The Overshoot Crisis

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Looking out the window of an airplane, particularly at night, admits a very different impression of civilization than we are accustomed to on the ground. From a bird's-eye view, the buzzing of the city is subsumed under a quiet stillness, revealing vast, intricate networks of streets and super-highways, man-made spiderwebs traced out by artificial light (if you've ever flown at night you can picture them). To me they evoke something almost alien: a gigantic slime mold of concrete and steel, spreading out across the natural landscape and reshaping it in strange and novel ways. It is a visual reminder that our collective actions may be following patterns on the macro scale that go unrecognized on the micro.

More so than at any time in history, humanity today is interconnected on a global scale, through a global economy and financial system, a worldwide internet, and a planetary ecosystem. To some extent the human enterprise now functions as a single coherent entity, what Nate Hagens calls the *super-organism.*[1] This refers not only to the physical structures of civilization, but all of its people, their needs and desires, machines, monetary and political systems – all functioning as one energy-hungry, metabolic organism. It is to the ant colony what we are to the ants, and it exhibits its own emergent behaviors. Zooming out and viewing civilization from this distance is a useful thing to do once in awhile, if only to see more clearly just how irrational our collective actions are – how blind and self-destructive this super-organism has come to be – despite being made up of (arguably) rational human beings. It is no wonder that the world's leading expert on ants, biologist and entomologist E. O. Wilson, accustomed to such a perspective, summed up our behavior in the following way:[2]

> "Humanity today is like a waking dreamer, caught between the fantasies of sleep and the chaos of the real world. The mind seeks but cannot find the precise place and hour. We have created a Star Wars civilization, with Stone Age emotions, Medieval institutions, and Godlike technology. We thrash about. We are terribly confused by the mere fact of our existence, and a danger to ourselves and to the rest of life."

Last month the Intergovernmental Panel on Climate Change (IPCC) published its latest report on the state of the climate crisis, detailing the current trajectory of global warming, the grave risk it represents to the world's ecosystems, and the deep and rapid cuts in greenhouse gas emissions needed to avert disaster.[3] Contrasting the report's dire implications for human well-being with the continued lackluster responses from governments around the world, UN Secretary-General António Guterres called the report "an atlas of human suffering and a damning indictment of failed climate leadership."[4] Indeed, annual carbon dioxide (CO_2) emissions set a new record in 2022.[5]

When faced with serious problems, our natural tendency is to look for someone (or some group of people) to blame. We are conditioned to assume that *somebody*, somewhere must be in charge, and if only

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[1] "Economics for the future – Beyond the superorganism", https://www.sciencedirect.com/science/article/pii/S0921800919310067
[2] E. O. Wilson, "The Social Conquest of Earth" (2012)
[3] https://www.ipcc.ch/report/sixth-assessment-report-cycle/
[4] https://www.wri.org/insights/2023-ipcc-ar6-synthesis-report-climate-change-findings
[5] https://www.iea.org/reports/co2-emissions-in-2022

they could be convinced of the importance of the problem or the efficacy of the solutions, they could turn things around. It is harder to come to grips with the idea that our collective behavior emerges from an enormously complex web of incentive structures and feedbacks; that no leader has the power to redirect the system's behavior, and that nobody is actually driving the bus. But I think this fundamental realization has been dawning on us for some time, namely that our biggest societal problems are not moral or individual, but systemic. The destruction of the natural world, widening inequality, growing social unrest, not to mention rising rates of mass shootings, depression, and anxiety – these trends are not caused by the decisions of a single leader, nor even by a small group of sociopathic elites (as compelling as that idea may be), but mainly by the colossal inertia of the system itself. It feels as if we have created a Leviathan that is now beyond our control.

To have any hope of adequately addressing the climate crisis, we need to see it for what it is: not an isolated issue, nor the be-all and end-all of our problems, but a *symptom* of a much larger and more fundamental conundrum. The root of the environmental crisis we're now facing is that the human super-organism has exceeded the limits of what Earth can support. As a civilization we are draining resources from the environment faster than they can be replenished, and we are outputting waste products faster than they can be absorbed (CO_2 being just one of these waste problems). This state of affairs, in which a species overtaxes the sources and sinks of its environment, is what ecologists call *overshoot*, and while for other species it can occur in a local biome, for humankind it is now happening on a planetary scale. We rely on a healthy ecosystem for our own survival, so as we erode the natural systems around us, the planet's capacity to support human life erodes along with it. In short, despite being both a part of and dependent on the tree of life, "humanity is busy sawing off the limb on which it perches."[6]

To understand the self-destructive things we are doing on this planet collectively, and to have any hope of undoing them, we need to step back and take a wider view – to picture the world not as a collection of individual events and isolated crises, but as an interconnected system in overshoot. My hope is that, by constructing better mental models for our predicament, we will be better equipped to address it.

How we got here: energy and the exponential

To understand how we got to this point, we first need to understand the central role of *energy* in modern society. Energy is the ability to do work: to lift a weight, turn a wheel, pump water through a pipe, light a bulb, or heat a furnace. All organisms need energy to function, and as animals we get energy from the food we eat, but vastly greater sums of energy are used to power nearly every facet of our modern lifestyle. For most of human history, the only energy available to us was the metabolic energy of our own bodies – human muscle power – along with that of domesticated livestock, plus some heat energy from burning wood. Change was slow from one generation to the next, and both the size of the human population and its overall impact on the planet were constrained. That changed dramatically with the discovery of fossil hydrocarbons – first coal, then oil, and later natural gas – along with the technology to harness them. All of a sudden a seemingly limitless supply of energy was marshaled to our command, sparking the industrial revolution and ushering in an era of unprecedented growth.

Our appetite for energy has been increasing ever since. Rates of energy use are typically measured in Watts, which is a unit of *power*, or energy-per-unit-time. Since the industrial revolution, global energy use has increased by at least a factor of twenty, from around 0.9 terawatts ('tera' means

[6] Paul Ehrlich quoted in Kolbert, "The Sixth Extinction" (2014)

trillion) in 1860 to 19 terawatts in 2021, while CO_2 emissions have risen by a factor of a hundred.[7] Over that same time, the human population itself has grown tenfold, from ~800 million to now ~8 billion, an increase made possible in part by the injection of fossil energy into the food chain via synthetic fertilizers.

The energy density of hydrocarbon fuels is extraordinary. Hagens estimates that a single barrel of oil contains the energy equivalent of five years of manual labor by a human worker.[8] Taking this analogy a step further, our surplus of fossil energy is akin to an army of inanimate 'energy slaves', a term coined by futurist Buckminster Fuller, who calculated in 1940 that the "total energy consumed by industrial man from mineral sources and water power" represented the work of 36 billion energy slaves, in addition to the ~2 billion humans alive at the time.[9] In this sense, today's 19-terawatt civilization is powered by 500 billion invisible workers.

It is important to stress that, over the past 200 years, our consumption of energy and materials has not only grown, it has grown *exponentially*. The word 'exponential' is thrown around colloquially to mean something vague like 'by leaps and bounds', but exponential growth actually refers to something very specific: it describes a quantity whose *rate* of change is proportional to its value. In other words, rather than increasing by a fixed amount each year, an exponential increases by a fixed *percentage*. Linear growth adds at a constant rate, while exponential growth *multiplies* at a constant rate (a culture of bacteria that doubles its numbers each generation - 2, 4, 8, 16 - is growing exponentially).

The sheer pace of this kind of growth defies intuition. For instance, an annual growth in GDP of 3% may sound 'slow and steady', a reasonable goal in the eyes of many policymakers, but how many of them realize that 3% per year results in a doubling time of just 25 years? In other words, if this rate of growth were to continue long-term, then each generation would produce and consume twice as much as their parents! Not only that, but a constant doubling time means that each generation will use as much as *all previous generations combined* since the doublings began. If that sounds farfetched, consider that nearly half of all the fossil fuel that has *ever* been burned was burned since I was born in 1990. More than half of all the plastic on Earth was produced since 2000.[10] It is estimated that China poured more concrete in three years, from 2011-2013, than the United States poured in *the entire 20th century*![11] On a fundamental level, this unprecedented period of growth is the result of a massive influx of cheap fossil energy: a temporary 'carbon pulse', a one-time planetary windfall.

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It is a common refrain that, since material standards of living have been improving over time (albeit with some bumps along the way), there is no cause for alarm; technology will continue to lift people out of poverty and life will keep getting better in the long run. This argument is not very convincing for a society in overshoot, not only because we are entering uncharted territory when it comes to ecological damage, but because the *way* we've been able to raise people's standard of living so far has relied on an ever-increasing demand for energy. It is no surprise that we are living better than our great-grandparents, considering the energy we're using to do it! Unfortunately this paradigm cannot last very much longer, as both energy inputs and pollution outputs are approaching planetary limits.

[7] https://ourworldindata.org/energy-overview
[8] "Economics for the future – Beyond the superorganism", https://www.sciencedirect.com/science/article/pii/S0921800919310067
[9] https://www.fulltable.com/vts/f/fortune/xb/50.jpg
[10] https://ourworldindata.org/grapher/cumulative-global-plastics
[11] https://www-new.gatesnotes.com/Making-the-Modern-World

The strain on the global ecosystem can be understood more concretely in terms of so-called *planetary boundaries*. According to the Stockholm Resilience Centre, a leading research institute for the study of human and planetary health, "Transgressing one or more planetary boundaries may be deleterious or even catastrophic due to the risk of crossing thresholds that will trigger non-linear, abrupt environmental change within continental- to planetary-scale systems."[12] These boundaries are far broader than global warming, and include: changes to the chemistry of the biosphere (the emission of greenhouse gases and aerosols, depletion of the ozone layer, disruption of the Nitrogen and Phosphorus cycles from fertilizers, and acidification of the ocean); displacing or over-harvesting renewable resources (freshwater use, land systems change such as deforestation and expanding cropland, and biodiversity loss); and the introduction of 'novel entities' into the environment (e.g. plastics, pesticides, and other chemical pollution). The original study estimated that three of these boundaries – climate change, biodiversity loss, and disruption of the Nitrogen cycle – had already been exceeded. According to their most recent assessment in 2022, land systems change, Phosphorus, and novel entities are now also beyond safe thresholds, with freshwater use and ocean acidity closing fast.[13] Now, just because a boundary has been crossed does not mean that the damage is fatal, but it *does* mean that the pressure humans are currently exerting on these systems cannot continue much longer without triggering 'tipping points' that do cause irreversible harm. The bottom line is that, whether or not global prosperity can continue, the current paradigm of indiscriminate over-consumption cannot. Given the very real ecological and material limits we are facing, another planet-wide doubling is unlikely to occur (nor would it be desirable), and a radically new paradigm is needed to transition from a growth-based society to a sustainable one. How can this be done? In other words, how can we bring the human super-organism into balance?

Thinking in systems

Some insight into the nature of the human super-organism and its penchant for growth comes from the study of *system dynamics*. In her excellent introduction to systems thinking, Donella Meadows defines a *system* as "a set of things–people, cells, molecules, or whatever–interconnected in such a way that they produce their own pattern of behavior over time."[14] All systems, from an air conditioner to a population of rabbits to the global economy, share some features in common. In systems lingo, they are made of three simple elements: stocks, flows, and interconnections between the two. A *stock* is a quantity. It could be the temperature in your house, the population of rabbits in a town, or a country's known oil reserves. A *flow* is a change in a stock over time: how fast the room is warming, the rabbits are breeding, or the oil deposit is being depleted. Flows are usually influenced by the value of other stocks (the temperature outside, the amount of rabbit food available, the capital invested in oil extraction), and these influences form the *connections* of the system (in a complex system a stock may have many different flows associated with it). When a flow is made to increase (or decrease) by the same stock that it regulates, you get a positive (or negative) feedback loop. The warmer the house gets, the closer it is to the temperature outside, and the less the heater needs to work (negative feedback); the more rabbits there are, the more baby rabbits there will be, and the faster the population grows (positive feedback). Of course,

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12 "Planetary Boundaries: Exploring the Safe Operating Space for Humanity", https://www.ecologyandsociety.org/vol14/iss2/art32/

13 https://www.stockholmresilience.org/research/planetary-boundaries.html

14 Meadows, "Thinking in Systems"

nothing can grow forever, so at some point a limiting factor will come into play, causing a restoring, negative feedback loop to grow in strength until it eventually brings the system back into equilibrium.

In this way, one can imagine the whole global ecosphere – human and nonhuman together – as an enormous system of stocks and flows, with all sorts of connections and feedback loops encoding the behaviors, goals, and interrelations of the world. (Mathematically, this model of stocks and flows is just a system of coupled differential equations, and the phenomenon of positive feedback is none other than the exponential function discussed earlier, which arises naturally from these types of equations). Once such a model is specified, the evolution of its stocks over time is easy to calculate with a computer, and in fact these kinds of models are ubiquitous: they are used in ecology to understand why populations rise and fall, in epidemiology to predict how a virus will spread, in businesses to analyze supply chains, and in cybernetics to model how information spreads through a social network.

One of the first scientific studies on global sustainability came in the early 1970's when the Systems Dynamics group at MIT was commissioned to build and analyze a model of the global economy. The results were published in 1972 in a report titled *"The Limits to Growth"*. The book was a bestseller and a bombshell to established attitudes about economic progress, but the study was widely ridiculed (and widely misunderstood) for supposedly predicting that civilization will collapse in the first few decades of this century, which, the critics said, clearly had not happened. However, subsequent studies have found that global resource consumption is by and large following the model trajectory,[15] and there is renewed interest in the study today for reasons which I imagine are by now obvious to the reader. In fact, Limits to Growth did not predict societal collapse in 2020, or 2040; it did not *predict* anything. Rather, the study aimed to understand the *possible behaviors* of a system such as ours, and how those behaviors may be affected by different societal goals and policies. In most of the model runs, what they found was that, "If present growth trends… continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity."[16] Using an updated version of the model in 2004, the authors reached the same essential conclusion:[17]

> "In our analysis we focused principally on the planet's physical limits, in the form of depletable natural resources and the finite capacity of the Earth to absorb emissions from industry and agriculture. In every realistic scenario… the expansion of population and physical capital gradually forces humanity to divert more and more capital to cope with the problems arising from a combination of constraints. Eventually so much capital is diverted to solving these problems that it becomes impossible to sustain further growth in industrial output. When industry declines, society can no longer sustain greater and greater output in the other economic sectors: food, services, and other consumption."

Crucially, incorporating technological innovation into the model, in the form of ever-increasing efficiency in various sectors, was generally unable to solve the problem of overshoot, but merely delayed – or in many cases actually accelerated – collapse. Whenever technology overcame one obstacle, another took its place. Whether the limiting factor is a lack of resources, the filling up of pollution sinks, or ever-rising costs, the era of unrestricted growth eventually comes to an end. That end need not be catastrophic, however. The authors stress that not all of their models lead to a sudden collapse, in fact some scenarios

[15] Herrington, G. https://advisory.kpmg.us/articles/2021/limits-to-growth.html
[16] "The Limits to Growth" (1972)
[17] "Limits to Growth: The 30-year Update"

manage "a smooth adaptation of the human footprint to the carrying capacity of the globe…with an orderly end to growth followed by a long period of relatively high human welfare."

The ability of a system to weather the storm when it comes up against limits or is subjected to shocks is called *resilience.* A resilient system is one that can adapt, self-correct, and guard against overshoot. We want systems that will bend, not break. In the system dynamics school of thought, the key to a system's resilience lies in its feedback mechanisms. Many would argue that democracy is a more resilient political system than autocracy because it has better feedback mechanisms in place. If a signal warning of the approach of some limit is clear, rapid, and effective, negative feedback loops will kick in to change course, bringing relevant flows back down to a sustainable level. But real signals have *delays*: it takes time for greenhouse gas emissions to heat the atmosphere or for pollution to leech into the soil, for scientific consensus to be reached, for public opinion to shift, for new leaders to be elected, for legislation to pass. Real signals also get corrupted: people are biased, results are distorted, misinformation spreads faster than truth. The longer the delays and the greater the corruption of the feedback signals, the more likely a system is to overshoot, be unable to stabilize, and eventually collapse. That we need more *resilient* systems to manage the transition to a sustainable society – that is the real lesson of the Limits to Growth report.

Complexity is another factor that can affect resilience, often negatively. Many systems in today's society are highly complex and efficient, but we must not mistake a system's performance under ideal conditions for its resilience when those conditions change. Global supply chains make a good example: so-called 'just-in-time' production sources parts from a complex web of suppliers, keeping inventories at a minimum and profits at a maximum, but when exposed to sudden shocks by the Covid-19 pandemic, they were revealed to be surprisingly fragile. Historian Joseph Tainter has argued more generally that, "at some point in the evolution of a society, continued investment in complexity as a problem-solving strategy yields a declining marginal return."[18] During the great mass extinctions in Earth's history, smaller, simpler organisms were more likely to survive than larger, complex ones. Thus complexity can be a double-edged sword, with power on the one side and fragility on the other.

Of course, the systems view is only one lens through which to view the world, and a model is only as valid as its weakest assumption. Simple 'toy models' like the ones used in the Limits to Growth study cannot be trusted to make precise predictions about the future, but they can be useful nonetheless, particularly for highlighting the blindspots of our current culture. That staggering growth rates cannot persist forever on a finite planet whose life-support systems are already being strained should not come as a surprise. What *is* surprising is how this basic fact has been obfuscated, even flat-out denied, for so long. How can we only now be recognizing that exponential growth is a very unusual phenomenon, and not a law of nature?

Economics and other mythologies

Every human conception of the world, whether it be a scientific theory, linguistic description, or mental image, is a kind of *model*. And while models can be extremely useful for the right question in the right context, models are *representations* of reality, not reality itself. When we lose sight of the distinction between model and reality, we can get swept into a kind of fantasy: the model becomes a belief system more important than what it was made to describe, and all sorts of mental gymnastics are performed to

[18] Joseph Tainter, "The Collapse of Complex Societies"

justify its dogma in the face of contrary evidence. Thus a mental model, be it cultural, religious, or academic, can become a mythology. Science is not at all immune to this trap. The great paradigm shifts in the history of science, from the Copernican to the Darwinian revolutions, were not easily or widely accepted at first. When cracks appear in the foundations of our mental models, we tend nevertheless to cling to the old belief system as long as possible – long after the floodwaters are impossible to deny – until the dam finally breaks.

The carbon pulse and the rapid growth it has enabled over the past two centuries has led to several mythologies which are especially dangerous in our era of ecological overshoot. Industrialization spawned new myths about the source of our newfound prosperity. It became common knowledge that social progress was due to human ingenuity, technological innovation and a free market, and while those things are certainly important, none of it would be possible without an unprecedented energy surplus. As our whole society grew more complex, we began to conceptualize the economy in more and more abstract terms, ignoring the fundamental energy and material requirements underpinning it. The myopia is pervasive. Turn on NPR's *Marketplace* and you will hear all about how the Federal Reserve is adjusting interest rates to try to ease inflation, or how homebuyers may be reacting to the housing market. That's all well and good, but you will *not* hear about how discoveries of new oil deposits are dwindling, nor how the quality of copper ore is dropping, nor how wild fish populations (which are the main source of protein for over a billion people) are in decline, even though these are the real material things that power the economy and supply the marketplace.

Philosophically, modern society tends to conceptualize Man as separate from Nature, and in that spirit we think of the human economy as a closed system, separate from the natural systems – physical, geological, and biological – on which it depends. The textbook model of the economy is a closed system of labor, capital, money, supply and demand – but the physical reality on which it is based is not. "There is no single, legitimate boundary to draw around a system. We have to invent boundaries for clarity and sanity; and boundaries can produce problems when we forget that we've artificially created them."[19] Conventional economic thinking draws the boundaries of the human economy so that its true sources and sinks can be conveniently ignored (for now). In this sense conventional economics is "energy blind". It is also "materials blind" and "waste blind". In the case of oil, for example, we pay only for the cost of its *extraction*, not the cost of creation (which is incalculable, given that it takes millions of years) nor the cost of pollution. We pay attention only to prices, and since the decline in quality of new oil wells is not yet reflected in the price of oil, it is not widely known. A handful of contrarians such as former World Bank economist Herman Daly have sought to develop an 'ecological economics' with these issues front and center, but they have been largely ignored. "Economics evolved in a time when labor and capital were the most common limiting factors to production" says Meadows. "As the economy grows relative to the ecosystem, however, and the limiting factors shift to clean water, clear air, dump space, and acceptable forms of energy and raw materials, the traditional focus on only capital and labor becomes increasingly unhelpful."[20]

Ultimately, 20th-century attitudes about economic progress could only have arisen during this unusual period in human history, because they treat growth as the norm. In the fever dream of the carbon windfall, we allowed a paradigm of never-ending growth to take hold in the cultural consciousness, and the goodness of growth itself became a mythology.

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[19] Meadows, "Thinking in Systems"
[20] Meadows, "Thinking in Systems"

> "The idea that there might be limits to growth is for many people impossible to imagine. Limits are politically unmentionable and economically unthinkable. The culture tends to deny the possibility of limits by placing a profound faith in the powers of technology, the workings of a free market, and the growth of the economy as the solution to all problems, even the problems created by growth."[21]

Technology and markets will undoubtedly play an important role in the sustainable energy transition. What are realistic expectations for 'renewable' energy is an enormous topic that is beyond the scope here, but the salient point is that technology is a tool, not a silver bullet. It can be powerful if directed toward appropriate goals, but if those goals include maintaining endless growth of the human super-organism, then technical and market solutions to overshoot are bound to fail. Technology and markets will be of service only if our mental models of the world are aligned with its biophysical reality.

When modelers don't fully understand the systems they're trying to model, they can fail spectacularly. In the 1990's, Yale economist William Nordhaus was one of the first to consider the 'social cost of carbon', i.e. the net damage inflicted on society per ton of CO_2 emissions. In a seminal paper, he wrote: "Our estimate is that approximately 3% of United States national output is produced in highly sensitive sectors, another 10% in moderately sensitive sectors, and 87% in sectors that are negligibly affected by climate change."[22] Lacking a systems perspective and using a simple cost function, he concluded that "the net economic damage from a 3º warming is likely to be around $^1/_4$% of national income for the United States in terms of those variables we have been able to quantify… my hunch is that the overall impact upon human activity is unlikely to be larger than 2% of total output." Nordhaus continued to argue that we shouldn't reduce emissions too quickly, because the economic cost today will be higher than the benefits of growth for the future. In this mindset, any reduction in crop yields from climate disruption can only be a minor setback, since agriculture represents just a small percentage of the world's GDP; taken to its logic conclusion, if global food production were to stop entirely, it wouldn't be such a big deal. Clearly GDP is a totally inadequate metric for the health of society, particularly when facing environmental crises. In the scathing words of one editorial,[23]

> "the Nordhaus model tells us that even the worst catastrophes will not really hurt the global economy all that much… if climate breakdown ends up starving and displacing a few hundred million impoverished Africans and Asians, that will register as only a tiny blip in GDP. After all, poor people don't add much "value" to the global economy. The same goes for things like insects and birds and wildlife, so it doesn't matter if global warming continues to accelerate mass extinction. From the perspective of capital, what most of us see as tremendous ethical and even existential problems literally don't count."

In 2017 Nordhaus used his latest model to reach the patently absurd conclusion that climate change "leads to a damage of 2.1% of income at 3°C, and 8.5% of global income at a global temperature rise of 6°C."[24] The following year he was awarded the Nobel prize in economics.

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[21] Limits to Growth: the 30-year update

[22] https://www.semanticscholar.org/paper/To-Slow-or-Not-to-Slow%3A-The-Economics-of-the-Effect-Nordhaus/6f11f586b195b8d81d6bb022d97f372258ed9e28

[23] https://mronline.org/2018/12/12/the-nobel-prize-for-climate-catastrophe/

[24] Nordhaus, "Revisiting the social cost of carbon", https://www.pnas.org/doi/10.1073/pnas.1609244114

The frustrating thing is that these 'experts' are not stupid. In fact, by and large they are highly intelligent within the bounds of their discipline. But without a larger perspective, they fail to see when their models apply and when they are meaningless. While reading Meadows' *Thinking in Systems,* I came across this quote which puts a finer point on it:[25]

> "Rational elites… know everything there is to know about their self-contained technical or scientific worlds, but lack a broader perspective. They range from Marxist cadres to Jesuits, from Harvard MBAs to army staff officers… They have a common underlying concern: how to get their particular system to function. Meanwhile… civilization becomes increasingly directionless and incomprehensible." — John Ralston Paul, political scientist

As the world gets ever more complex, specialists become ever more specialized, and academic disciplines become isolated. As ecologist William Rees has been pointing out for decades now, professional ecologists seldom consider human activities at all, even though humans now represent the dominant agent in most ecosystems on Earth, while economists completely ignore ecology, even though the entire economy depends on it. This sort of compartmentalization in the minds of 'rational elites' amounts to a failure of imagination, and it has led us to mental models of the world that literally make no sense. With experts confined to a narrow field of view, steeped in an economic mythology that no longer matches reality, system-wide issues like overshoot are difficult to even see, let alone address. A wider perspective is desperately needed.

Conclusion

> "A bunch of mildly clever, highly social apes broke into a cookie jar of fossil energy and have been throwing a party for the past 150 years. The conditions at the party are incompatible with the biophysical realities of the planet. The party is about over and when morning comes, radical changes to our way of living will be imposed. Some of the apes must sober up (before morning) and create a plan that the rest of the party-goers will agree to." - Nate Hagens

The choice between prosperity and sustainability is a false one, predicated on a myth that growth is the only option. In reality, the era of exponential growth in energy and complexity is coming to an end. Our energy throughput will be lower in the not-too-distant future, and it is up to us whether we get there by design or by disaster. Importantly, sustainability does *not* mean zero growth of any kind. It just means the system *as a whole* is in balance. There will always be progress in science, evolution in philosophy and art, changes in culture and lifestyles. Some industries will continue to grow while others diminish, and new ones are born. The developing world may grow its energy use while rich countries lower theirs through more efficient use of resources. There is no reason in principle why a sustainable economy can't provide us with healthy, fulfilling lives, but it will require a profound shift in our mental models of the world.

A systems view will be absolutely essential to distinguish policies that will actually help the overshoot crisis from policies that will only delay or exacerbate it. It is not enough, for example, to point out that electric cars have a lower carbon footprint than cars that run on gasoline. One must look at the whole picture and ask, if all the vehicles currently on the road (1.5 billion worldwide and counting) were

[25] Meadows, "Thinking in Systems"

replaced with a new fleet of electric ones (and replaced again every few decades when they wear out), what that would mean for stocks and flows of lithium, cobalt, and copper; for aluminum, glass, and silicon; for charging infrastructure and battery waste and people's willingness to take public transit?[26] Ultimately we may conclude that the root of the problem is not internal combustion engines, but that our cities require each household to have its own personal vehicle in the first place. Without a holistic view of the problem, we will end up pursuing solutions that only create more problems of their own.

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To many of us surrounded by the wonders and comforts of modern life, it seems impossible that such an advanced civilization could one day disappear, but we tend to forget that throughout history human societies have come and gone, in various ways, for various reasons. In "*Collapse*", Jared Diamond's popular account of how past societies have either triumphed over or succumbed to their environmental challenges, the story of Easter Island makes a chilling example. Once a lush forested environment, Easter Island was slowly and steadily destroyed over a period of several hundred years by a combination of unsustainable logging and fishing, until the entire ecosystem fell apart. Much of the logging was done in the service of transporting and erecting enormous stone statues to honor the gods of one clan, and outdo the statues of their rivals. Sadly, as the environment degraded the competition to build bigger and bigger statues only increased until, when their society finally collapsed, "islanders turned to the largest hitherto unused source available to them: humans, whose bones became common not only in proper burials but also (cracked to extract the marrow) in late Easter Island garbage heaps."[27] Some of the largest stone heads they had ever attempted are still sitting half-finished in the quarry, never to be raised.

Diamond notes a common pattern in the way those societies which failed to properly manage their resources met their end:

> "In fact, one of the main lessons to be learned from the collapses of the Maya, Anasazi, Easter Islanders… is that a society's steep decline may begin only a decade or two after the society reaches its peak numbers, wealth, and power. …The reason is simple: maximum population, wealth, resource consumption, and waste production mean maximum environmental impact… On reflection, it's no surprise that declines of societies tend to follow swiftly on their peaks."

Collapse is not an event, but a process, and the evidence suggests it may already be underway. How far it progresses and what kind of world will be left in its wake depends on our willingness to question existing intellectual paradigms, shed outdated modes of thinking, and speak new ones into being.

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[26] Simon Michaux, https://www.youtube.com/watch?v=MBVmnKuBocc
[27] Jared Diamond, "Collapse"