These processes feed back on each other annually, at worst, if not moment-by-moment. You cannot point to a moment in time and say, this is the moment when the rise in agriculture caused the rise in population. Both trends happened in parallel over the past 200 years, at least. They cause each other via positive feedback loops.

3.5 Two Posters, Nine Classes, Twenty-four Slides

It is very difficult to show these looping effects, and well over 30 other trends, on a simple set of graphs with a time line.

What we have chosen to do is arbitrarily classify the global ecological mega-concerns, and a few associated social and economic trends, into nine classes. Then for each mega-concern we have imagined a cause-effect chain; we have broken it into components that fall within the nine larger classes, and linked those components. So, for example, the growth of the agricultural industry plays a role in the population overshoot, in high-consumption lifestyles, in exhaustion of both renewable and non-renewable resources, and in the overflow of waste into the environment. In some fashion, through discussion of potash mining or industrial aquaculture wastes, the agricultural industry should appear explicitly or implicitly in a linked causal web of its own throughout the panels.

We then drafted graphic slides with causal linkages between the elements, and added to them several explanatory slides, and finally formed them into two graphic poster displays that fit onto standard 3’ x 4’ poster display boards.

So, among the slides you see, there are two slides showing the combined poster layouts, several slides showing the interconnecting mega-concerns by class, and several overview and explanatory slides making a total of twenty-four slides in all.

3.6 Off-Slide Connections

So each of the class-based panels consists of a collection of causes and effects that fall into that class. Directed arrows within a major panel show cause-effect relationships within the panel. Cause-effect linkages to other class panels are shown as arrows to/from little portals containing reference letters, usually to the right or left of the panel.

Also, each slide in the PowerPoint deck is numbered and referenced in the following discussion.

4 Descriptions of Slides

4.1 Two Poster Slides (Un-numbered Slides)

These contain all of the following slides. They are formatted to fit on a 3’ x 4’ poster board display.

4.2 Title Page (Slide 01)

Describes the purposes of this poster display.

4.3 Overview (Slide 02)

In this overview panel you see a sampling of the trends assigned to each of nine major classes of trends. You also see the five future scenarios.

Classes of past and current trends;

- A – Human population overshoot
- B – High-consumption lifestyles in energy-rich and soil-rich nations
- C – Imminent exhaustion of non-renewable stores
- C/D – The changing air/water/landscape (not shown in overview)
- D – Overconsumption and destruction of renewable funds
- E – Overflow of waste beyond the ability to absorb
- F – Anthropogenic climate change
- G – Increasing global ecological fragility
- H – Increasing exhaustion of technological props
- I – Maturing social evolution

4.4 Key Concept - Energy Returned on Energy Invested (EROEI)

To really understand the trends that are driving modern societies, it is absolutely necessary that you first understand the fundamental role that is played by energy flows through those societies. This perspective comes from the branch of economic study called biophysical economics and these are some of the tenets of that economic paradigm:

- All ecosystems, all societies, and all economies consume high-quality energy as they function, and they cannot function without energy.

- Energy can be graded with respect to quality. High quality energy has the ability to do work and is associated with low entropy. Low quality energy has little ability to do work and is associated with high entropy. Examples of high quality energy are the Sun's rays, gravitational or chemical potential energy, and heat in a high-temperature reservoir. Examples of low quality energy are waste heat, and infrared radiation.
- As energy flows through a society from Sun to food plant, to a person's muscles, to waste heat, work is done. We use our muscles to build and operate our society. At the same time the energy is converted from high quality to low quality, AND IT CANNOT BE USED AGAIN. Energy cannot be destroyed (first law of thermodynamics), but it cannot be used for the same purpose twice (second law of thermodynamics). So, for a society to function, it needs a steady flow of high quality energy sufficient to keep us alive and let us do work.
- The energy that flows through our modern society has the standard source of annual amounts of the Sun's rays captured in food plants, but it is supplemented by other sources of high quality energy that can be used to do work such as hydroelectric energy, and energy from burning fossil fuels, from wind, from tides, from waves, from nuclear generating plants, etc.
- The amount of supplemental high quality energy used by modern societies greatly dwarfs the amount that comes directly from the Sun, and this has allowed the population of the Earth to expand greatly beyond what would normally be sustainable.

4.5 Key Concept - Hubbert's Peak

The phenomenon called "Peak Oil" was foreseen by Hubbert in the 1960s, and is expected to come about some time this decade. The issue is somewhat misunderstood by many. They argue that the Canadian tar sands (recently re-dubbed the oil sands), for example, contain immense amounts of oil (thick tar, really) that can supply the world's needs for many decades to come. The problem is it is of very low quality in two ways: it is energetically very expensive to extract, having an EROEI of 2; and it is very dirty to burn, putting a double load of dirty greenhouse gases out for every unit of usable energy - one unit to get the energy, one unit to use the energy.

Hubbert argued that, as the consumption of fossil fuels climbed, so did the world's population. He argued that when the production eventually peaks and starts to decline, then the world's economies will. US oil production peaked in the early 1970s, causing the great oil crisis, and radically changing world politics and economics. World oil production is expected to peak in the next 5-30 years.

It took 200 years (1775-1970) for the 'peak oil' phenomenon to start to manifest itself. It is reasonable to wonder whether the back side of the curve, the future of oil production, will look like the first half. Probably not. We have harvested the easiest and highest quality oil so far, and we are now working on the most difficult and lowest quality extraction sites. When production of oil starts to fall, global societies will come under extreme socioeconomic stress.

It was with the realization of the key role that energy production has played in the blossoming of our current modern world, and the peril that lies in wait for us when this energy flow abates, that we decided to draw the causality network from the point of view of energy flows.

4.6 Methodology (Slide 03)

This slide outlines the steps followed to produce the detailed slides (not shown here) and these summary graphic slides for display purposes.

4.7 Panel A – Human population overshoot (Slide 04)

Thesis: "Exploitation of fossil fuels enables a human population surge and a technological surge."

This slide summarizes the portions of the causal web that fall into this class or category title. Most of the classes have a similar slide or panel devoted to them, but some have more than one slide, and some classes overlap and share a slide. This slide is devoted to class A – Human Population Overshoot.

"Human population overshoot" is meant to imply that there are currently an unsustainable number of people on planet Earth.

In a recent projection coming from the UN, it was said that the population of the Earth was expected to level off and remain at 10 billion people for the future. But the quality of fossil fuels being extracted is dropping down to critical levels very quickly. We do not believe that this UN model factors in the post-peak levels of production of oil and gas, nor does it factor in the rapidly declining average EROEI of the fossil fuels being used.

In another model using the "ecological footprint" techniques developed by W Rees, it has been determined that the current load of 7 billion people on the Earth is 1.6 times the Earth's capacity. A quick calculation would then show that the Earth can sustainably support no more than 4.4 billion people, assuming the current rate of extraction of renewable resources and creation of waste products per capita. Again, this does not, we believe, factor in the effects of declining EROEI, or the fact that the Earth's systems are currently stressed and degrading quickly.

Other estimates, comparing the average per capita consumption of the average North American to the total energy available via photosynthesis after fossil fuels have been consumed put the carrying capacity of the Earth at between a mere 50 million to 200 million.

These estimates are "all over the map" and there clearly needs to be further attention given to this critical issue. But, what is clear, is that the 10 billion number is not remotely realistic. The number of people on the Earth at present is not sustainable, and when we "run out of gas", the numbers must crash. This will not be a pleasant experience for our children and grandchildren.

In Panel A we display the elements of the causality map that have led most directly to this state of population overshoot.

It all started with James Watt. In 1765 James Watt, a Scottish inventor, corrected a design problem in the Newcomen steam engine that radically improved its efficiency, and thereby enabled humankind to more effectively utilize the immense store of energy found in readily accessible deposits of coal. Coal in various forms had been used as fuel for several centuries, but with this adjustment to the design of the steam engine, Watt finally and ultimately unleashed immense power to be put into the hands of farmers and industrialists.

In 1776, Adam Smith, a Scottish moral philosopher, published his book *An Inquiry into the Nature and Causes of the Wealth of Nations*, in which we find the first well-articulated description of the economic processes that have shaped our modern world. Trade and economic activities have existed since the time prior to the writing of the ancient cuneiform tablets in Mesopotamia. But Smith was noticing the systemic ways in which a self-adjusting and self-correcting economic system was shaping and forming within and between nations in Europe.

In 1798 Thomas Robert Malthus, a British clergyman and scholar, published the first of several editions of "An Essay on The Principle of Population" in which he argued against the popular views that society would continue to improve limitlessly, and he pointed out that, eventually, population growth must be checked by famine and disease. The specific predictions of Malthus were, unfortunately, overwhelmed by the success of the industrial revolution, of which he had barely witnessed the birth. But his arguments remain valid in spirit. Today we know that there are physical limits to the carrying capacity of the Earth. We know that there are social limits to the amount of comfort and well-being we can appreciate. The population cannot grow without limit. Society cannot improve without limit. Malthus was looking forward, trying to guess what happens when those limits are reached, and breached. His vision may have been unclear, but he could see the shape of the dilemma we face today.

The period 1760 to 1840, the period of the industrial revolution, is a time when the roots of our modern world were forming; modern beliefs and trends were being established; and concerns about the ultimate destination of modern society were being formulated. The defining moment for the birth of the industrial revolution is often stated to be the date of James Watt's invention.

Panel A documents the causality map for the trends that enabled explosive growth in the population of the Earth, explosive advances in technological capabilities, and those trends that arose in support of that or fell out of that. There is no intended time line within this panel. It forms a massive self-reinforcing positive feedback vortex which was unleashed by Watt's invention, and which continues to operate today. Some of these trends existed well before 1765 (e.g. exploitation of forests). Some did not really start until much later (e.g. development of public health programs, 1880). Nevertheless, the trends mentioned within this panel were enabled, developed and played a significant role from 1765 to the present day.

In this panel we find the one root cause, the ultimate distal cause, of today's ecological crises: the exploitation of fossil fuels. People and animals each require a quantity of calories per day determined by metabolic needs. This energy is obtained from the Sun, by way of photo-synthesis, as high-energy sugars, fats and starches in plants, which we harvest for food. The construction of roads, bridges, homes, boats, mines, mills, and factories requires the expenditure of energy. Similarly, the operation of transportation systems, industrial systems, and government administrative systems also requires energy. Prior to 1765, the energy supply to accomplish this construction and operation of the artifacts of society came largely from photosynthesis. The amount of developed farmland and its productivity was a limiting factor for the amount of energy available. The population was fairly stable because the supply of food was stable. Life for the poor was difficult, and many died of hunger and disease. All work was done by people, or by powerful animals. The amount of work done annually was limited by the amount of calories available in human and animal food.

In pre-industrial times they were aware of the link between area of land used for food production and population. Measurements in those pre-industrial days were dominated by biophysical and metabolic concepts. A mile was a thousand paces. Power was measured in horsepower. Large areas of land were called “hundreds” because they could support 100 families. Small lots of land were called “ploughs” because they could support one family with a pair of oxen. We find these measurements of land area strange today because they vary in true area. A plough of good farmland was a lot smaller than a plough of rocky land. But they were well-adapted for the economy of the time, having been established in the time of the Roman empire.

However, with the improvement of the steam engine by James Watt, the amount of energy available to do work, whether on the farms or off, was greatly increased, and the industrial revolution was unleashed. With that, the metabolic basis of measurement was abandoned for more objective and invariant measures, and the understanding of the link was weakened. With open access to this source of non-metabolic energy in coal, having an estimated EROEI of 60, more construction could happen faster, more energy could be put into food production using mechanized tractors, and more energy could be spent on the operations of the mines, mills and factories, and the operations of government and other social institutions. There was a rising flood of activity and innovation, enabled by a rising flow of cheap energy.

And things quickly got even better. With the industrialization of the extraction and refinement of oil and gas, with estimated EROEI of 100 circa 1930, the pace of innovation picked up, as did the pace of the rise in the population. There was a positive feedback loop that just kept lifting that ‘cap’ - that limit on the population size - higher and higher. More people need more food, more jobs, larger economy. Larger economy needs more energy. Expanding energy production and food production enable the economic growth and the population growth. And that positive feedback has continued until today.

Along with this cycle of growth there has been a trend towards increased complexity in almost all aspects of social organization. Whereas a person living in the 1880s could reasonably expect to successfully enter adult society with three years of education, a modern student needs from 16 to 19 years to find reasonable employment. Similar increases in complexity are happening in justice, in politics, and in health care. Our social life is serviced and managed by a large variety of social, professional and other institutions, all with complex rules of governance.

We also see this rising complexity in national and international commercial and business practices, and in international social systems such as transnational corporations, United Nations agencies, international defence pacts, treaties, agreements, and quasi-judicial panels.

But complex processes consume more energy than simple processes due to more steps in the process, more infrastructure, and more people. This complexity could not be afforded energetically in a pre-1765 society. It requires large amounts of energy to operate such complex social systems, and that energy can be traced back directly or indirectly either to photosynthesis, or to fossil fuels, or to a similar alternative energy source.

In summary, in 1765 the world was poised to enter the industrial age, but the limit on the amount of available energy through photosynthesis placed a cap on the human population that could be fed, and the social complexity that could be supported. With the improvements in the efficiency of the Newcomen engine that James Watt designed in 1765 that bottleneck in the flow of energy from sources other than photosynthesis was opened up, and the flow of cheap high-quality energy immediately started a process of population growth, economic growth, and social complexification. As society adjusted to these ongoing changes, our modern world emerged.

Note that processes in Panel feed into Panels B, C, D and E, which feed back into Panel A.

4.8 About Panels A and B (Slide 05)

This slide was added as part of the poster display. For more detail about Panels A and B, see the appropriate sections in this document.

4.9 Panel B – High Consumption Lifestyles (Slide 06)

Thesis: "The technological surge enables an extremely high-consumption lifestyle".

This is a companion panel to Panel A, in the sense that the trends and events described here happened in parallel to those described in Panel A. We saw not only an increase in population, with an associated increase in complexity, but also an increase in per capita consumption, described here. The trends in panels A and B form a self-reinforcing causal network of social evolution, enabled by a flow of energy derived from sources supplementing photosynthesis.

But the high-consumption lifestyle was only available at first to the countries in which the industrial revolution had taken hold, primarily the European powers with Britain in the lead, and in some of the colonies of the European empires. The US, Canada, Australia and New Zealand, in particular, seemed to be beneficiaries of this technological surge, possibly due to their temperate climates, their vast stretches of forest and tillable land, their natural deposits of fossil fuels, and their social and political heritage. When the US broke free of its colonial relationship with Britain at the beginning of the industrial revolution, that set them on a course of their own which ultimately led them to become the dominant world power, replacing European colonial powers in that role.

In these select countries, free-market capitalist economies arose and came to dominate the economic practices. These economies were characterized by rising rates of per capita consumption of natural resources in the form of consumer goods. In the 1920s, with the utilization of high-grade oil having an unbelievable EROEI approaching 100:1, energy was exceedingly cheap and profit was easy to make. There was a potential profit margin of 10,000% to be shared by the oil companies with their commercial cohort. New monetary and banking systems were invented to enable commerce on a scale not seen before. As local industries flourished in the extraction, manufacturing, and distribution of these goods, a well-paid middle class arose which played the dual role of making the goods (for a good wage) and consuming the goods (at a good price). At the same time, the “captains of industry” became very wealthy, positioned at the top of this positive feedback loop.

With the advent of information technology, the ultimate abandonment of the “gold standard” for money, and the creation of financial institutions having a global mandate, the modern world enhanced and enforced the global system of high-volume extraction and consumption of resources. Populations continued to climb, and industrialized societies continued to complexify. This organized the world into two kinds of places: those that enjoyed the benefits of the technological surge, and those that provided the raw resources and labor needed to feed the industries and societies birthed by the technological surge. This modern division of the world mimicked, in many ways, the previous division of the world under European colonialism enforced by military conquest. Unfortunately, this neo-colonialism based on financial subjugation reinforces and perpetuates the 1st/3rd world divide, a fact that is strongly resented by many 3rd world citizens.

At some time during the 1900s two interesting phenomena started to happen:

1) The movement among industrialists world-wide to “drive out costs” stepped into high gear. This movement had two large-scale effects forming a positive feedback loop:
   a) Driven by declining marginal returns, as described in Panel C, the migration of extraction and manufacturing operations to sites in underdeveloped countries increased. Jobs migrated to countries like Mexico, Japan, China, Indonesia, and the Philippines, where labor was cheaper and/or closer to the sources of extraction.
   b) The share of wealth flowing through the developed countries that was formerly enjoyed by the middle class of wage earners declined, and they had less money to spend on discretionary consumer goods. To keep the purchases flowing, they had to be less expensive, of lower quality, and less durable.
2) The phrase “creative destruction of capital” was coined approximately 1950, as it was realized that the goal of competition is the destruction or usurpation of the competitor’s capital. Dominant corporations with large research budgets began to destroy their own capital by making their own products obsolete more quickly than their strongest competitors were able to do. Products were designed with built-in obsolescence at a lower price to encourage a greater flow of product output, and suppress competition.

By such processes the “Maximum Power” phenomenon described by HT Odum and CAS Hall is seen to dominate not only natural ecosystems, but the evolving global human ecosystem driven by the flow of cheap energy.

One final note. In this panel we see a curious pair of positive feedback loops: the first of which drives up the standard of living of the middle class, and the second of which drives it back down again. Panel B is also part of a larger positive feedback loop that goes from A and B to panels C, D and E and back to A and B again. The practice of extracting the easiest and best first leads to declining effectiveness of extracts, and so the effects of Panels A and B become ever more pronounced.

Panels A and B are the good news. The ecological impact of the trends in Panels A and B is described in panels C, D, E, F and G. The ability of technological innovation to rise to meet the challenges of the unintended consequences of previous innovations is described in Panel H. The political and social evolution of the developed countries to their current matured state is described in Panel I.

4.10 Panel C – Imminent Exhaustion of Non-Renewable Stores (Slide 07)

<u>Thesis:</u> "Some resources cannot be renewed in commercial time scales."

In Panel C we include trends in the consumption of non-renewable resources. While it is common to distinguish between renewable and non-renewable resources, the distinction is actually difficult to make in practice:

1) Many resources have a fixed supply determined when the Earth cooled. Metals and minerals fall into this category, and are very aptly called non-renewable resources.
2) Many resources are replenished naturally at a high rate, such as wood grown in a forest, or water flowing in a river. These are very clearly renewable.
3) Some, however, are replenished at very slow rates and may be renewable in geologic periods of time (millions of years) or in historic periods of time (centuries) but are not renewable in commercially realistic time periods. Fossilized water as is found in the Ogallala aquifer in the mid-western US, or tillable soil, are two excellent examples of critical resources that many consider to be renewable, but which are not renewable in practice.
4) The distinction is further complicated when you consider that the fund (the generating source) from which an eminently renewable resource flows might itself be extinguished, converting an eminently renewable resource into a depleted non-renewable resource. Clear-cut forests, collapsed fish stocks, destroyed or inaccessible nesting sites or summer mating grounds, and extinct species are all examples of such extinguished funds of renewable natural resources.

Just so, Panel C looks at the mostly non-renewable resources. Panel C/D looks at those resources which have some characteristics of being both renewable and non-renewable, but which also, in some sense, belong to all people on the Earth, or global commons. Panel D looks at those resources which are renewable, but the funds from which they spring are under pressure and declining, or extinguished.

Some clearly non-renewable resources are being consumed at ever-increasing rates, such as potash used to make fertilizer to grow food, and other metals and minerals, of which a few are expected to be exhausted in the very near future. An economic principle called "substitutability" would say that that is of no concern, as technological innovation will find a suitable substitute, and life will go on, the absence of the exhausted resource not being noticed.

However, admittedly, the central focus of this panel is on the store of energy found in fossil fuels, and its consumption by the developed countries. The constant flow of that energy is needed to maintain a constant process of extraction and use of the other resources. This need for ever-increasing amounts of energy to extract and process the ever-increasing amounts of other resources forms a positive feedback loop with a triple kick. A positive feedback is NOT good news. The strength of that positive feedback is enhanced by three things:

1) The rising need for energy to feed and house the rising population;
2) The rising unit cost (in energy) of that energy (due to declining EROEI);

3) The rising unit cost (in energy) per capita to provide the goods (in higher costs to extract and process resources).

In other words, our efficiency at producing useful energy is falling quickly, and the need for energy is rising faster than the population.

In those countries in which the technological surge had taken hold as described in panels A and B, social and economic complexity also surged, and with that, the per capita consumption of natural resources. Of course, when consuming natural resources such as fossil fuels, metals, and minerals, it is reasonable that one would use the materials that are of highest quality, closest proximity, or easiest access first. We are naturally inclined to spend our energy on the work that has the highest energy payoff. Our financial system tends to mimic this natural biophysical system, but often it varies and obscures the biophysical reality behind the dollars, so it is more simple to think of costs and benefits as being denominated in units of energy.

This rule of easiest and best first can be called the effect of "declining marginal return". For example, if you want to grow corn, and your back yard contains both good soil in one spot and poor soil in another spot, you will plant the corn in the good soil first. Only when the good soil is all occupied will you consider planting it in the poor soil, with a lower payoff. If we denominate the cost and the benefit in terms of energy, we get fewer calories returned from poor soil for the same effort of planting. Equally, if you also own a plot of equally good land a few miles away, you will fill the nearby plot before you consider planting corn in the far away plot. Of course, it can get complicated, but fundamentally, you are always looking for the highest payoff in energy for the least effort.

The problem of declining marginal returns has played a significant role in our evolving modern global economic system. As described in Panel B, it contributed to the hollowing out of manufacturing in developed countries. Like a forest fire that has exhausted its fuel at the place of the lightning strike, it burns outwards. So, the sophisticated techniques used to extract resources were first applied where the industrial revolution was spawned, and have been applied further and further afield. The phenomenon of declining marginal returns has, in this way, played a significant role in organizing the manner in which we have consumed our non-renewable resources, and pushed both the costs and benefits of our high consumption lifestyle out into foreign places.

4.11 Panel C/D – The Changing Air/Water/Landscape (Slide 08)

Thesis: "Air, water and land usage follows trends that cannot be reversed in historical time scales without a significant reduction in population, and associated energy consumption."

This is a hybrid renewable/non-renewable panel with a focus on the global common resources. It is difficult to classify such resources as either renewable or non-renewable. They would seem to stand in a class by themselves, partaking of key characteristics of both of the other classes of resources.

People the world over have a common interest in the air, the water, and the land. Air and water are nomadic in nature, moving over time from country to country, and it seems odd to argue that any person, corporation, or state has a claim on any air or water, other than a right to draw from the common supply from time to time as needed.

Air – It is common knowledge that greenhouse gases are accumulating in the global airways, causing global warming. This is quite probably the greatest problem we face with respect to air quality. But there are other problems. CFCs have caused ozone depletion, but this problem seems to be under control now. Volatile persistent organic pollutants (POPs), riding the air currents, grasshopper their way northward towards the Arctic, where they accumulate. Acid rain eats away at the mortar, cement, and steel in our ancient and modern buildings. The citizens of major cities worry about smog indices almost daily.

Fresh Water – Our hydrological cycle used to guarantee an endless supply of fresh water. However several major rivers are now drained before they reach the sea as the waters are turned aside for urban, industrial or agricultural uses. Headwaters that depend on an endless supply of glacial melt-water are drying up in the summer as the glaciers disappear. Groundwater in major aquifers is removed at rates that exceed recharge rates, and water tables drop below the levels reached by long-established wells. Urban waste water is laced with the residues of medicines, household cleansers and chemicals that the water treatment plants cannot remove. Mercury levels in man-made reservoirs bioaccumulate in fishes, and ultimately, in fishermen and their clients. Chemicals from mining, manufacturing and farming enterprises enter streams and rivers, causing genetic damage to fish.

Fossilized Water – Massive underground aquifers, acting as reservoirs of ancient water and having very small recharge rates, are being pumped dry for urban, industrial and agricultural use.

Ocean Water – Micro-plastics (fibers of nylon and other bits of garments, and other plastic products) are ubiquitous, being found in both the Arctic and Antarctic oceans. Larger shards of plastic migrate to the five great oceanic gyres, forming the so-called “garbage patches” that stretch for thousands of square miles in the five greatest oceans of the world. Temperatures of the world’s oceans are rising, causing significant failure of metabolic processes in oceanic biota. The level of acidity in the world’s oceans is changing, also causing significant failure of metabolic processes. Trophic networks are stressed as organisms fail to adapt, or migrate to new locations.

In short, the temperature and the chemical composition of the world’s oceans is changing, even as the load of medium and micro-sized plastics is climbing. Having evolved in an environment that has been stable for millions of years, oceanic biota and the trophic networks of which they are a part are ill-prepared to survive these sudden changes.

Land – Land is different, and some kind of property rights associated with land are a feature of most ancient societies. In our modern society, people, towns, cities, corporations and states all stake a claim on pieces of land. But this localized claim on lands and the assets associated with them militates against the needed management of these resources. In our overpopulated world, some countries are massive exporters of food, and others are massive importers of food. In such a world, all people in the importing countries are certainly key stakeholders with respect to the farmland in the exporting countries.

Similarly, forests, attached to the land and so subject to the same property laws, are the lungs of the world. Massive extents of forest take in large volumes of carbon dioxide from the air during the day, and release large volumes of oxygen to the air at night. The tropical and temperate zone rain forests, and the boreal forests, are a primary source of oxygen that humanity needs to breathe. We all have a common interest in the health and welfare of the world's forests.

As the forests remove carbon dioxide from the air, they create a storehouse of carbon that eventually becomes the fossil fuels we now burn. When we burn fossil fuels we are undoing the work of eons of forest activity. The way to control this burst of new carbon dioxide is to have the forests expand and grow ever more abundant. However, our need for farmland is causing a shrinkage of forest lands, exacerbating the problem of greenhouse gases.

So, all people of the world are somehow stakeholders in the state of the air, the water, and the land on this Earth. We all have a common interest. There is a famous paper entitled "The tragedy of the commons" in which the author describes our inability to manage such resources in which many people have a common interest. The ability to manage such a resource becomes all the more difficult when some local stakeholders have elite status through property rights of some kind, and their personal needs are in conflict with the common needs.

You will note that the insidious problem of "declining marginal returns" also plays a behind-the-scenes role of reducing the productivity of our farmlands as this causal web brings about an evolving landscape.

In this panel, then, we see the trends that indicate a failure to manage the "global commons" of air, water and land.

4.12 About Panels C, C/D and D (Slide 09)

This was added as part of the poster display and provides a brief explanation of the said panels. For a more detailed description, see this document.

4.13 Panel D – Overconsumption of Renewables (Slide 10)

Thesis: "Renewable resource usage follows trends that cannot be reversed in historical time scales."

This thesis, in fact, declares that our renewable resources are not really renewable. The natural funds from which they spring can and are being rapidly extinguished.

Perhaps it is possible to make a long list of renewable resources that are not being overharvested by our global practices. Other than alternate energy sources, none come to mind.

Forests are being razed. Tillable soil is being degraded. Coral reefs are being bleached, inundated with silt, or killed for lack of oxygen. Wild fish stocks are harvested until the stocks collapse and the trophic networks on which they depended are disrupted. Biodiversity built up over thousands, or possibly millions, of years is being dissipated at a high rate. The ability to produce food is being degraded. The access to fresh air, fresh water, and wild lands and oceans is being dissipated, as discussed in the previous panel.

In recent years the branch of economics called ecological economics has put a great deal of effort into understanding and measuring the value of the "environmental services" that humankind derives from such renewable funds. Strangely, when these global environmental services are flowing from a healthy fund, they have little or no value. In disinterest we turn away looking for other ways to extract value from nature. But, as we extinguish and degrade these funds, the relative value climbs. We cannot recreate such natural funds. Once extinguished, they are gone.

4.14 Foundation Earth (Slide 11)

This slide was added as a brand mark on the poster display.

4.15 Panel E – Overflow of Waste (Slide 12)

Thesis: "Global waste disposal systems are becoming overwhelmed, disrupted and/or clogged with anthropogenic products.

We are fouling our own nest, and we have nowhere else to go.

This is an eventual outcome of a population that exceeds the Earth's carrying capacity. As mentioned under panel A, the world's population is now, at seven billion people, considered to be at 1.6 times the Earth's ability to provide renewable resources and absorb wastes.

All of the trends found in this panel are the logical effect of trends seen in other panels. Population overshoot and high-consumption lifestyles, coupled with the large expenditure of energy on extraction and processing of renewable and non-renewable resources to produce low-quality disposable products, cause an immense throughput of mass in the form of biophysical and industrial wastes, chemicals, volatile gases, and worn out or discarded goods. The global ecosystems of the Earth have been tuned, over millions of years, to absorb the biophysical wastes of the biota which they contained. We are now exceeding that waste-absorbing ability, both in volume (of biophysical wastes) and in type (of non-biophysical wastes).

4.16 Overview (Slide 13)

This is a duplicate of slide 02, used as the top centerpiece of the second part of the poster display.

4.17 About Panels H and I (Slide 14)

Introduction to panels H and I.

4.18 Panel F1, F2 and F3 – Anthropogenic Climate Change (Slides 15, 16, 17)

Thesis: "Global climate is now changing rapidly in response to mankind's products and activities. When natural positive feedback loops kick in, it will be uncontrollable."

It is understood that a husband might deny the news, delivered by a police officer, that his wife, whom he had kissed a half hour before, has just died in a traffic accident. This kind of denial of tragic news is understandable. In the same way, most of modern society has gone through a series of stages of denial of the bad news. They denied, at first, that climate change was happening. Then they denied that it was anthropogenic. Now they tell themselves it will be a small change and believe that they can carry on business-as-usual with small "mitigation" activities.

The worst damage might be avoided if we immediately and drastically curtail all burning of fossil fuels, but this would have dire consequences for food production and distribution, not to mention the production of a variety of goods and services of far less import. The political will to study the problem and undertake real preventive action does not exist. In fact, it seems there are strong political lobbies that can and would prevent any such action. There is a sinister subset of society for whom maintenance of the status quo can bring riches, and they are willing to use bad science and propaganda to obfuscate and befuddle the public. Then there is a crowd of unbelieving fools who use sarcasm, mockery, buffoonery and sophistry to attack and embarrass those that disagree with them.

Panels F and G are in some sense subsets of Panel E. Global warming can be viewed as just another fouled-up waste disposal system overheating. Many believe that, if we behave, and stop doing bad things, it will get better. They think we can weather a few droughts, storms, and famines, though that would be tragic. However, several things are causing grave concern to climatologists worldwide:

- When the global climate changes, all worldwide weather patterns will be affected, farmlands will be turned to deserts, coastal plains will become underwater continental shelves, northern expanses will thaw, and oceanic currents and global air currents may shift, putting places like northern Europe in the deep freeze.
- When the albedo of the northern and southern ice caps change, and when the permafrost decomposes and produces massive amounts of methane, humankind will no longer be able to control further climate change. This event is called a 'climatic tipping point', meaning a point beyond which there is no return.

Should the above changes happen, and should humankind survive with some semblance of modern society intact, our infrastructure will be in the wrong place, and will need to be rebuilt. However, we may no longer have access to cheap high-grade energy and resources to do the work.

Notice the two positive feedback loops which might be called the permafrost feedback and the albedo feedback. Both of these are on the verge of starting. It is not known how powerful they may be.

4.19 About Panels E, F, and G (Slide 18)

This slide was added for the poster display. More detailed information is found in this document.

4.20 Panel G – Increasing Global Ecological Fragility (Slide 19)

Thesis: "Ecological fragility increases with loss of complexity. A complex trophic network is needed to keep an ecosystem robust. Recovery is in geologic time scales."

In this panel we see the current ecological trends which are directly eroding the fabric of the trophic web which is humanity's life support system, and of which we are an integral part. To the left are the local effects, and to the right are the more global effects. In the same way that predators disappeared from the Prairies when their major prey, the buffalo, were removed, humans will disappear from the Earth when the trophic web that supports us collapses. This trophic web consists of many interconnected smaller local webs. We have, by reason of overzealous harvesting, or unintended damage, eroded many of these smaller local webs of life causing the collapse of local populations that have failed to recover. In the wake of these collapses we see expanses of unpopulated landscape, whether oceanic or terrestrial, where once dense populations with many species existed; and we see sparse populations of opportunistic organisms that blossom occasionally, and then fade. We know that formerly robust trophic networks are now gone.

In this panel we see the trends that are eroding trophic networks on a local and global scale, both by overzealous harvesting and extraction activity, but also by indifference and neglect. We cannot remain ignorant of the unintended consequences of our actions.

No matter what humankind may do on this planet, life of some kind with modern DNA will very probably survive, and over a few tens of millions of years, a new and widely variant biota will develop and repopulate the Earth. The survival of life is not the concern. The concern of many modern scientists and ecological activists is whether there is a place for humankind on the Earth in the very near future. A trophic network that is dominated by an apex predator, such as humankind, is a complex web of interconnected species of plants, animals, bacteria and other biota. If we wish to continue to have a place here on this Earth, we must not destroy the web of life that supports us, gives us the air we breathe, gives us the water we drink, gives us the food we eat, gives us the productive land in which we live.

4.21 Panel H – Increasing Exhaustion of Technological Props (Slide 20)

Thesis: "Our technological marvels have made this a better world. But they are fueled by energy. Lack of energy will force difficult decisions about resource allocations."

The availability of cheap high-quality energy derived from fossil fuels will come to an end sooner or later. Alternative energy sources cannot hope to fill the gap created when fossil fuel production fails. Some experts see the evidence of that failure happening now. Others see some hope that such a dilemma can be put off for a few more decades. Many politicians and members of the public put their hope in North America's energy self-sufficiency expected to return within a few years. There is no scientific basis for such a hope. Discovery rates are declining. Production trends are declining. EROEI for existing and future production facilities are declining. All alternative energy sources are feeble in comparison, at best.

We use that energy for a variety of key activities, such as to:

- produce food at levels far above the natural limits of photosynthesis, process that food, and deliver it to far-away places;
- develop fertilizers, herbicides, pesticides, antibiotics and antiviral medicines to protect our food sources and ourselves;

- maintain sophisticated medical research labs to develop treatments for environmental problems such as cancer, and to keep the bacterial and viral diseases at bay;
- operate complex public social institutions such as educational institutions, judicial institutions, public utilities, health care institutions, and government administrations;
- operate complex private or commercial institutions such as corporations, professional organizations, news organizations, or food distribution systems;
- maintain and operate urban infrastructure, and maintain and operate transportation systems.

Herbicides, pesticides, antibiotics and antiviral medications have a short life span as the target biota adapt to them. To have a continuous array of such tools at our disposal we must dedicate a large stream of energy to the educational and research institutions. Without these tools there will be a resurgence of weeds, germs, disease and famine. And the cycle goes on as new technologies are deployed and the biota adapt.

Fertilizers (containing nitrogen and phosphorous) are a key requirement of fertilizers to build DNA within food crops. A large population of people requires a continuous supply of nitrogen and phosphorous in our food to build and maintain our DNA. To have a continuous supply of food, we must dedicate a large stream of energy to the production of fertilizers, herbicides, pesticides, antibiotics, and antivirals, as well as to the production and distribution of food.

It is clear that when the supply of energy starts to decline, these technological props that have elevated our society to such heights will begin to fail, and social and economic stresses will become severe.

4.22 Panel I – Maturing Social Evolution (Slide 21)

Thesis: Social dynamics, operating on a previously unseen global scale, are driving the evolution of our local, national, corporate and international societies towards an unwanted climax.

This may be the most controversial panel of the set, and the most difficult to support with unchallenged scientific studies. At the same time, it may be the most important panel for us to understand, because it examines the reasons why we, as a global community, are unable to take the necessary steps to avoid impending disaster. Like the often-mentioned deer caught in the headlights, we see the danger, but we are frozen into inaction as we try to comprehend the incomprehensible.

Social institutions, both good and bad, that used to function reasonably well in the past no longer function as well. The educational systems are no longer seen to prepare youth to enter adult society successfully as unemployment rises globally. The justice systems are no longer seen to deliver justice as the average citizen lacks access due to complexity and cost. The political leaders are losing credibility as political debate has become a pretence, and polarized partisan politics has become increasingly deadlocked. The scientific world view that was so effective in building the technologies on which we now depend has morphed into a quasi-religion, and is under attack from all directions by those with extremist ideologies.

Transnational corporations with sociopathic intent drive global agendas while national governments struggle with massive debt loads and staggering economies. In the United Nations, where one would hope global leadership might be found, meticulous bureaucracies belabor discussions, and voting blocks redirect agendas away from the real solutions.

The behavior of world leaders appears to be little better than that of adolescent bullies, tricksters, mischief makers, and delinquents. We must ask ourselves, how did we ever come to this sorry state?

4.23 Where to, now?

As the energy flowing from fossil fuels declines, global societies will become less complex, local activities will replace far-reaching activities, and priorities will be frequently reset again and again. John Michael Greer, in his book, "The Long Descent", calls this process catabolic collapse. Should this kind of slow deflation of complexity happen, humanity may survive. Along with social and economic decline, there will probably be a similar decline in technological abilities, largely because complex educational systems are no longer sustainable, and complex refining or manufacturing facilities are no longer sustainable. This loop of catabolic collapse is a possible positive feedback loop that may lead to ultimate total collapse. Potentially, a society might rise from the ashes of such a gentle catabolic collapse.

Such a "soft landing" has three desirable components:

- Some measure of modern civilization and technological know-how survives, powered by renewable energy sources that are, themselves, sustainable.
- Social justice and a respect for nature are the twin pillars of social norms.
- Population levels are maintained well below carrying capacity, and so a standard of living well above mere subsistence level is possible for most of humanity.

Such a society would have to scavenge metals and minerals, and otherwise would have to learn to live in an impoverished world.

By reversing the concepts in each of the major panels, we see some of the conditions that humanity may need to achieve in the near future to bring ourselves to such a soft landing:
A – Population must be brought down to a level such that the ecological footprint is well below 1 Earth;
B – A lifestyle of "enough is enough" needs to be adopted by those in the developed world;
C – We must strictly control world-wide access to and consumption of non-renewable resources, and begin to manage them;
C/D – Air, water and land need to be managed as global commons in some fashion;
D – We must immediately stop destroying the funds from which renewable resources flow, and rehabilitate those that have not yet been extinguished;
E – We must limit the anthropogenic products being made and put into the environment, and undertake cleanup of the most polluted areas, and start a process of rehabilitation of the air, land and water and their associated ecosystems;
F – We must stop producing greenhouse gases completely and immediately, and allow the atmosphere to clear the air;

G – We must stop the destruction of wild habitats, enlarge them, connect them and rehabilitate them;
H – We must stop abusing those technological props that remain to us, and start using them much more wisely;
I – We must reshape our political and social institutions at every level in very profound ways such that the sociopathic and foolish decisions of the last few decades are not repeated.

WOW! This looks impossible.

But, if we value a future for our children, we must take this list seriously. Perhaps the words are wrong. Perhaps the cure need not be as drastic as described above. Perhaps we can find an easier solution. Perhaps, if we think through the implications of each of the modern trends, we can craft a path to a soft landing that does not look so impossible.

These things, at least, we believe must be part of the solution and must be undertaken as soon as possible:

- World-wide human population must be reduced before the food production and distribution systems fail;
- World-wide combustion of fossil fuels must be severely restricted to avoid more serious climatic changes;
- World-wide loss of biodiversity must be halted, and wild habitats must be rehabilitated to avoid destruction of the trophic web that supports humankind.