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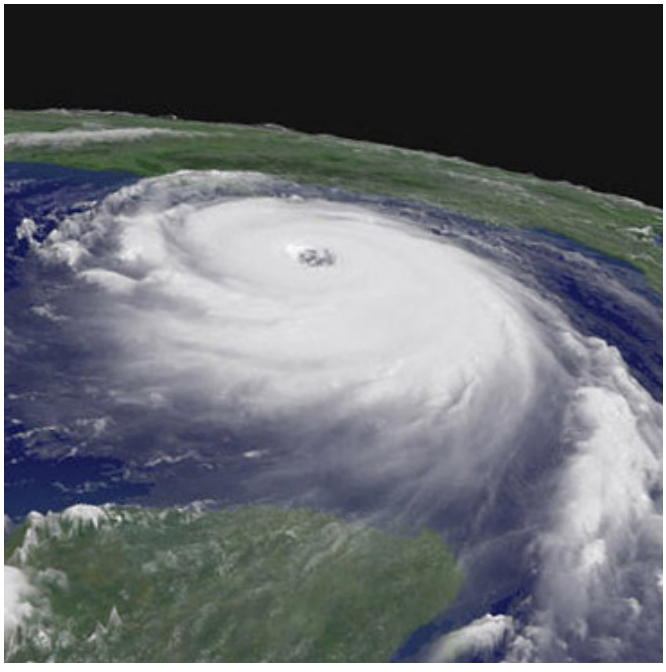
Global Storm Warning: Crisis and Transformation

by Hardin Tibbs



This survey of future global prospects is adapted from keynote presentations delivered internationally by the author in the period 2001 – 2006

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The cover shows a satellite photograph of Hurricane Katrina taken on Aug. 28, 2005, at 11:45 a.m. EDT by NOAA when the storm was a Category Five hurricane. Image courtesy of the National Oceanic and Atmospheric Administration (NOAA).

Global Storm Warning: Crisis and Transformation

Future Global Prospects

The terrible events of 9/11, Hurricane Katrina and many others in the last ten years or so raise worrying questions about where the world is going. Were those events forerunners of worse to come? Is the global environmental and social system sliding towards a tipping point? In short, is it time to issue a 'global storm warning' – and how can we be sure this is justified?

There are a lot of dots to be connected when trying to understand what might happen next on the world stage. Beyond the volatility of climate and the dangers of terrorism, there are plenty of other issues pressing in on our collective global future, and seemingly only distant cause for hope.

In this presentation I will look at the main issues and how they link up, and what could happen next as they continue to reinforce each other.

My approach is to use 'futures thinking' as a lens for looking at global issues. Instead of relying only on an analysis of what we know of the situation today, it goes deeper into how the issues interrelate by thinking out along the future timeline. This is a bit like planning to move furniture in a room and remembering that drawers will need space to open.

We need a big canvas for this kind of global thinking. I will look several decades ahead as well as looking back the same length of time into the past.

In the last 50 years there have been rapid and extremely significant changes. They included rapidly accelerating science and technology, the advent of weapons of mass destruction, a doubling of the human population, enormous affluence coexisting with abject poverty, and a huge expansion of global communications and travel. The result is many more people, who have much greater freedom to communicate and travel, and who are interacting far more. The number of business firms in the world is vastly greater than it was in 1950, and they have far more powerful technology at their disposal. It's not surprising that we find ourselves living in interesting times, as the saying goes.

Where will things go next? Will we simply see more of the same, or could there be major discontinuities? There is a great deal of speculation in the media about the shape of the future, but it is generally discussed as if the overall context will simply be more growth, more expansion, more of all those things that we saw during the last half century. However, it is just as likely that there will be major discontinuities on several fronts. As future thinkers like to say, a trend is only a trend until it bends.

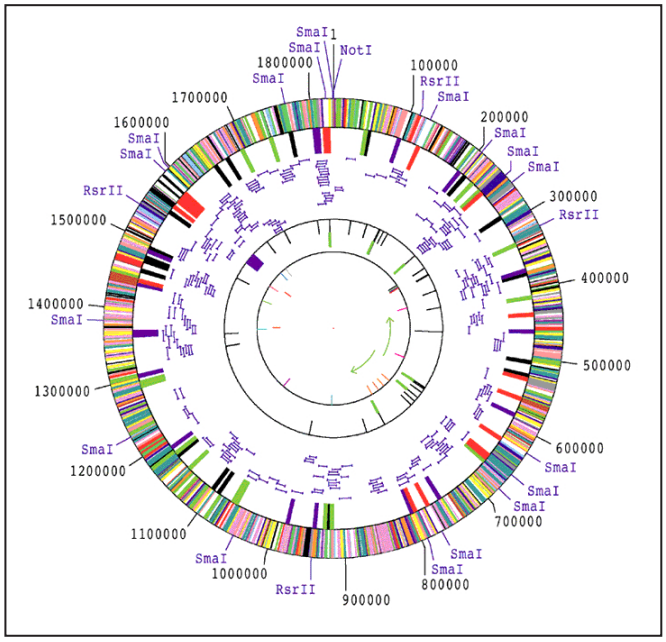
It seems that we will have ever more powerful technology. We may see either a continued steady deceleration of population growth, or even – to think the unthinkable – a crash and far fewer people in the world. We will almost certainly be managing the pattern of industry and trade in new ways, particularly with respect to their social and ecological effects. That in turn will depend on completely new ways of thinking about social organization, economic structure, political power and world order.

It is no longer a question of waiting to see if these things will happen. In many important respects, a vast global change is already underway. The climate is now changing, with implications for such things as food production and coastlines. Technology is racing ahead, into areas that go far beyond the reach of any previous social or political compact. The Earth's resources are being drawn down far faster than they are being replenished, and global oil production, water supply, and food production are now all at or approaching their peaks. Endemic social inequity and injustice, and the failure to share globally the prosperity that industrialization can bring, has already precipitated the first warfare of the century, with more threatened.

The critical question we now face is whether all this is going to develop into a perfect global storm, leaving a wake of destruction through the core of our civilization, or whether we will somehow manage to pull off a deep enough transformation that we can avoid massive shocks and smoothly build a new global civilization.

That is the question that I would like to explore in this presentation.

Science fiction writer Vernor Vinge envisages a situation in the relatively near future when computers are designing their own successors and we lose the ability to understand the technology we've unleashed.



Available for download from the Internet: the Haemophilus influenzae Rd genome, the first genome of a free living organism to be completely mapped

(Published in Fleischmann et. al., Science 269:496-512, 1995.)

Technological Change

In many ways technological change is the underlying driver of change in a whole range of other areas. We have had an onslaught or tsunami of technology since 1950. The rate of growth is not simply an acceleration, it is an acceleration of an acceleration. It is advancing very rapidly indeed and moving into areas that used to be purely the province of science fiction.

Thinking about the science fiction I read when I was growing up, and witnessing the world unfolding today it often feels as if those stories are coming true. Science fiction writer Vernor Vinge talks about a coming 'technological singularity.' He envisages a situation in the relatively near future when the advance in technology accelerates to the point where the technology is creating itself and computers are designing their own successors. At this point, he says, we lose the ability to understand the technology we've unleashed—it moves beyond the human capacity for comprehension. The technology starts to accelerate away from us. This is the sort of scenario in which we end up downloading our mental lives to silicon. I have some reservations about that possibility because it raises the whole question of what human nature actually is. But certainly there are people seriously speculating along these lines, suggesting that this might happen. As our technological power increases it raises more questions like this. Ethical, social, and environmental issues are coming to the fore.

The advances are rapid but they are also uneven across the entire spectrum of technology. We are very well aware of the advance in information technology. Biotechnology is developing very rapidly, advances in materials technologies are in the pipeline, and there are a number of interesting possibilities around energy. Energy is a critical factor because without an adequate supply of energy, none of the other things can be done. Information exchange is expanding very rapidly but how much this improves knowledge, let alone contributes to wisdom, is another thing. It is certainly having a very broad impact on the economy and it is driving change in many areas, including, for example, threats to privacy.

Biology

Biology is now one of the fastest growing areas of scientific research, dependent in many ways on information technology. The bioinformatics industry is expanding extremely rapidly because it would not be possible to sequence genomes without simultaneous advances in computer technology. A typical genetics laboratory is now sequencing tens of millions of base pairs a day and this information all has to be stored and easily accessed. The computer industry is providing biotech companies with ever faster equipment to capture and process it.

We can change genes and modify the physical appearance of the organism, and that is the province of science. But when it comes to the question of what we should do with this ability, we are no longer in the realm of science.

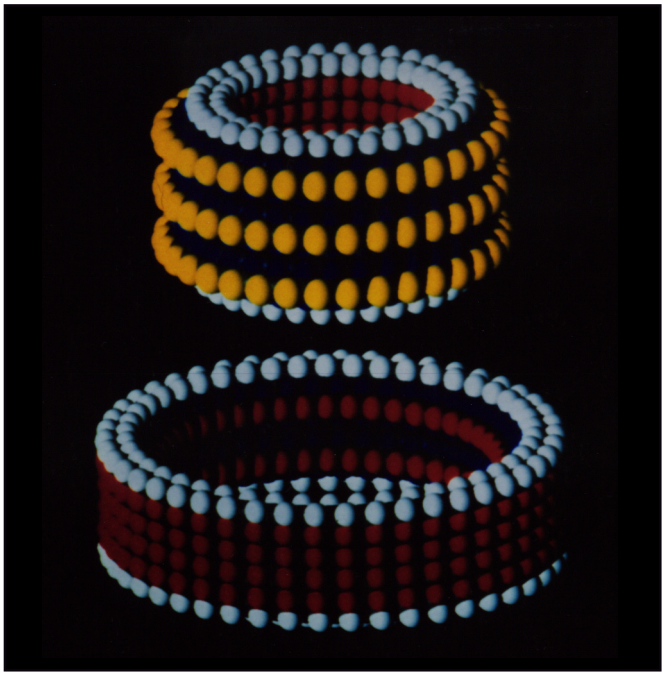
The amount of data is extremely large, and genome size is referred to using the same terminology that is used for computer memory storage.

Developments occurring in the laboratory can very rapidly have large effects in the world. An example of real world impact is the sudden appearance and rapid expansion of genetically modified crops. Whole genomes can now be downloaded from the Internet, and the Internet has become the principal means of exchange for this information. I downloaded from the web this gene map of the first organism to have its genome fully sequenced.

If you look at this from the brave new world of science it looks very exciting. However, consumers tend to have values that are potentially in conflict with the products of biotechnology in that they prefer things that are natural. They want products that are ecological, pure, chemical-free, green, healthy, and so on. Of course the concept of 'natural' gets slippery when you start to look at it closely, but the overall message is clear.

People are apprehensive about messing around with the design of nature. Reports from 'citizen juries' and similar consumer review processes show that people are particularly nervous about alterations in the human food chain. They're much more enthusiastic about possible therapies, and interestingly this involves less gene pool risk because it affects just the individuals with the medical condition. Modifying the food chain does carry a higher risk and this is something people seem to highlight instinctively.

It seems that some biotechnology strategies, particularly in the area of agricultural products, have been shaped by chemical companies using traditional chemical industry thinking rather than by biological or whole-systems thinking. We are in the very early stages of the strategic and ecological thinking in this new field and some caution is needed. This is a technology that raises a number of very significant ethical issues. We know that we can modify the genotype and change the phenotype. Altering the genes will change the physical features of the organism, and that is the province of science. But when it comes to the question of what we should do with this ability, we are no longer in the realm of science and need to look beyond the viewpoint of the scientific community. We need to recognize another perspective: that life itself has its own agenda, its own purposes and intent that must be respected. The strategy for biotechnology needs to take these considerations into account and cannot afford to be purely reductionist.

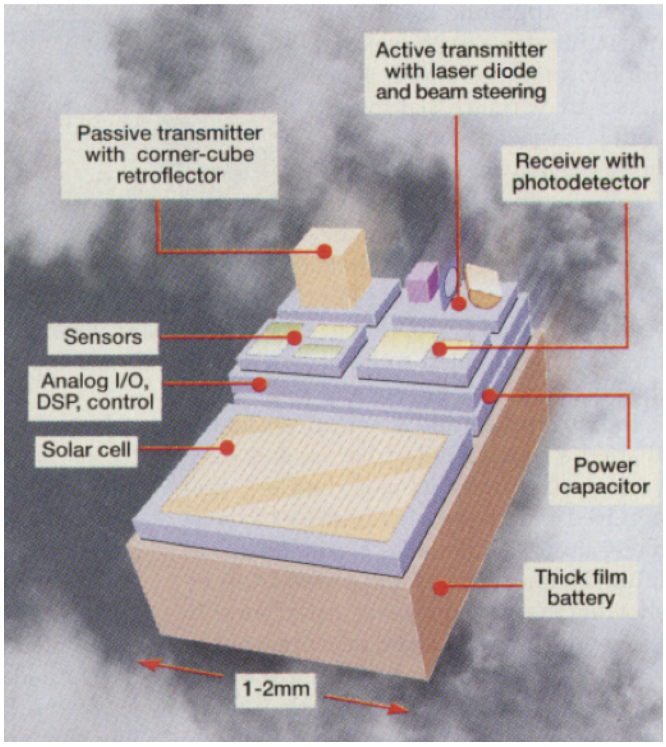


This hypothetical nanoscale cylindrical bearing was designed by Ralph Merkle at Xerox Parc in Palo Alto, California. It is assembled from individual atoms—the red ones are carbon, which means the body of the bearing is made of diamond. (Source: Ralph Merkle)

Nanotechnology

Nanotechnology is a bit further off, but the trend lines for the development of this technology show that it should be having a significant impact by the end of this decade.

The implications of nanotechnology are very significant because we could make machines that use vastly less energy, that are vastly smaller, and require vastly less material to make.



A self-contained surveillance device only 1 mm across (Source: New Scientist, 1999)

This emerging technology is largely driven by computer industry investment in R&D for microchip fabrication. The basic idea of nanotechnology is that we will be able to manipulate atoms as if they were Lego bricks and build things atom by atom. This will allow us to make things at the atomic level of size and precision. For example, an object such as the cylindrical bearing in this slide would weigh much the same as a large organic molecule but would be an engineering component. This kind of potential is emerging in laboratories around the world, particularly in the United States and Japan.

The implications of nanotechnology are very significant because we could in principle make machines to perform the same functions we currently enjoy, but that use vastly less energy, that are vastly smaller, and require vastly less material to make, and so forth. There is work going on at places like MIT in the United States on what they call 'sheet architecture' for nanotechnology. For instance, you might have a thin transparent film that looks like a sheet of plastic that you stick on your window. It would contain at the nanoscale, at the near atomic scale, a vast array of invisibly small heat pumps to push heat in and out of the room through the glass, either acting as room heating or cooling devices. So instead of having a large box under your windowsill to do the air-conditioning you just have a sheet of what looks like transparent plastic. And the slight air pressure differences from the wash of air swirling behind people when they walk past may actually be enough to power devices like this.

Here is another example of the sort of thing that we have ahead of us. This is a self-contained surveillance device about one or two millimetres across. This is small, the size of a sesame seed, but not yet anywhere near close to nanotechnology. Just imagine reducing this a few thousand times to get the nanotechnology equivalent. At Berkeley University they've had these things running for several hours at a time. The immediate objective is to make them just small enough so that they're below the limit of resolution of the human eye and they float in the air like dust particles.

These devices have some form of sensor on board, plus a solar panel and a battery and a transmitter so that they can be used for surveillance. If we were meeting here in 10 years' time the room might need to have virus-level air filters to make sure that there were none of these things floating in the air. And at the entrance you might need some sort of personal scanner, like the scanners airports have, to see if you'd actually breathed any of these things into your lungs on your way to the meeting. There might of course also be other similar things in your bloodstream monitoring your vital signs and announcing your identity.

When biotechnology meets that kind of technology all

Although these may not be the specific things that happen, we should expect breakthroughs at least as surprising as this, given the accelerating advance of technology.

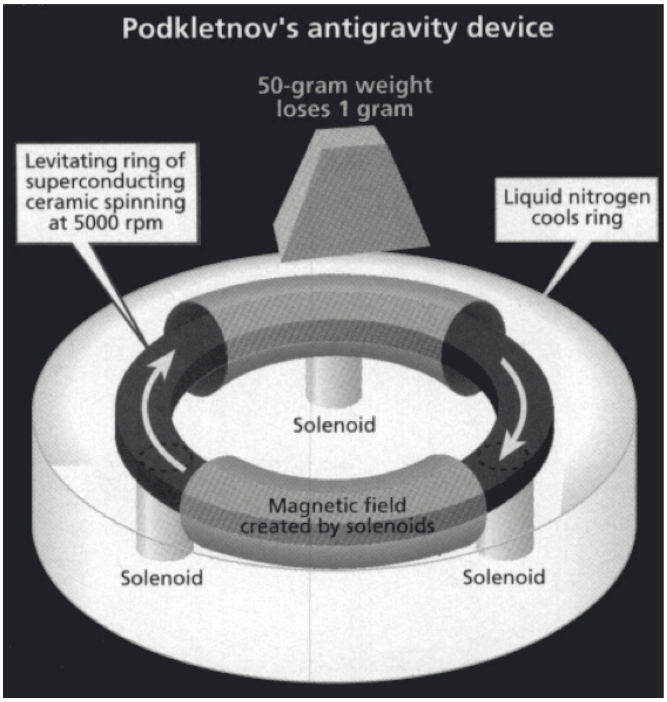
sorts of other interesting things become possible. There are laboratory experiments combining information technology and biotechnology in attempts to enhance intelligence. Scientists are putting chips into the brains of unfortunate animals to see if brain functions can be replaced with appropriately coded chips. They can then watch the thought processes in a rat's brain as it negotiates a maze. They can see the difference between the older rats and the younger rats, as the older rats have trouble remembering where they are in the maze. All this can be read using an implanted chip. The people doing this work suggest that relatively soon we'll be able to use the brain as a read, write, erase medium rather like a computer storage disk. This has interesting implications for education as well as for less savoury activities.

New directions in physics

There are even more exotic things in the pipeline. The following speculations may be slightly tongue in cheek but the point they make is important. Although these may not be the specific things that happen, we should expect breakthroughs at least as surprising as this, given the accelerating advance of technology.

There is an emerging point of view in theoretical physics that really there isn't any such thing as mass. What you have is electric charge and energy interacting together at the atomic level to create the illusion of mass. If that is true it should be possible to manipulate things like gravity and inertia and so on. This has some very interesting implications, not least for transportation technology.

Keen readers of New Scientist may remember an item from 1996 in which Russian scientist Eugene Podkletnov, working in Finland, claimed to have accidentally discovered a gravity shielding effect produced by an experimental rig that he was playing with. It consisted of a spinning superconducting ceramic ring, and he discovered that anything placed over it lost two percent of its weight. NASA commissioned a replica because maybe if you stack enough of these up you would get lift off, and if you can make them a little more efficient you don't have to have quite such a big stack.

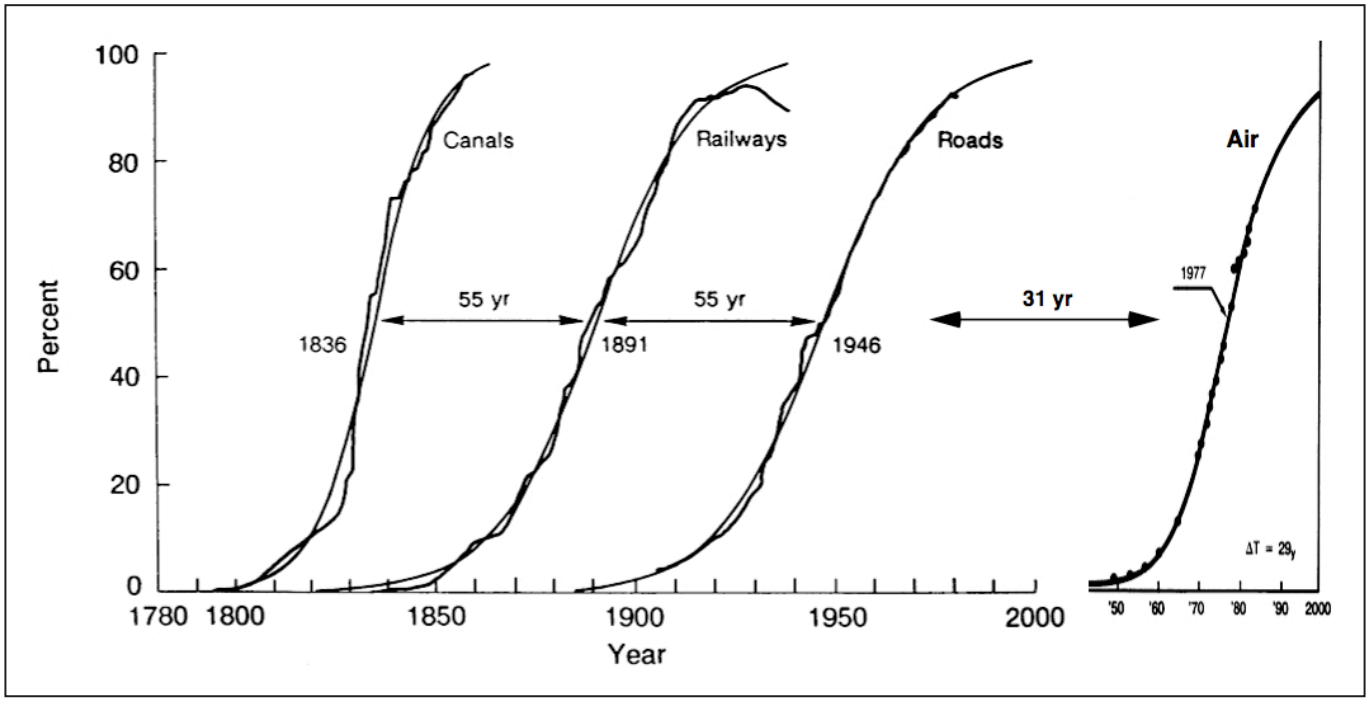


Gravity shielding has been demonstrated in the laboratory using this experimental apparatus
(Source: New Scientist, 1996)

If this seems far-fetched, it is worth recalling that only 100 years ago, at the start of the 20th century, heavier-than-air powered flight was still considered to be in the realm of fantasy. As late as October 1903, Simon Newcomb, professor of mathematics and astronomy at Johns Hopkins University, published an article which showed scientifically that powered human flight was 'utterly impossible.' Just weeks later, in December 1903, the Wright brothers took off for the first time in their heavier-than-air flying machine.

Meanwhile, the science fiction writer Arthur C Clarke has publicly stated his view that the much maligned cold fusion is alive and well, and that there is a radical energy

There have been successive waves of new transportation technology about every 50 years since the Industrial Revolution. According to this pattern the growth of air transportation will be decelerating soon, maybe by 2010.



The growth of major transport infrastructures in the United States to final saturation level, showing replacement by a new form of transport. Will aviation also be superseded soon?

Source: (left) A. Grübler, 1988; (right) T.H. Lee and N. Nakicenovic, 1988 (horizontal scale compressed to match)

revolution in prospect. He claims that people in various laboratories around the world are getting good results with it. And there is the even more exotic zero point energy in which energy is drawn direct from the quantum vacuum. According to Newtonian physics the vacuum is by definition empty. According to quantum physics it is full of things that don't last for very long: virtual particles that appear and disappear very rapidly, but while they're there you can snatch some energy from them. It sounds too good to be true, but in principle the basic mechanics seem to be viable, even if the size of the energy flux is in question.

It gets even more exotic. Think of a future vehicle with gravity shielding and faster than light drive. Miguel Alcubierre is a relativity theorist who was challenged in the early 1990s to determine whether under general relativity it is theoretically possible to go faster than the speed of light. You are probably aware that this is not supposed to be possible. This is one of the central tenets of twentieth century science—you do not go faster than the speed of light. But now it seems that theoretically you can. The idea resembles the *Star Trek* warp drive, and involves enclosing your spaceship in a 'bubble' of space. By warping the space at the front and back edge of the region that forms the bubble, contracting space ahead and expanding it behind, the bubble plus spaceship can be moved through space faster than light. Inside the bubble space remains normal

There are two factors that enable us to look at the very big picture. One of them is human population dynamics. The other is the flow of materials through the entire industrial economy.

in the relativistic sense, so that the spacecraft experiences no mass increase or time dilation at lightspeed. An early critic said you'd need all the energy in the known universe to do this. A later rebuttal suggested that you could use far less energy by adopting a 'Doctor Who'–style approach, creating a special bubble that was large enough on the inside to have the spacecraft in it, but very small on the outside and therefore easier to move.

The growth of transportation technology shows there have been successive waves of new transportation technology about every 50 years since the Industrial Revolution. It is very tempting to speculate that there might be something else on the horizon because according to this pattern it looks as if the growth of air transportation will be decelerating soon, maybe by 2010. Of course, if terrorists and global warming protestors have their way it might decelerate even sooner. This whole line of thought is certainly not a prediction, only a speculative scenario, but perhaps there is indeed something lurking in the wings that would be significantly better. If we apply the rule of thumb test for technology replacement it would need to be something about 10 times more efficient or advantageous than our existing aviation technology.

Global Challenge

But technology presents us with concerns as well as opportunities. It is causing serious stress in global systems. It is very exciting at one level but what real world effects is it having? Is technology compatible with a globally viable ecosystem? Plenty of people in the world don't even have access to fresh water, so the economic rhetoric that the market will deliver the benefits of advanced technology to everyone everywhere doesn't seem to work in practice.

The proponents of globalization say that globalization is increasing inequity only in those places where it hasn't been seriously attempted. This of course is rhetoric too. We urgently need to address serious questions from multiple perspectives, not just from within the framework of one particular discipline. In this presentation I would like to expand my approach beyond the boundaries of conventional economic thinking, to bring in some other features of the real world that we need to think about. There is that old joke that an economist is someone who doesn't pick up a $20 bill lying on the ground because if it was real somebody else would have already picked it up. The problem is not economics itself, but its undue dominance in decision making, and I want to propose a broader field of appreciation in thinking about global issues.

Human population dynamics

If we are going to look into the future it is useful to do so in terms of large-scale factors that we know about a long way back into the past. There are two factors that enable us to look at the very big picture in this way. One of them is human population dynamics. Projections by the United Nations show global population growth smoothly slowing and levelling out, but there is a nasty alternative scenario.

In ecological population dynamics there are two broad population behaviours. On the one hand there is 'S-curve' behaviour, shown by species that moderate their growth, which slows down and levels out as they begin to saturate the carrying capacity of their environment. Alternatively, there is 'J-curve' behaviour, in which the species does not have that capability, and the population growth punches up above the carrying capacity and then falls dramatically until it is back at a level from which it can regrow. As to which one of these will turn out to be the behaviour of the human species, we don't yet have the answer.

The global flow of materials

The other large-scale factor is the flow of materials through the entire industrial economy. This is growing very rapidly. Whereas the population is currently growing with a doubling time of 40 years—in 40 years' time population will be twice what it is today if today's growth rate is maintained—the consumption of materials is doubling twice as fast as that. It is doubling about every 20 years. Pollution tracks this consumption growth very closely because pollution is the flow of materials getting dumped into the environment at the end of its economic life. For

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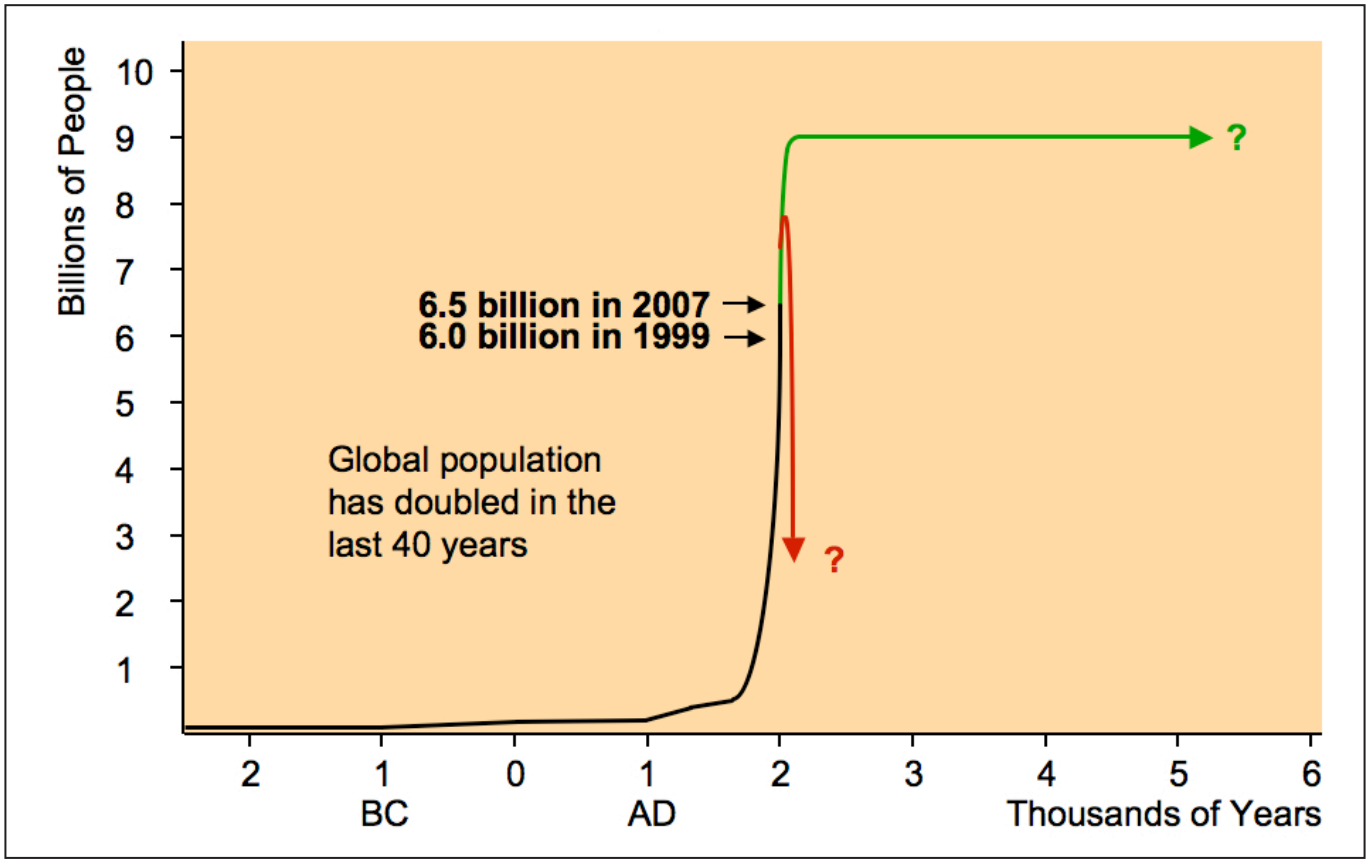

The global growth of human population, with two possible scenarios for the future
(Historical data from Joel Cohen, 1995)

example, the release of carbon dioxide into the atmosphere has doubled twice since 1950.

We can see from this that the industrial economy is growing very fast, but we also need to ask how big it is relative to the natural global system. If it is still small compared to the global system, then even with rapid growth we still have plenty of time before it becomes a problem. But if it is already large compared to the global system, then the rapid growth will become a serious issue.

There are a number of ways of gauging how big the industrial system is compared to the biosphere. For example, we can look at the release of toxic heavy metals into the environment compared to the natural background rates of release of these elements. And what we see is that the amount being released by the human economy is many times greater than the natural release into nature, from the weathering of rock and so on. This is important because the biosphere has only evolved to absorb a certain level of these metals, and they are highly toxic, which is why they are of interest. So here we see that the size of industry is already significantly bigger than the biosphere.

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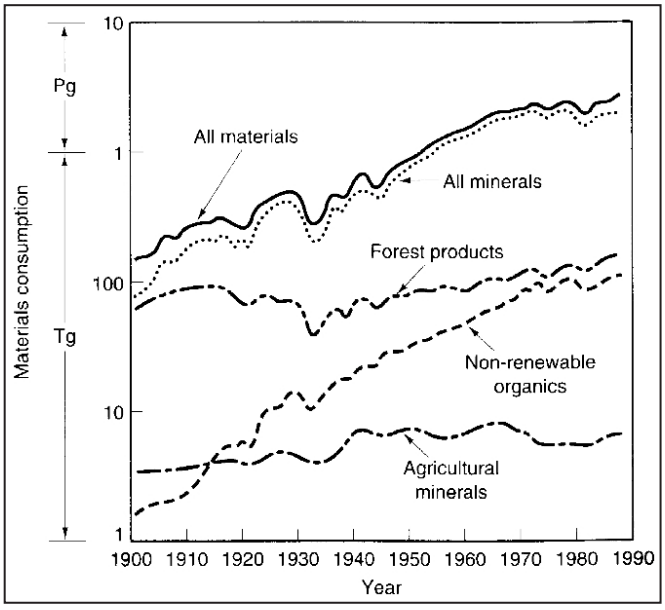
	Artificial Flows	Natural Flows	Ratio
Lead	332	28	11.9 : 1
Zinc	132	45	2.9 : 1
Copper	35	6.1	5.7 : 1
Arsenic	19	12	1.6 : 1
Antimony	3.5	2.6	1.3 : 1
Cadmium	7.6	1.4	5.4 : 1

Worldwide emissions to the atmosphere (thousands of tons per year)

(Source: Nriagu, J. O., 1990)



The growth in materials flowing through the industrial economy (United States, 1900–1989)

(Source: T.E. Graedel and B.R. Allenby, Industrial Ecology (New Jersey: Prentice Hall,1995) p.147)

There are other measures of this. In 1986 a team at Stanford University attempted to measure how much of the natural global productivity was being taken by the human economy. And what they found was that we were taking 40 percent of the NPP, the 'net photosynthetic product' of the terrestrial biosphere. This means that almost half of the net growth of biomass in any one year was being taken by the human economy. And if this amount is expanding in line with the growth of total materials consumption, it is growing very fast and will double in 20 years. The surface of the earth however, which provides the background for this rapid growth, is obviously not getting any bigger. So according to this analysis, the scale of human activity is already half the size of the biosphere, and is rapidly overtaking it.

Exponential growth like this is very bad news for the kinds of public decision-making processes that we tend to have in Western-style democracies. Here is a riddle for schoolchildren that illustrates the point. Suppose you have a pond, and on this pond there is an imaginary water lily growing, which doubles in size every day (it is growing exponentially). At this rate of growth it will completely fill the pond after 30 days. Now suppose that you decide not to do anything about it until the pond is half full. When will that be? When you first hear this question, there is a tendency to think that the pond will be half full halfway through the month. But that is not correct, because every day the lily doubles in size, and in fact the pond is not half full until the 29th day—and on the last day it doubles in size once more and covers the pond.

This means that if there is an exponentially growing problem and you decide to wait until it reaches a reasonable size before you act, you're not going to have very much time left to do something about it. You can see from the diagram that until about the twentieth day the problem is so small it is not even visible. This is very significant in terms of decision-making response time. If the global flow of materials is growing exponentially, then by the time we see some real impact it may be too late to do anything

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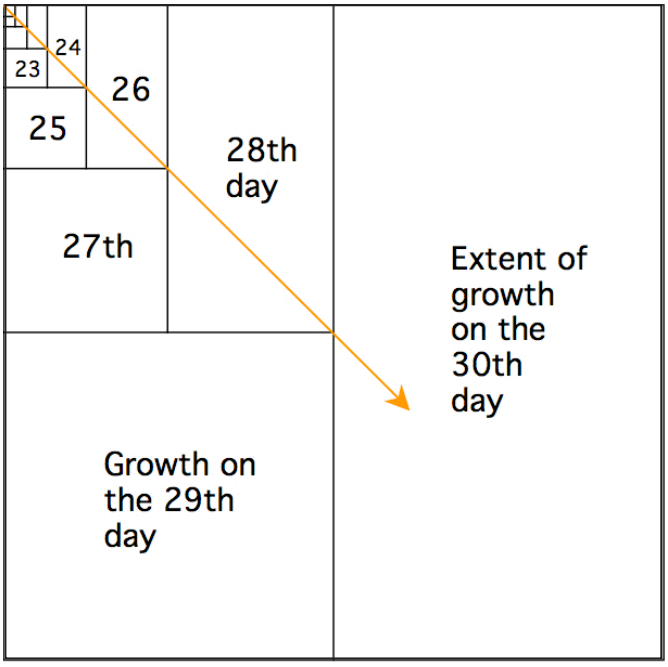

Exponential growth: a water lily doubles in size every day and will fill the pond in 30 days
(Source: Donella Meadows, 1992)

about it. If you scale the 40 percent of NPP in 1986 to the pond example, making the assumption of a 20-year doubling time, you see that we're now in approximately the early afternoon of the last day.

We live in interesting times. As Professor Wilson at Harvard has said: 'One planet, one experiment.' We have no back-up, no control experiment. This might be all right if ecosystems showed progressive, steady degradation under pressure from pollution, because at least this would give us some warning—despite the so-called boiled frog syndrome. But many ecosystems don't respond like that, they absorb significant environmental impacts with no sign of degradation and then suddenly collapse without warning.

Take as an example Big Moose Lake in the Adirondack Mountains in the United States. From the late nineteenth century onwards it received a very heavy loading of sulphur from acid rain from the burning of high sulphur coal upwind in the Ohio River Valley. That stabilized in the 1920s at around 3.5 million tonnes a year. Right up until the 1940s this had no effect at all on the acidity of the lake. The lake was full of fish, the water was fine. But very shortly after that the lake water acidified extremely rapidly and the lake is now completely dead. The original graph showed the species of fish that died as the acidity increased. This poses an ugly question: will the global ecosystem show similar behaviour?

Might we be living in that pre-1940-type regime thinking everything is more or less all right out there when in fact the entire system may be teetering on the brink of collapse? In the lake example the ecosystem was in fact showing degradation if you knew where to look. It turns out that the buffering capacity of the soil in the lake watershed was neutralising the acid rain. However, around the early 1940s that neutralising capacity was used up and the next domino was the lake water.

Is there any evidence that globally we might be on the brink of this sort of non-linearity? Here is a graph of past climate which points to one possibility. It is based on deep ice cores from the Antarctic and shows temperature and carbon dioxide in the atmosphere tracking each other up and down very closely over the last several hundred thousand years. In the past, the temperature changes happened 500-1000 years before the gas changes – so the gas changes were the consequence of temperature changes. The 100,000 year-long temperature swings were caused by periodic variations in the Earth's orbit and a slight wobble in its spin axis. Today, human activity has pushed the carbon dioxide level far off the scale compared with the past record, which is causing scientific concern that the temperature will rise to follow it, though so far the warming is modest. A parallel concern is the evidence that climate variability is increasing and that is likely to mean more and larger storms. The insurance losses for major

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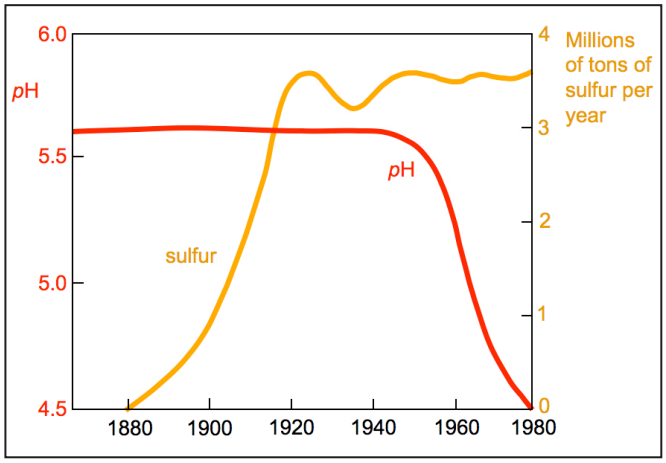


Ecological non-linearity: rapid acidification only after years of acid rain (Source: Stigliani, 1988)

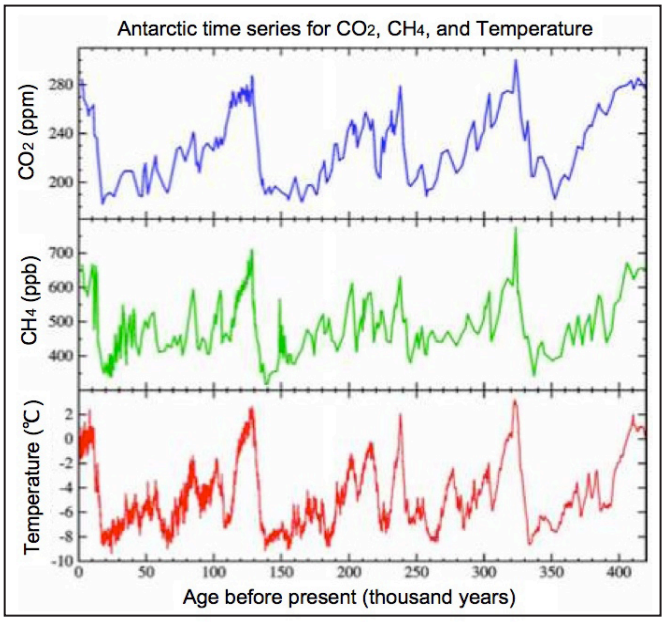
storms were much greater during the 1990s than in any previous period. They were several times up from the storm levels in the 1950s and 1960s, for example.

Resource depletion

The 1970s fear about resource depletion, which in the 1980s we decided wasn't really a concern, is now back on the radar screen again. It is now thought that the peak of global oil production may occur in the next few years. Roughly speaking, the pattern of resource extraction from an oilfield or mine follows a 'normal' or bell-shaped curve and the point of concern is not when the resource completely runs out, but when it reaches the peak level of extraction. After that point the amount of resource that can be extracted begins to decline. When we reach that point for global oil production, we will move into what would be a permanent global oil shortage. There are a few things that could offset that, but even if any one of those things started immediately it is unlikely that it would come on stream fast enough to offset this peak effect. We're certainly looking at the beginning of the end of oil and, of course, major political disruption in the Middle East could bring us to that point much sooner.

In the late 1990s, when this global oil shortage scenario began to emerge, the official view of the major oil companies was that world oil reserves were very large, and based on what they knew they were finding it was inconceivable that there would be a permanent oil shortage. In the ten years since, official opinion has broadly accepted the peak oil argument. Current calculations by oil companies forecast peak production by 2025. Overestimates of official reserve positions have since come to light and may have been a factor in the revised view. It is interesting how the official position on this issue has shifted over a ten-year period from dismissing the idea to putting a date on it, although still a more distant date than claimed by the leading peak oil proponents, some of whom expect the peak by 2008.

In addition to global environmental issues, we face serious social challenges. The main concern is that despite exponential growth of global economic output we are not seeing an equitable distribution of prosperity around



Carbon dioxide and temperature vary together far back into the past (Source: J.Hansen, 2006)

If the world were a village of 100 people, 20 would earn 89% of the entire world's wealth, seventeen would be unable to read and only four would own a computer.

the world. If the world were a village of 100 people there would be 60 Asians, 12 Europeans, 15 from the western hemisphere (nine Latin Americans, five North Americans and one from Oceania) and 13 Africans. Eighty people would be non-white, 20 would earn 89% of the entire world's wealth and 25 would live in substandard housing. Seventeen would be unable to read and 13 would suffer from malnutrition. Only two would have a college education and only four would own a computer. This question of global inequity is a very important one to address if we are going to cope with close to a further doubling of population. The situation is hazardous enough already without doubling the scale of the problem.

Global Solutions

I would now like to turn to possible solutions, which takes us back to technology. I do not want to suggest that there are technological fixes for all these issues, but I do think that the role of technology will be very significant. You can see this from the so-called 'IPAT' equation by Paul Ehrlich, which is a classic in environmental studies. This equation, I = PAT, basically says that the impact on the environment (I) is the product of: how many people you have in the world, population (P); how affluent they are, consumption per capita (A); and what kind of technology they are using in order to be affluent, the ecological impact of technology (T). More sophisticated versions of this equation with additional terms have been developed subsequently, but the overall message is the same.

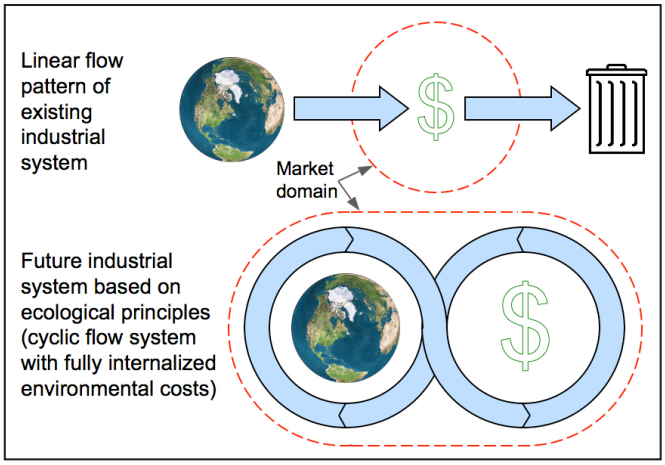
Impact	Population	Affluence	Technology
0.25 =	x 2	x 4	x 0.03

Suppose, just as one example, we want to achieve a reduction to one quarter of today's environmental burden, at the same time as global population doubles and affluence increases by a factor of four. This allows for one more doubling of population and for many more people to be affluent in the interests of equity. To achieve that, the equation shows that the performance of technology has to improve enormously and the pollution loading from the technology has to drop to a tiny fraction of what it is today. You can't reach that level of performance with the current approach of cleaning up pollution after it leaves the end of the pipe. It won't get you there.

Even cleaning up what goes in at the *beginning* of the pipe doesn't get you there, and you end up having to think about a systemic redesign of industry. The entire architecture of industry would have to be different. What exactly does that mean? One way of thinking about this is to realize that nature already runs a global-scale system for transporting and continuously processing materials. It's called the biosphere. Nature manages to run it on ambient solar energy input and has kept it going for millions of years.

How does nature do it? There is a set of principles underlying the design of natural ecosystems and the entire biosphere. It goes roughly like this:

- all outputs are inputs somewhere else
- waste exists only at the level of the species
- concentrated toxins not found at the system level
- system runs on ambient energy at low temperature
- identity in the system is defined in process terms



Systemic redesign of industry (Source: Tibbs, 1991)

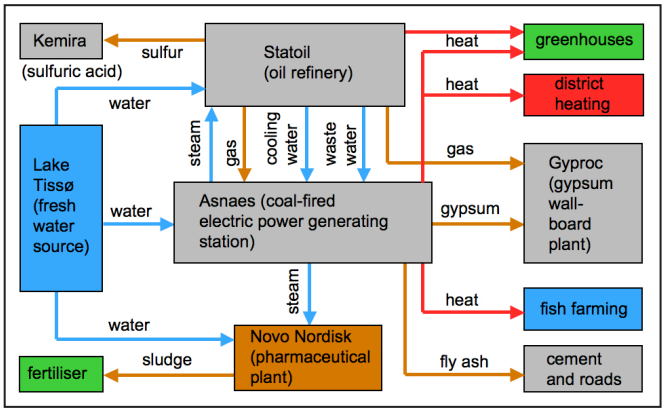
The entire architecture of industry would have to be different. One way of thinking about this is to realize that nature already runs a global-scale system for transporting and continuously processing materials. It's called the biosphere.

- system is dynamic, information-driven
- system permits independent activity of each member
- activity patterns are meshed cooperatively
- competition and cooperation are interlinked.

There is no reason in principle why we shouldn't emulate these principles in the design of industry. The most important principle is that there is no such thing as waste at the level of the whole system. In nature, waste exists at the level of the species, but there is always another species to deal with it. But industry does produce waste at the level of the whole system. Similarly, there are toxins in nature, but only in tiny quantities. You do not find rivers of snake venom running through the landscape—snakes deliver their biodegradable venom exactly where it is needed on a just-in-time basis.

The starting point for a systemic redesign of industry is to notice that today's system uses materials in a straight-through flow. I'll call this a 'linear' system. We extract resources from the earth: the biosphere or the earth's crust. We process them through the market domain and we throw away the residue. But we could change that to a cyclic pattern where materials flow around the industrial system indefinitely once they are brought into it. This would be a 'cyclic economy,' where the circular flow of materials minimizes the use of virgin materials. The system's energy use and the entropy of the materials are kept as low as possible, and the size of the material flow is decoupled from the size of the economic flow. Economic transactions can continue to grow but they require less embodied mass. This is a view that sees the industrial system as a dependent subsystem of the biosphere.

We could move to a large-scale cyclic economy by taking this approach. In principle this could be done using today's technology. It would require political will and a lot of innovation but it doesn't require any fundamental breakthroughs. Of course, if we were able to make use of nanotechnology it would be much easier. On the other hand, having nanotechnology without this kind of environmental discipline would probably make environmental problems much worse.



The industrial ecosystem at Kalundborg

(Source: Novo Nordisk/ H Tibbs)

Principles of a Cyclic Economy

- Industrial system seen as dependent subsystem of biosphere
- Economic flows decoupled from materials flows
- Environmental costs fully internalized into market domain
- Cyclic flow of materials
- Virgin materials use minimized
- Information substitutes for mass
- System 'entropy' kept as low as possible

An example of this thinking applied at the industrial facility level is the industrial ecosystem at Kalundborg in Denmark. This consists of a number of economically independent firms with an infrastructure for sharing what would otherwise be waste flows. One of them is a wallboard company making plasterboard that used to buy 30,000 tonnes of mined gypsum from Spain every year. It now uses industrial gypsum recovered from the flue gas scrubbers at the power plant. This type of thinking could be applied on a much larger scale and eventually it could be applied across the entire global industrial system.

As industry grows larger, sooner or later it must reconfigure itself into a system of flows that mesh with the natural planetary system. We are now discovering that the survival of the fittest means the survival of what fits best.

The value loop

In management textbooks the sequence of value-adding activities in an economy is known as the value chain. But in a cyclic economy, where materials move in a circular flow, value would need to be created in a circular flow too. Instead of a 'value chain' there would be a 'value loop.' The use of virgin materials would be minimized via reprocessing and recycling, with no overall waste, and energy input for materials reprocessing would be kept as low as possible.

The value loop would lead to a completely different approach to business management, product strategy and so on. Companies at the ends of the chain, such as mining companies, would face a challenge relocating themselves to the value loop. Instead of digging things out of the earth's crust they would be extracting their raw material from the local urban industrial ecosystem. This requires a rethink, a different mindset. The biggest part of the challenge would be the significant cultural shift required.

Dupont is an example of a company that is beginning to develop product strategies based on this kind of approach. They have launched a high performance biopolymer called Sorona. This will allow them to move from an oil-based feedstock pathway, to a recycling pathway that uses some biomass inputs, to a cyclic pathway once there is enough polymer in the loop.

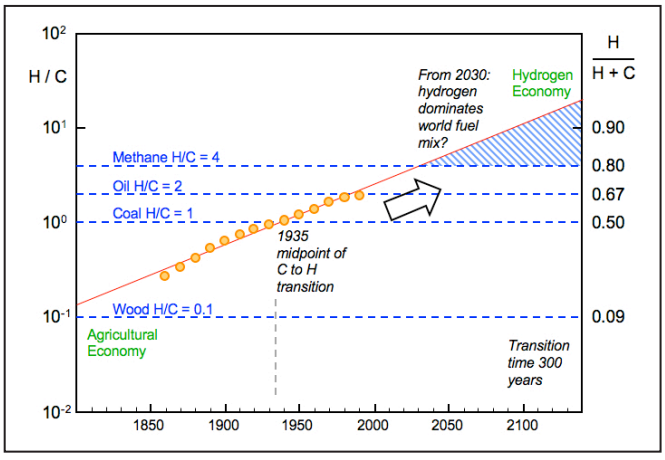
Decarbonization

Another feature of systemically redesigned industry would be decarbonization—reducing the carbon intensity of energy. Every ton of carbon in fuel releases 3.66 tons of carbon dioxide. As economies have industrialized they've moved from high-carbon energy sources to low-carbon energy sources. This is why environmental technologists propose that we might go the next step to pure hydrogen gas as an energy carrier, the ultimate zero-carbon fuel for the energy system of the future.

Decarbonization is a special case of what is known as dematerialization, a reduction in the materials requirement, or the mass intensity, of industrial production. One aspect of this is to make products using less material. Another implication is that we must stop materials being lost as they are used, which means redesign.

Car brakes are a good example. When you slam on the brakes at high speed on a highway the forward kinetic energy of the car is turned into heat by the brakes and some of the brake pad itself is worn down into a fine powder. Anybody who has a car with alloy wheels will be well aware of this effect. In the case of an individual car this doesn't seem very important, but seen at the huge scale of all cars it does become significant. The largest source of copper pollution in San Francisco Bay is from car brake pads worn to dust and then washed into the bay when it rains.

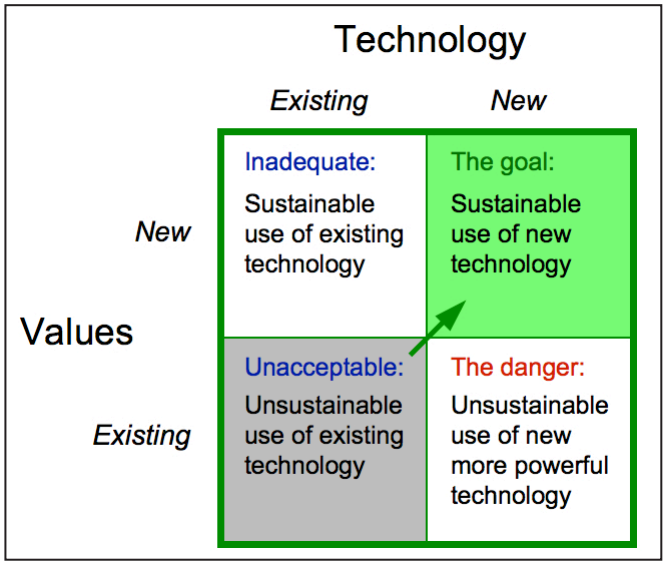
An alternative is the regenerative braking technology now available on some hybrid vehicles. The electric motors that drive the wheels are turned into generators as you brake. This converts the energy of motion of the car back into electricity that can be stored on board, and the release of heat and dust, the inefficiency and waste, is completely eliminated. Taken across the entire car global fleet, this kind of design change can make an enormous difference.



Decarbonization: a steady long term transition from carbon to hydrogen in the mix of fuels used worldwide

(Source: based on Ausubel, 1996.)

Is there any prospect of new social values that could change the context for technology? Jonas Salk suggested that as global population growth decelerates, we will see a new set of values emerging in response.



New values are needed to guide the application of new technology (Source: Tibbs, 1998)

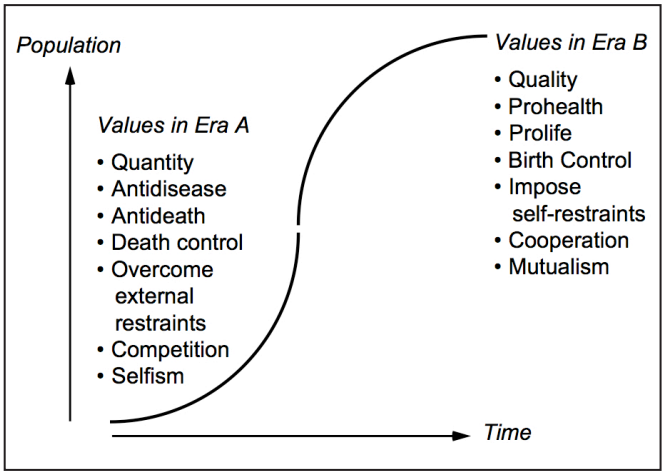
The Architecture of industry

The entire architecture of industry would be shifted if these types of system and design changes were propagated across the whole spectrum of industrial products and processes. The ideas I have described form part of a comprehensive project of change. The overall analysis is global. As industry grows larger, sooner or later it must reconfigure itself into a system of flows that mesh with the natural planetary system. This suggests a new reading of Darwinism, or maybe this is what Darwin meant in the first place. We are now discovering that the survival of the fittest means the survival of what fits best, rather than what fights best.

Can better technology alone solve our problems? I've discussed technology a lot, but if 'better' means technology that is simply faster, stronger and more effective, then no, it isn't enough. In fact it will add to our problems. Something else needs to change. What is that something else? Broadly speaking it is a new context, a new set of social values brought to bear on the design and deployment of technology. The essence of the challenge we face is that we do not need simply to improve technology but more importantly to change the values that shape its design. Better technology must mean it is applied in a systemic way that consciously aims for better social and environmental outcomes.

New values and the 'Cultural Creatives'

Is there any prospect of new social values that could change the context for technology? Jonas Salk, the developer of the polio vaccine, suggested that as global population growth decelerates, and we turn the top corner of the S-curve, we would see an entirely new set of social values emerging in response. These sorts of values are appearing in the OECD countries, where in some cases fertility is already below replacement level. In the United States, demographic analysis points to a crosscutting group dubbed the 'Cultural Creatives.' They are described as an emerging group with very different values from either the 'traditionals,' representing about 25 percent of the population in OECD countries, or the mainstream



New social values emerging as population growth slows (Source: Jonas Salk, 1995)

The essence of the problem is that we are on a track that appears to be leading straight towards disaster. The World Wildlife Fund expressed it succinctly: we're consuming renewable natural resources 30 percent faster than the global capacity to regenerate them.

'moderns' who comprise about 50 percent. Cultural Creatives have a very different, holistic approach to life. They value authenticity, 'big picture' learning, engaged action and idealism, globalism and ecology, gender equality, altruism, self-actualization and spirituality.

This group has grown from about five percent in the 1960s to its current 25 percent or more and represents a steadily growing leading edge. It may well be that the Cultural Creatives are the group who will form the political constituency for the ideas I have been describing. They promise the sort of transformative thinking that could resolve many of the dilemmas inherent not only in the way we use technology but in our present economic relationships and the serious social tensions they breed.

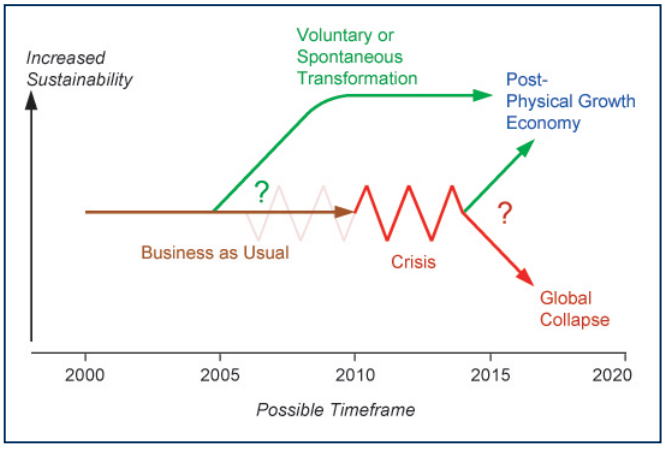
Scenarios and Implications

The overall situation we face can be summarized in a single diagram, which sets out the scenarios for the world as a whole. The essence of the problem is that we are on a track that appears to be leading straight towards disaster. The World Wildlife Fund has expressed it succinctly: we're consuming renewable natural resources 30 percent faster than the global capacity to regenerate them. This situation can be ignored while the natural capital stock lasts, but our whole civilization is teetering on the edge of bankruptcy.

There are a couple of broad choices. Either our society could voluntarily begin to move along a path that increases relative sustainability, or it can choose to wait and see what happens, which we can call 'business as usual.' If we take this path and we hit a crisis, two further possibilities open up. The jolt could be just enough to force us to do what we could not do voluntarily before, and we will scramble to get on a path towards sustainability. But the crisis could be so severe that it would plunge us back into the Stone Age. The plain message is that 'business as usual' is no longer a path that leads reliably to an optimistic outcome.

'Business as usual': tensions

On the surface, the 'business as usual' world looks reassuringly solid. But the orthodoxy seems to be resting on thin ice.



Global scenario framework: possible paths into the future depending on the level of sustainability

(Source: Tibbs, 1998)

The 'business as usual' worldview is often seen through the lens of neo-liberal economic thinking and the rising importance of commerce and business. The so-called 'Washington Consensus' expressed the best of this thinking. It emphasized fiscal discipline, liberalization of foreign investment, a competitive exchange rate, trade liberalization, privatization, deregulation and secure property rights. It also called for redirection of public expenditure priorities towards fields offering economic returns and the potential to improve income distribution, such as primary health care, primary education and infrastructure. Its failings were that it did not go far enough in addressing social inequity and weak social institutions, and it ignored ecology.

These shortcomings undermined trust in economic thinking. Not much has been heard from anti-globalization protestors since September 11, 2001. But in many ways protest against globalization in the 1990s marked the beginning of a prolonged political struggle against the existing global balance of economic power. Its particular focus was opposition to multilateral trade agreements

Either society can begin voluntarily to move along a path that increases sustainability or it can wait and see what happens. If we hit a crisis, the jolt could force us do what we could not do voluntarily before.

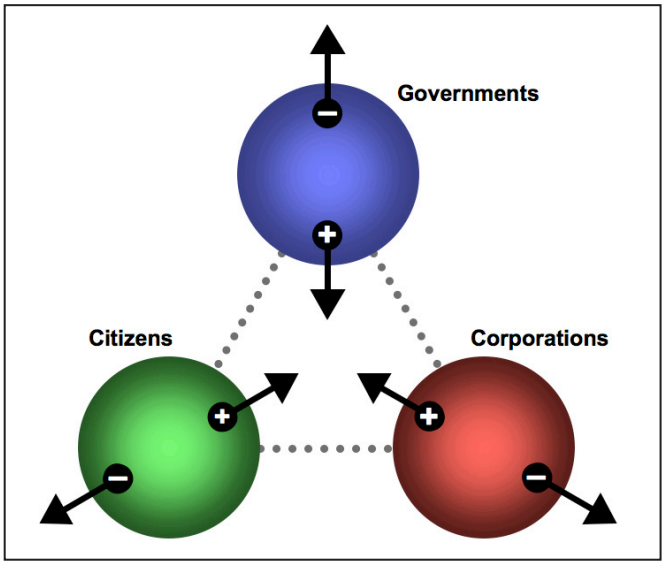
and global corporations. Many of the protesting NGOs themselves operate globally and what they seek is in effect sustainable globalism rather than unsustainable globalization.

Corporations are likely to find that there is significant pressure growing against them over the next few years, even though it is temporarily lost in the noise of anti-terrorist efforts and climate change activism. The pushback against social injustice is unlikely to go away, and will probably culminate in changes to corporation law worldwide. In short, the tide is running against business framed as only existing to make stockholders rich. Public distrust is fueling a growing international political movement to make corporations more socially and environmentally accountable. Already in the United States there is talk about reviving the corporate death penalty.

The possible outcomes can be framed in terms of three groupings—governments, business corporations and citizens (forming themselves into organizations such as NGOs to rival the clout of corporations)—either coming together or flying apart. The positive scenarios happen when the three come together cooperatively and the negative scenarios are where they're pulling against each other and failing to cooperate. With the multiple combinations that result from that simple structure you can build a set of scenarios to explore the range of geopolitical futures that could play out while the business as usual path is still being bankrolled by the planetary environment.

A new political culture

These tensions are driving changes in politics. So-called 'Third Way' politics was an early instance of this. This new framing of national politics took globalization seriously and argued that the three key areas of power—government, the economy and the communities of civil society—all need to be constrained in the interests of social solidarity and social justice. Third Way politics proposed a new social contract: no rights without responsibilities. It sought broad supply-side policy to reconcile economic growth with reform of the welfare state, which it reconstructed as the 'social investment state.' Even if the Third Way itself is not the future of politics, there is certainly a new kind of political culture emerging, in which the old left-right polarity is breaking down and people are looking to position relative to the centre in quite different ways than before.



The three main fields of power in society: will they cooperate or be in conflict?

Relationship

Personal experience is another factor driving political change, as illustrated by the rise of 'relationship.' This is something new in sociological terms. In the past, when people got married, what kept them together was the social institution of marriage itself and the social pressure that went with it. But the idea of marriage as a social institution has steadily weakened, and it is no longer enough to hold people together. What has taken its place is the idea of relationships, a term that was not used 30 years ago. The sociologist Anthony Giddens has described an emerging 'democracy of the emotions' as people focus on relationships. As people pay more attention to the quality of their relationships, democratic ideals are

Social and environmental externalities are becoming the limiting factors—not access to capital and labor, which were the constraints before—so we shouldn't be surprised to see them turned into performance criteria.

becoming important at the family and personal level. As a result people are beginning to demand a higher level of democratic performance in the public sphere. This implies steadily rising expectations for the quality of public political process.

Multiple bottom lines

All of this is moving us beyond profit as the sole criterion for business success, and beyond economic measures for the performance of the economy as a whole. We are moving into a 'multiple bottom line' regime for the future: people, planet, and profits. This means aiming to sustain and enhance social capital and ecological capital, as well as ensuring economic viability. This makes perfect sense. Social and environmental externalities are becoming the limiting factors—not access to capital and labor, which were the constraints before—so we shouldn't be surprised to see them turned into performance criteria.

This multiple bottom line approach is emerging on several fronts in parallel, not simply under the rubric of sustainability. The triplet of people, planet and profits has been framed in terms of three kinds of capital. There are probably four or even five kinds of capital, because 'people' capital might be thought of as divided into human and social capital, and technological capital and money capital could be treated separately. This thinking opens the way to a completely new systemic design for the sustainable economy of the future.

A new model for business

With this background we can imagine a significantly different model for business. The existing growth-oriented model was appropriate for the rapid growth phase of industrialization. But this is about to give way to a mature phase in which the emphasis is not on rapid quantitative growth, but on qualitative development. If growth levels out it does not have to imply an intellectual and cultural flatline. It is the physical growth that decelerates—the number of people and the mass of materials flowing. A physically stablilized global civilization would be free to emphasize cultural development and ecological balance.

When you put together everything that I have been talking about, you see the potential for a future form of business organization with a completely different set of characteristics no longer focused on growth. It is likely to be primarily concerned with the stable management of complex systems to ensure the best environmental and social outcomes. In the optimistic scenario, the one where major disasters are avoided, there is a historic deceleration of physical growth. But a new stage begins—a period of non-material development focused on well-being, education, cultural refinement and a renaissance of spiritual awareness.

Industrial Growth Model for Business	Post-Industrial Development Model
• Maximize throughput	• Dematerialize throughput
• Labor productivity	• Resource productivity
• Value chain	• Value loop
• Economies of scale	• Economies of micro-scale
• Economics of scarcity	• Economics of abundance
• Physical growth	• Systems sustainability
• Physical assets	• Intellectual assets
• Financial bottom line	• Triple bottom line
• Limited social role of firm	• Wide social role of firm
• Centralized control	• Distributed intelligence
• Linear hierarchy	• Networked hyperarchy

Conclusion

I have argued that we face issues so serious that a global storm warning seems entirely in order. At the same time we have dazzling new capabilities and potential solutions if only we will make use of them. Global change is now rolling. It is up to us to embrace new values and new technologies, and experience the future as transformation not crisis.

March 2007

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