Chapter 19
Tipping Points

On March 4th, the National Academy of Sciences announced that a section of the Arctic Ocean seafloor holding vast stores of frozen methane is showing signs of instability and widespread venting of the powerful greenhouse gas. According to a press release, research conducted by University of Alaska scientists, and published in the journal *Science*, indicates that the permafrost layer under the East Siberian Arctic Shelf, long thought to be an impermeable barrier sealing in methane, is perforated and is starting to leak large amounts of the gas into the atmosphere.

“Release of even a fraction of the methane stored in the shelf could trigger abrupt climate warming,” warned the Academy.

As a greenhouse gas, methane is more than thirty times more potent than carbon dioxide (CO2), though it doesn’t linger in the atmosphere as long. On land, most methane comes from wetlands (natural and artificial) and agricultural zones associated with livestock and rice production. In frozen soils, it reaches the atmosphere when organic material stored in permafrost begins to thaw and decompose, gradually releasing methane. Under the sea floor, however, when frozen methane hydrates begin to thaw they can be released abruptly.

The East Siberian Arctic Shelf encompasses more than two million square kilometers of seafloor, and research shows it is already releasing the equivalent of 1 million tons of methane a year. One reason for alarm is the shallow nature of the Shelf. In deep water, methane gas oxidizes into CO2 before it reaches the surface (which can be absorbed by the ocean). In shallow water, it reaches the atmosphere more easily as methane.

Some researchers downplayed the news, however, arguing that methane is the not the main concern with climate change…CO2 is. One scientist used this analogy: say you are driving down the highway at 70mph and you suddenly see traffic stopped ahead. You hit the brakes only to discover they don’t work. That’s CO2. Then you realize that the accelerator is jammed as well, which means you’ll hit the first vehicle on the road at 80 mph instead of 70mph. That’s methane.

But other scientists have a different concern – they worry about methane’s role in pushing climate change past a *tipping point* – a threshold where a system crosses into a new physical state, and once there doesn’t return its previous state without a great deal of difficulty, if ever. In physics, it’s the point where a tiny amount of added weight causes a balanced object to suddenly topple.

In this case, the ‘topple’ scientists are worried about is runaway global warming.

President Obama’s science advisor, John Holdren, recently told a congressional committee “Climate scientists worry about ‘tipping points’…thresholds beyond which a small additional increase in average temperature or some associated climate variable results in major changes to the affected system.”

The 'tipping' potential of methane hydrates is very much on the mind of Dr. James Hansen, our nation's top climatologist. In his book, *Storms of My Grandchildren*, Hansen describes how fifty-five million years ago, the Earth endured a catastrophic extinction event called the Paleocene-Eocene Thermal Maximum (PETM) in which the planet reached a 6 degree Celsius rise in temperature and an atmospheric content of CO2 of 1400 parts-per-million (ppm). The PETM run-up itself lasted only 20,000 years, capping a *six million*-year warming trend.

What trigged the PETM? No one is totally sure, but Hansen says that the rapid injection of methane hydrates into the atmosphere almost certainly played a huge role. He notes that each liter of melted hydrate expands into 160 liters of methane gas, which oxidizes into CO2 and stays in the atmosphere a long time. In other words, after six million years of warming, a 'tipping point' was likely reached, causing the rapid melting of methane hydrates, which, in turn, triggered the catastrophic warming spike.

Moreover, after the PETM, it took at least 100,000 years for natural processes to 'scrub' the excess CO2 out of the atmosphere.

"This is a reminder," writes Hansen, "that if humans are so foolish as to burn all fossil fuels, the planet will not recover on any time scale that humans can imagine."

Today, following global cooling of many millions of years, the methane hydrate 'gun' is fully loaded. Data is scarce, but there could be as much as 5000 gigatons of CO2-equivalent in the form of methane ice on the planet today. By comparison, scientists think that only 1500-2000 gigatons of methane were released during the PETM.

All of this led Dr. Hansen to lower his estimate for a "safe" amount of atmospheric CO2 from 450 ppm – a threshold he held for years – to 350 ppm.

Today, atmospheric CO2 stands at 390 ppm, and rising.

According to current climate science, this means we are, minimally, slated for a 2 degree Celsius increase in a century or so even if we follow Dr. Hansen's advice and rapidly reduce our greenhouse gas emissions. If start now, but move slowly, we're facing a 4 degree Celsius rise; 5 degrees if we start late; 7 degrees Celsius if we do nothing at all.

Already, Hansen sees early signs of trouble all around the globe: (1) the Arctic sea ice is melting faster than models predicted; (2) glaciers are disappearing; (3) the Greenland and West Antarctic ice sheets are losing mass; (4) the subtropical regions are expanding toward the poles, and at a faster rate than predicted; and (5) coral reefs are suffering from multiple stresses.

"If the world does not make a dramatic shift in energy policies over the next few years," he concludes, "we may well pass the point of no return."

Compounding the bad news, a new University of California at Davis study says it is harder than experts thought to predict when sudden shifts in Earth's natural systems will occur – a worrisome trend for scientists trying to identify the tipping points that could push climate change into the disaster zone.

“Many scientists are looking for the warning signs that herald sudden changes in natural systems,” said UC Davis theoretical ecologist Alan Hastings. “Our new study found, unfortunately, that regime shifts with potentially large consequences can happen without warning – systems ‘tip’ precipitously.”

This means that some effects of global climate change on ecosystems can be seen only once the effects are dramatic, Hastings said. “By that point returning the system to a desirable state will be difficult, if not impossible.”

A tipping point isn’t a new idea. In ecology, it forms the backbone of the concept of *resilience*, which describes the ability of an ecosystem to absorb disturbance, such as floods, fires, or pests, and still retain its basic structure and function. Resilience is the capacity to undergo change without crossing a threshold into a different system. A prolonged drought, for example, might ‘tip’ a grassland ecosystem into a desert, especially if it were compounded by additional environmental stressors, such as overgrazing by animals. In contrast, a resilient grassland can ‘bend’ with a drought without tipping into a desert condition – if it isn’t overstressed.

Research and practical experience have shown, for example, that the ‘just the right amount’ of grazing by herbivores – wild or domestic – can increase a grassland’s resilience by diminishing the possibility of a catastrophic fire, increasing plant vigor and diversity, improving soil health, and by reducing erosion. Additionally, humans can help build resilience by restoring damaged riparian areas, improving the water cycle, protecting open space from development, and manage for land health objectives.

Of course, there’s not much that any plant, animal or human could do to improve a grassland’s chances if the planet warms 5 degrees Celsius and the rains stop falling.

But short of that catastrophe, there is a lot we can do at the local level to push tipping points farther toward the horizon. In their book *Resilience Thinking*, ecologist Brian Walker and science writer David Salt, put it this way: “Resilient socio-ecological systems have the capacity to change as the world changes while still maintaining their functionality. Resilient systems are more open to multiple uses while being more forgiving of management mistakes.”

The problem, as they see it, is we aren’t doing enough to repair the cracks that are appearing in the capacity of our communities, ecosystems, and landscapes to provide the goods and services that sustain our well-being. Instead of building resilience, the response from most quarters has been for ‘more of the same’ that got us into this situation in the first place: more control, more intensification, and greater efficiency.

For Walker and Salt, efficiency and optimization are the roots of our trouble. Efficiency reduces resilience by eliminating natural obstacles that slow the effects of catastrophic shocks to systems.

Optimization aims to get a system to an optimal state and keep it there so it can continue to deliver the maximum sustained yield. In the process, however, it demotes the importance of 'unmarketable' values, such as ecosystem services (food, fresh water, fuel, fiber, environmental cleansing, aesthetics, etc.) to the point where they are simply taken for granted. This is leading into a serious situation.

"The ruling paradigm – that we can optimize components of a system in isolation of the rest of the system," they write, "is proving inadequate to deal with the dynamic complexity of the real world. Sustainable solutions to our growing resource problems need to look beyond a business as usual approach."

The more you optimize elements of a complex system, the more you diminish that system's resilience. The drive for an efficient optimal state, they argue, has the effect of making the total system more vulnerable to shocks and disturbances. By contrast, the key to sustainability lies in enhancing the resilience of socio-ecological systems, not in optimizing isolated components of the system.

The trouble, of course, is that humans are phenomenally successful short-term optimizers. So, with the 'mother of all tipping points' – climate change – bearing down upon us, it is becoming increasingly urgent that we begin to consider long-term consequences of our actions and make the necessary changes before it's too late. As Walker and Salt warn, when a system with little resilience crosses over a threshold into a new regime, it frequently no longer provides us with the goods and services we need. And by the time a tipping point is reached, it's often too late.

Their advice? Build resilience into our systems, even if it's expensive or inconvenient, which it often is under our Business-as-Usual optimizing economy.

"Managing for resilience," they conclude, "is all about understanding a socio-ecological system with particular attention to the drivers that cause it to cross thresholds between alternate regimes, knowing where the thresholds might lie, and enhancing aspects of the system that enable it to maintain its resilience."

In other words, pay now or pay later. And pay quickly, for time is running short.

Another reason to act quickly is yet one more fast-approaching tipping point with big consequences: the decline of fossil fuel production, frequently referred to as 'peak oil.' The idea is as simple: there is a finite, physical limit to the amount of oil and natural gas stored in the Earth's crust and at some point their production will tip downward. When it does, all sorts of problems will begin, not the least of which will be rising energy prices. This threshold may be arriving soon. According to a slew of official reports recently, the permanent end of the era of cheap oil is coming as soon as next year, and the world will face serious oil supply shortages beginning in the 2011-2015 time frame.

The Smith School of Enterprise and the Environment at Oxford University in England, for example, recently published a paper stating that the energy industry's capacity to meet projected future oil demand is at a tipping point and that we need to accelerate the development of alternative energy fuel resources in order to ensure energy security and meet demands.

Sir David King, Founding Director of the Smith School, and a former chief scientist of the United Kingdom, says the world's oil reserves have been exaggerated by up to a third. That means, according to the law-of-supply-and-demand, the consequence will be shortages and price spikes. More ominously, if we don't develop new sources of energy quickly there will a tipping point in overall energy availability, which is very bad news for an energy-intensive global economy.

"We all recognize that oil is a finite resource," he said. "We need to look at other low carbon alternatives and make the necessary funding available for research, development and deployment today if we are to mitigate the tipping point."

King's thesis is taken a step further in a 55-page paper called "Tipping Point: Near-Term Implications of a Peak in Global Oil Production," published in March by *Feasta*, an Irish foundation that focuses on the economics of sustainability. According to chief author David Korowicz, our civilization is structurally unable to endure an energy withdrawal, which means with the passing of the peak of oil production there is a high probability that our integrated and globalised civilization could collapse.

"The laws of thermodynamics," he writes in the summary, "are the inviolate framework through which all things happen – the evolution of the universe, the direction of time, life on earth, human development, the evolution of civilization, and economic processes…we are at a point where these flows are, with high probability, about to begin decreasing."

And I thought the release of methane hydrates was bad news.

If that weren't enough, there is another tipping point on the minds of scientists these days: we may be crossing the geologic threshold from the 12,000-year old *Holocene* to a new era being referred to as the *Anthropocene*. Scientists say the rapid expansion of the scale of human activities since the Industrial Revolution has now generated a global geophysical force equivalent to some of the great forces of nature. And they may be just as long-lasting as a geologic event.

Moreover, researchers have now identified nine planetary thresholds which should not be crossed if we want to maintain life-as-we-know it on Earth. They are: climate change, stratospheric ozone, land use change, freshwater use, biological diversity, ocean acidification, nitrogen and phosphorus inputs to the biosphere and oceans, aerosol loading, and chemical pollution. Unfortunately, a recent study published in the journal *Nature* by a group of scientists says three of these boundaries – climate change, biological diversity and nitrogen input – may already have been crossed.

In other words, we're entering a new geological era in which our activities are threatening the Earth's capacity to regulate itself and stay healthy – the *Anthropocene*.

The term was coined by scientist Paul Crutzen, who won the Nobel prize for chemistry in 1995. In a paper published in 2000, Crutzen and another researcher noted that many human activities now dwarf their natural counterparts. They wrote: "it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term 'anthropocene' for the current geologic epoch." The name promptly caught on in scientific circles and peer-reviewed papers.

Currently, there is a formal process underway to designate the *Anthropocene* as the current era. The International Commission on Stratigraphy (ICS), based in England, makes the official call, and a recent survey among members indicated that half the commission thought the time had come to seriously consider a name change. One point of debate, however, involves an official 'start date' to the era – should it be 1800 (dawn of the Industrial Revolution)? 1945 (detonation of the Atomic Bomb)? 1988 (the year Dr. Hansen told Congress that climate change was real)? Or 2000 (the year the name was proposed by Dr. Crutzen)?

On this last point, Dr. Jan Zalasiewicz, a professor of geology at the University of Leicester, England, and Chair of the 'Anthropocene Working Group' for the ICS, told a reporter recently that the year 2000 was important because it marked a "time of dawning realization that human activity was indeed changing the Earth on a scale comparable with some of the major events of the ancient past. Some of these changes are now seen as permanent, even on a geological time-scale."

Personally, I vote for 2000 – the year that I consider the *Age of Consequences* to have begun.

Whatever the ICS finally decides on for a start-date, the day it officially designates the end of the *Holocene* and the start of the *Anthropocene* a tipping point of immense proportions will have been crossed. Whether a 'toppling' of society follows, as some expect, remains to be seen.

Which brings us back to resilience.

The *Holocene* was characterized by stability (sea levels, climate) and resilience (the ability of natural processes to handle stress and change). In the *Anthropocene*, if the climatologists are correct, stability will be a memory. Everything from rising temperatures and sea levels to the increased frequency and destructiveness of storms will become the 'new normal,' replacing 12,000 years of relative calm. This, of course, would actually be a return to the 'old normal.' The Earth's history is a cascade of dramatic (though slow) climatic swings, from warm to freezing and back again, over the millennia. It's the stable *Holocene* that was the anomaly, luckily for us.

But what about resilience in the *Anthropocene*? Will the planet be able to handle the new stresses? Will we?

Today, we are pushing the planet out of its current stable *Holocene* state, into the great unknown. The *Holocene* was coterminous with human civilization. Will civilization last long into the *Anthropocene*? No one knows, though it seems clear that the *Holocene* would have extended for quite a while longer if we hadn't interfered with the planet's basic processes (the previous age, the *Pleistocene*, lasted two million years). And there's no reason to think the civilization wouldn't have extended right along with it.

But that's not an option, apparently, if we cross over these tipping points. Will we pull back in time? I don't know, though it's looking increasingly unlikely. If we don't, then how and where we build resilience will become the issue of greatest concern.

I, for one, have my fingers crossed.