THERE'S NO APP FOR THAT

Technology and Morality in the Age of Climate Change, Overpopulation, and Biodiversity Loss

RICHARD HEINBERG

post carbon institute

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About the Author

Richard Heinberg is Senior Fellow-in-Residence of Post Carbon Institute, and widely regarded as one of the world's foremost educators on the need to transition away from fossil fuels. He is the author of thirteen books, including *Our Renewable Future: Laying the Path for One Hundred Percent Clean Energy* (2016). He has authored scores of essays and articles that have appeared in *Nature*, *Christian Science Monitor*, *Wall Street Journal*, and elsewhere; has been quoted and interviewed countless times for print, television, and radio; and has spoken to hundreds of audiences in fourteen countries.

About Post Carbon Institute

Post Carbon Institute's mission is to lead the transition to a more resilient, equitable, and sustainable world by providing individuals and communities with the resources needed to understand and respond to the interrelated economic, energy, ecological, and equity crises of the 21st century.

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This manifesto also owes a great deal to the existing literature on technology criticism; if readers wish to delve deeper, see the Appendix for a list of indispensable resources. See Appendix also for image credits.

There's No App for That: Technology and Morality in the Age of Climate Change, Overpopulation, and Biodiversity Loss

By Richard Heinberg

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Introduction

We depend on technology. It wakes us in the morning; grows our food and cooks our meals; transports us to and from work or school; entertains us; informs us of world events; enables us to communicate with family, friends, and co-workers; lights, heats, and cools our homes and offices; and treats our injuries and illnesses. We are so reliant on our machines that we barely lift a skeptical eyebrow when we're encouraged to believe that new technologies will solve the most severe global challenges humans have ever faced—in particular, the three big problems of climate change, overpopulation, and biodiversity loss. Why shouldn't technology overcome these challenges? It does everything else for us, after all.

Yet in many respects these very problems are side effects of past technological development.[1] Climate change is a side effect of burning fossil fuels—sources of energy that power virtually all aspects of the modern human world, including transportation, manufacturing, and food systems. Rapid population growth has occurred due to improvements in sanitation, medical care, and agriculture. We're

losing biodiversity because of deforestation (helped by industrial forestry equipment), overfishing (helped by modern industrial fishing equipment), and environmental pollution (often from the agricultural chemicals that grow food for 7.5 billion humans). All of these issues are related and compound one another.

When confronted with problems tied to past technological development, our reflex is to propose new machines to address them. Today, environmental engineers are hard at work inventing and perfecting machines to suck carbon dioxide out of the atmosphere to save us from climate change,[2] and technologies to replace energy from fossil fuels with energy from sun and wind.[3] Agricultural scientists are using gene transfer technologies to develop crops they hope can feed eleven or twelve billion of us (or more!) by the end of the century.[4] And biologists are sequencing the genomes of extinct and endangered animals and plants with the hope of re-growing them in laboratories.[5]

But here's the thing. Technology *isn't* saving us from climate change,[6] over-population,[7] or collapsing biodiversity.[8] While solutions have been proposed, some of which are technically viable, *our problems are actually getting worse rather than going away, despite the existence of these "solutions."* Greenhouse gas concentrations in the atmosphere are rising. World population is growing more, in net numbers annually (85 million), than the entire populations of most countries. And more species are disappearing every year.

Are we just not trying hard enough? Certainly we could try harder. We could invest more in solar and wind power. We could develop manufacturing processes that save energy and don't use toxic chemicals that end up putting children and wildlife at risk. We could produce artificial, lab-grown meat so that we don't have to use a third of the planet's arable land for livestock production[9] to feed a growing population. We could assemble a genetic library of all the world's species so that any one of them could be brought back from beyond the pale of extinction whenever needed.

However, the real problem isn't just that we aren't investing enough money or effort in technological solutions. It's that we are asking technology to solve

problems that demand human moral intervention—ones that require ethical decisions, behavior change, negotiation, and sacrifice.

By mentally shifting the burden for solving our biggest problems onto technology, we are collectively making fundamental moral and tactical errors; moral, because we are abdicating our own human agency; tactical, because purely technological solutions are inadequate to these tasks.

It's not hard to understand why we are so quick to reach for the techno-fix. We tend to imagine that the twenty-first century will be a time of technological solutions because that was how the last century seemed for most of us. We *did* solve many problems with technology. We solved polio with a vaccine. We solved hunger (temporarily and partially) with the Green Revolution. We "solved" World War II with the help of the atomic bomb. Yes, most of us are aware that technology also *created* enormous problems, yet to solve those problems we tend to assume that we just need more of the same.

> *Machines won't make the key choices for us.*
> *Instead of a century of technological solutions, the next decades will instead be a time for reckoning with questions that even the most advanced computer cannot meaningfully address.*

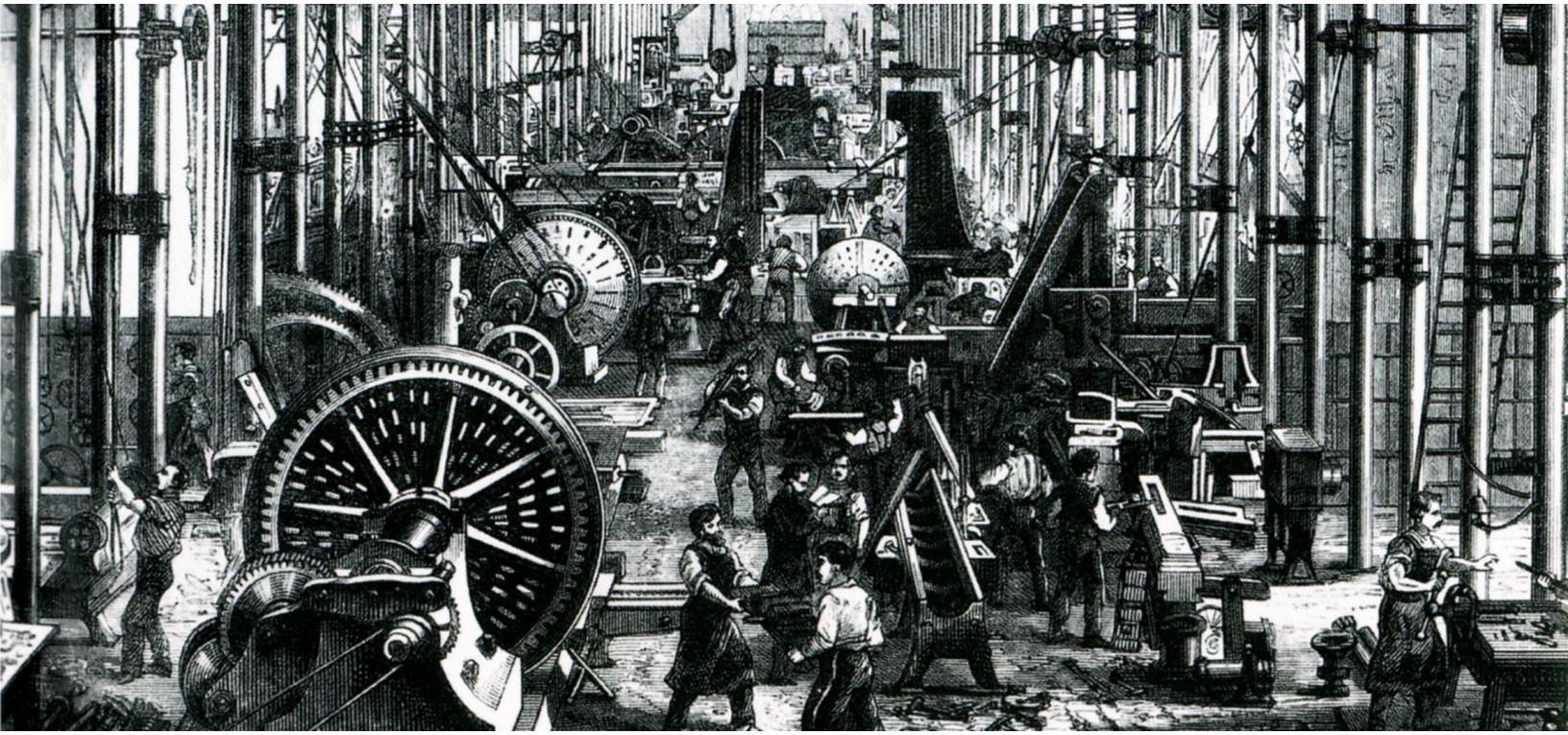
However, climate change, overpopulation, and species extinctions are rife with ethical implications. Averting catastrophic climate change will require us to radically redesign our economy—but how, and to whose advantage? The only humanely acceptable solutions to overpopulation will require a shift in our attitudes toward reproduction and women's rights, and the political will to provide universal access to family planning.[10] And maintaining the world's biodiversity will require preserving habitat[11]—and that means changing land use policies and ownership rights, thus reining in the profit motive. If we do make collective moral choices that lead to the successful resolution of each of these dilemmas, we may

find that the results are mutually supportive. Reducing population would likely make it far easier to address climate change and biodiversity loss.[12] Maintaining biodiversity (particularly in forests and soils) could help stabilize the climate, while protecting the climate would help preserve biodiversity.[13]

Further, once we choose to restrain our numbers and our environmental impact, *technology can assist our efforts*. Machines can help us monitor our progress, and improved technologies can help deliver needed services with less energy usage and environmental damage. Some ways of deploying technology could even help us clean up the atmosphere and restore ecosystems.

But machines won't make the key choices for us. Instead of a century of technological solutions, the next decades will instead be a time for reckoning with questions that even the most advanced computer cannot meaningfully address. We need to rethink what we delegate to machines, and what we take responsibility for directly as moral beings. And the sooner we engage in that conversation, the better our prospects.

Often moral questions are left to the protracted, thoughtful consideration of professional philosophers speaking to one another in formal conferences using an arcane vocabulary. The moral questions that humanity is confronting now are neither abstruse nor academic; they are plain, simple, and urgent. They concern every one of us, and they will surely impact our children and grandchildren. If we put off acknowledging and addressing these questions, we will in effect have made a moral choice—but one whose consequences will be very difficult for any of us to live with.



1. Three make-or-break problems confronting humanity

Humanity has always faced challenges imposed by the limits of our ecosystems: our population has grown in good times, and fallen during famines and plagues. Also, we've always impacted our environments: we have reduced the abundance of other species and even caused or contributed to the extinctions of a fairly short list of animals (numbering in the hundreds) including the dodo, the passenger pigeon, and probably the mastodon and mammoth.[14] We also caused environmental pollution in pre-industrial times when mining tin or lead, or when tanning leather near streams or rivers.[15]

It is the *scale* of today's challenges and impacts that differs from anything we have encountered in all the hundreds of millennia of our existence as a species. There are far more of us now, and each of us has (on average) a far greater impact on the environment.[16] Further, our population continues to grow quickly—and especially in the poorest of countries.[17] Climate change is by far the worst pollution

issue in human history, already impacting the entire planet and threatening the viability of future generations. And other species are going extinct at least a thousand times the "background" or normal rate, with two thirds of assessed plant species currently threatened with extinction, a fifth of all mammals, and a third of amphibians.[18]

How did the scale of human numbers and environmental impacts burgeon so quickly? While we humans have been developing tools and exploring new environments for centuries and millennia, our efforts got turbocharged starting in the nineteenth century. The main driver was cheap, concentrated sources of energy in the forms of coal, oil, and natural gas—fossil fuels. These were a one-time-only gift from nature, and they changed everything.

Energy is necessary to all we do, and with cheap, abundant energy, much became possible that was previously unimaginable. Naturally, we used technology to channel newly available energy toward projects that seemed beneficial—growing more food, extracting more raw materials, manufacturing more products, transporting ourselves and our goods faster and over further distances, defeating diseases with modern medicine, entertaining ourselves, and protecting ourselves with advanced weaponry.[19] In short, fossil fuels increased our power over the world around us, and the power of some of us over others.

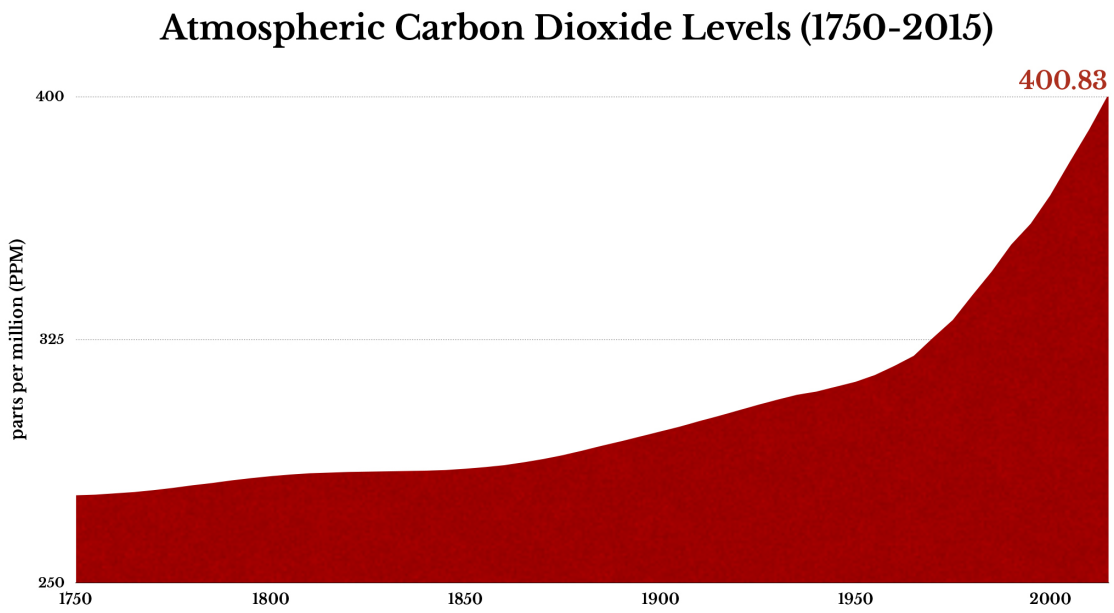
But our increasing reliance on fossil fuels was in two respects a bargain with the devil. First, extracting, transporting, and burning these fuels polluted air and water, and caused a subtle but gradually accelerating change in the chemistry of the world's atmosphere and oceans. Second, fossil fuels are finite, nonrenewable, and depleting resources that we exploit using the low-hanging fruit principle. That means that as we extract and burn them, each new increment entails higher monetary and energy costs, as well as greater environmental risk.[20]

Fossil fuels made us a more successful species, able to increase our numbers and per-capita consumption, and powerful enough to steal more and more ecological space away from other creatures. Of course, this success has had side

effects, including the depletion of topsoil,[21] the fouling of air and water, and the increasing lethality of warfare. But there are three of these side effects that, if left unchecked, will make everything else irrelevant:

Climate change

At the dawn of the industrial age, the carbon dioxide content of the global atmosphere was 280 parts per million. In 2015 it averaged 400.83 ppm, and it continues to rise quickly.[22]



Carbon dioxide levels have increased rapidly since the dawn of the Industrial Revolution, from around 280 parts per million (ppm) in 1750 to over 400 ppm today. Source: Oak Ridge National Lab, CDIAC; National Atmospheric & Oceanic Administration.

Greenhouse gases (of which carbon dioxide is the principal one, along with methane and nitrogen oxides) trap heat in the atmosphere, causing the overall temperature of Earth's surface to rise. It has increased by over one degree Celsius so far; it is projected to rise as much as five degrees more by the end of this century.[23]

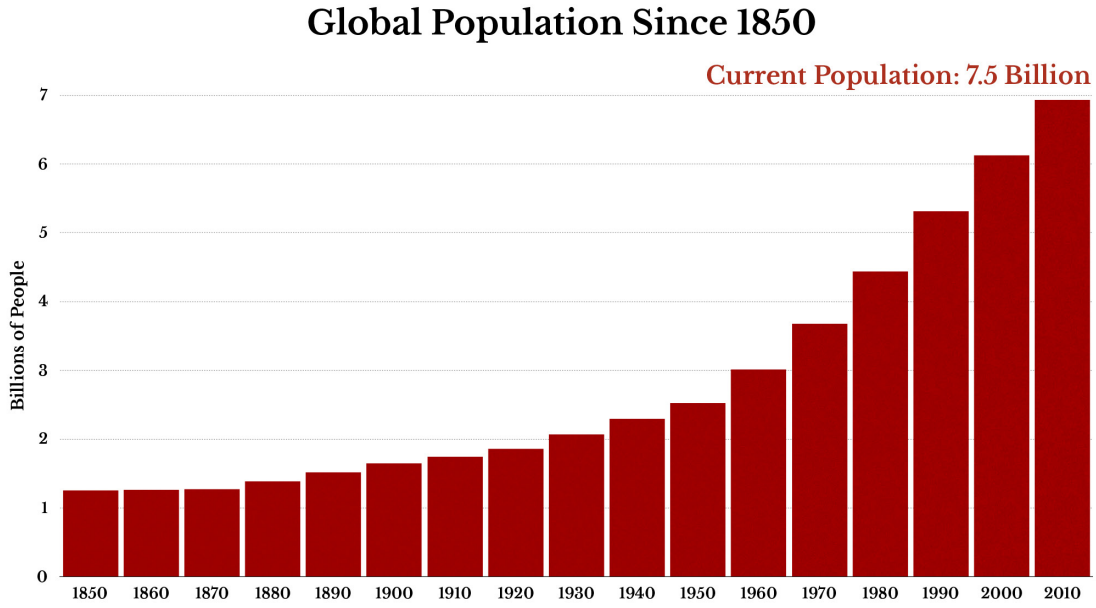
Now, a few degrees may not sound like much. But the planet's climate is a highly complex system. Even slight changes in global temperatures can create a

ripple effect in sea levels, weather patterns, and the viability of species that have evolved to survive in particular conditions.

Moreover, climate change does not imply a geographically consistent, gradual increase in temperatures. Different places are being affected in different ways, and the people hit hardest are often those who are most vulnerable and least responsible. The American southwest will likely be afflicted by longer and more severe droughts.[24] At the same time, a hotter atmosphere holds more water, leading to far more severe storms and floods elsewhere.[25] Melting glaciers are causing sea levels to rise, leading to storm surges that can inundate coastal cities, placing hundreds of millions of people at risk.[26] And global agriculture may be seriously impacted, undermining efforts to produce more food to feed a growing population.[27]

Overpopulation

At the start of the nineteenth century, the global human population stood at about one billion; in the two centuries since, it has grown to 7.5 billion.[28]



Human population levels have grown exponentially over the last two centuries, from less than 1 billion people at the turn of the 19th century to over 7.5 billion people today, and rising. Source: United Nations Population Division.

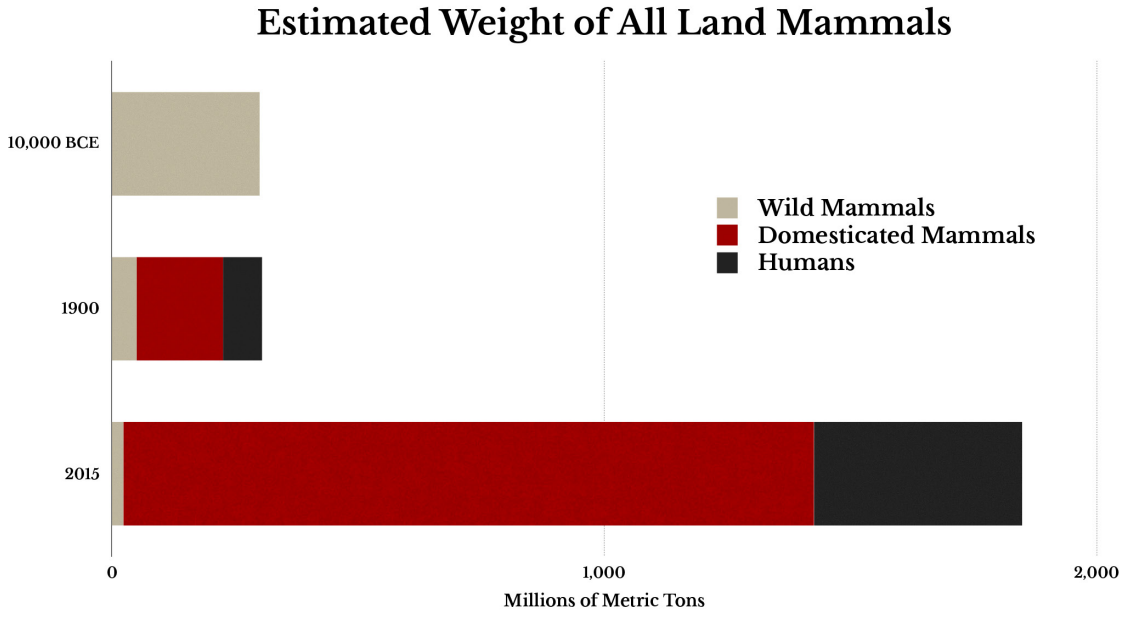
Our current rate of growth is 1.1 percent per year. While that may seem innocuous, *any* constant rate of increase is unsustainable over the long run: at one percent per year of compounded growth, any quantity will double in about 70 years. If our numbers were to continue growing at one percent annually, our population would increase to over 157 *trillion* during the next thousand years. Of course, that's physically impossible on planet Earth. One way or another, human population growth will end at some point; but when, and under what circumstances?

Currently, on a net basis (births minus deaths) we are adding over 85 million new people to the planet each year.[29] That's roughly equivalent to the populations of New York City, Los Angeles, Tokyo, and Mexico City combined, close to the highest annual number in history (even though the percentage rate of population increase has slowed somewhat in recent years, it is a slowly shrinking percentage of an ever-larger number). This amounts to another billion people approximately every 12 years. Each year we must find ways to feed, house, and otherwise care for these additional fellow humans. The United Nations predicts that world population will reach more than 11 billion by 2100[30]—and most of the growth will occur in nations that are already severely challenged to provide for their current populations and to protect their natural environment.[31]

Rapid population growth creates political instability,[32] contributes to deforestation and other environmental problems,[33] and impairs our efforts to tackle climate change.[34] It also complicates efforts to achieve greater economic equality: the larger our human population, the greater the reduction in living standards of those in wealthier nations that would be required in order to achieve global economic equality (since population is growing faster in poor countries than in rich ones). Overpopulation touches on nearly every environmental problem, and many political issues as well. For example, the diminished economic prospects of the American working class have much to do with growing multitudes overseas who can do the same jobs for a fraction of the cost.

Vanishing biodiversity

As people proliferate, they displace other species. It has been estimated that humans—along with our cattle, pigs, dogs, cats, and other domesticates—now make up about 97 percent of all land mammal biomass.[35] The other three percent is made up of all the deer, foxes, bears, elephants, and on and on—all the world's remaining wild land mammals. Meanwhile deforestation and other land-use impacts are also wreaking devastation on the world's plant biodiversity.[36]



Until the dawn of the Agricultural Revolution, the vast majority of land mammals on Earth were wild. While that has shifted over the last 10,000 years with the domestication of animals, it wasn't until the last century that humans and our mammals (the vast majority raised for food) took over the planet. Today, wild species account for only about 3% of the total weight of mammals on the planet. Source: Vaclav Smil, Harvesting the Biosphere (2012). Data prepared by Nathan Hagens and Paul Chefurka.

Biological richness is being lost even at the microscopic level. Our use of agricultural chemicals has led to the disappearance from farm soils of bacteria, fungi, nematodes, and other tiny organisms that provide natural fertility.[37] As these microscopic soil communities are destroyed, carbon is released into the atmosphere.[38] Even in the human gut, microscopic biodiversity is on the decline,

leaving us more prone to immune disorders, multiple sclerosis, obesity, and other diseases.[39]

Some biologists call this widespread, rapid loss of biodiversity the "sixth mass extinction."[40] The geological record tells of five previous events when enormous numbers of species perished; the most severe occurred at the end of the Permian period, 251 million years ago, when 95 percent of all species disappeared.[41] Arguably we are now approaching, or perhaps in the early stages of, another massive die-off of species potentially on the same scale as those five previous cataclysmic events.

What does loss of biodiversity mean for people? At the very least, it means that today's children are set to inherit a world in which many of the animals that filled the lives, dreams, and imaginations of our ancestors, that provided the metaphors at the root of every human language, will be remembered only in picture books. But biodiversity loss also has enormous practical implications for public health and agriculture.

Among other things, natural systems replenish oxygen in the planetary atmosphere, capture and sequester carbon in soils and forests, pollinate food crops, filter freshwater, buffer storm surges, and break down and recycle wastes.[42] As we lose biodiversity, we also lose these ecosystem services—which, if we had to perform them ourselves, would cost us over $125 trillion annually, according to some estimates (it's not possible to actually replace natural ecosystem services in many cases; the total value is a nominal comparison only).[43] One recent study found that a single superfamily of species—bees—provides crop pollination services worth more than $3,250 per hectare per year, many billions of dollars in total.[44]

* * *

Of course, climate change, overpopulation, and biodiversity loss aren't the only challenges humanity is confronting. Other serious environmental problems—including the depletion of topsoil,[45] minerals,[46] and fossil fuels[47]—could have

catastrophic impacts for future generations. While discussion of those issues has been omitted in order to more sharply focus the argument of this essay, a broader treatment of resource depletion and related issues would only serve to underscore again and again the core argument presented here.

Humanity also faces a range of social problems, of which the most insidious is increasing economic inequality, which contributes to political instability, terrorism, and the rise of authoritarian regimes. We will discuss economic inequality separately, for reasons that will become clear, in section 4.

2. Everybody's favorite techno-solutions

Most policy makers—and most ordinary people—believe that technologies and markets will eventually provide solutions to the three big problems outlined above, and that these solutions will require few or no basic changes to our economic system or to the daily lives of most wealthy or middle-class citizens. The transformative technologies that are most often discussed as solutions to climate change, rapid population growth, and species loss are generally presented in the following way:

Alternative energy

Most environmentalists optimistic about technology hope that nuclear power, and/or power from sun and wind, will provide enough energy to replace the enormous amounts we currently derive from depleting, climate-changing fossil fuels.

New nuclear reactor technologies have been proposed and tested, with the promise that they might overcome the problems of cost and risk that plagued the first generations of atomic power plants.[48] The prospects are even brighter for solar and wind technologies. Power from photovoltaic solar panels and wind turbines has been getting cheaper with each passing year—to the point where new commercial projects are now often cost-competitive with natural gas and even coal.[49] Renewable energy is popular with most citizens, including many who are unconcerned about climate change. The efficiency of solar panels and wind turbines is increasing.[50] And research into energy storage technologies (for example, batteries, flywheels, pumped hydro, compressed air and hydrogen) aims to reduce or even eliminate difficulties arising from the inherent intermittency of these energy sources.[51]

Carbon capture and storage (CCS)

It is technically possible to capture carbon dioxide from the burning of coal and other fossil fuels, then concentrate it and store it underground or use it for commercial purposes.[52] This way we could continue to employ fossil fuels for some power generation, if only during the period of transition to alternative energy sources, while avoiding greenhouse gas emissions into the atmosphere. It would also be possible to plant trees or other crops, which would absorb atmospheric carbon as they grew; this biomass could then be combusted under controlled conditions, with the carbon captured and stored underground in old, depleted oil or gas wells. This latter pathway is known as Bio Energy with Carbon Capture and Storage, or BECCS.[53] Every component of CCS technology has been tested, and pilot projects are in operation.

An altogether different method of carbon capture that's gaining increased attention is "carbon farming"—using soil-building agricultural techniques to capture atmospheric carbon and sequester it, particularly in degraded and depleted soils.[54] The amount of carbon that potentially could be stored this way is a matter of ongoing research; optimistic estimates suggest that an additional 1 billion

to 3 billion tons of carbon could be sequestered annually, equivalent to 11 to 34 percent of current emissions from fossil fuels combustion.[55]

Electric self-driving cars and Transportation-as-a-Service (TaaS)

Solar and wind power generators produce electricity, but only 18 percent of our current final energy is consumed as electricity; much of the rest is used in the form of liquid fuels derived from oil.[56] Most of those liquid fuels are consumed in the transportation sector—in automobiles, trucks, ships, and airplanes.[57] Thus, fully replacing fossil fuels with renewable energy sources in order to minimize climate change will require alternative fuels, alternative transport technologies, or both.

Electric cars, which could potentially be powered by sun or wind, are getting cheaper and better as battery technologies improve.[58] Electric motors are more efficient than internal combustion engines; they're also simpler and more reliable.[59] Electric trucks are also being developed.[60]

Self-driving cars enhance the possibility to shift from a general pattern of private automobile ownership toward transportation-as-a-service (TaaS), in which a self-driving electric car could be summoned at a moment's notice with a smartphone. TaaS has been described as "a high-tech car rental service where you use a vehicle only when you need it, thanks to the technological marvels of global

positioning satellites, automated driving, and electric power."[61] Far fewer vehicles would be needed, as they would be in nearly constant use rather than sitting in parking lots and garages for most of the day.[62] That translates to a substantial reduction in the materials and energy required in vehicle manufacturing. Insurance costs would also be dramatically reduced. Altogether, the average American would spend much less per year on routine transportation, thus putting billions of dollars in consumers' pockets. A recent study suggested that electric, self-driving cars could provide up to 95 percent of passenger miles travelled by 2030.[63]

Solar radiation geo-engineering

Technologies have been proposed to manipulate the large-scale environmental processes that affect the Earth's climate, so as to counteract global warming. The hope is that these technologies would buy us time for harder solutions, like transitioning away from fossil fuels.

Surface-based geo-engineering might employ something as simple as pale-colored roofing materials.[64] More ambitious proposals include fertilizing the oceans with powdered iron—which theoretically could sequester carbon, enhance the natural marine sulfur cycle, and might also enhance dimethyl sulfide production and, consequently, cloud reflectivity.[65] Growing high-albedo crops might reflect more sunlight and heat back into space,[66] as could filling parts of the oceans with white foams or pale-colored floating litter. We could stimulate more arctic sea ice formation by pumping deep cooler water to the surface.[67]

Troposphere-based geo-engineering might include spraying fine seawater to whiten clouds and thus increase cloud reflectivity.[68] Upper atmosphere-based geo-engineering could include releasing stratospheric sulfate aerosols, or other reflective substances.[69] And geo-engineering from space could be accomplished with satellite-based mirrors or orbiting dust clouds.[70]

Agricultural biotechnology

Population growth and the negative agricultural impacts of climate change will require us to grow more food under conditions that are likely to be drier and/or less stable. A new biotechnology known as CRISPR-Cas9 enables the cell's genome to be cut at any desired location, allowing existing genes to be removed and/or new ones added more precisely and easily than with previous gene splicing technologies.[71] This opens the possibility of developing crops that are more productive and that can thrive in more extreme conditions.[72] CRISPR has been tested in crops including wheat, rice, soybeans, potatoes, sorghum, oranges, and tomatoes.[73] Goals include everything from boosting crop resistance to pests, to reducing the toll of livestock disease. Scientists claim to have created a strain of wheat resistant to powdery mildew,[74] and drought-resistant corn and wheat strains are being developed, with market prospects potentially in five to ten years.[75]

Genetic reconstitution of extinct species

Using the same CRISPR-Cas9 gene-editing technology, it may now be possible to bring some animals and plants back from extinction.[76] Indeed, ecologists at the University of California, Santa Barbara have already published guidelines for choosing which species to revive if we want to do the most good for our planet's ecosystems.[77] By establishing a genetic library of existing species, we could give future generations the opportunity to bring any organism back from beyond the brink. Doing so could help restore ecosystems that once depended on these species. For example, mammoths trampling across the ancient Arctic helped maintain grasslands by knocking down trees and spreading grass seeds in their dung. When the mammoths disappeared, grasslands gave way to today's mossy tundra and taiga, which are melting and releasing greenhouse gases into the atmosphere. By reviving the mammoth, we could help slow climate change by turning the tundra back into stable grasslands.[78]

* * *

This is hardly an exhaustive list of new and developing technologies; others include artificial intelligence (AI), 3D printing, space weapons, nanotechnology, robotics, immersive virtual reality, quantum computing, nano-medicines, and electromagnetic weapons (the list could go on). Some of these other new technologies may end up having large impacts on daily life, the economy, and society at large, but they are less likely to provide comprehensive solutions for the three big problems we're focusing on here. If our three big problems of climate change, overpopulation, and biodiversity loss are truly "make-or-break," so are the proposed technological solutions outlined above.

In focus: Geo-engineering

Technologies to remediate climate change have been discussed for almost as long as climate change has been a topic among scientists,[79] but only recently has the debate about these technologies shifted from theory to strident advocacy.[80] Nearly everyone agrees that climate geo-engineering entails significant risks and faces numerous obstacles; yet, due to the steady worsening of the climate crisis, potential methods are being discussed with ever-greater seriousness. Geo-engineering methods fall into two broad categories: direct interventions in the Earth's climate through the management of solar radiation, and new techniques capable of slowing or reversing the buildup of greenhouse gases in the atmosphere.[81]

One of the more widely discussed examples of radiation management consists of injecting aerosol-forming substances, such as sulfuric acid, into the upper atmosphere to increase the planet's albedo and generate a cooling effect. Aside from the intended cooling, this would produce various geochemical side effects, including ozone depletion and changes to hydrological cycles.[82] Consequences would likely include droughts and flooding in Asia and Africa,[83] affecting communities already severely stressed by climate change. Further, this would be only a partial fix as it would not solve ocean acidification[84] and would need to be maintained indefinitely to be effective. The general scientific consensus is that much more research is needed before implementation can be considered. However, several small-scale trials are currently underway.[85]

The most prominent method for extracting greenhouse gases from the atmosphere is BECCS, or Bio-Energy with Carbon Capture and Storage. This entails growing large quantities of biomass, burning it to generate electricity, then capturing the resulting carbon dioxide and transporting it for storage in geological reservoirs. The process would theoretically be carbon negative and would also supply useful energy; hence it is a favorite of policy makers.[86] However, enormous amounts of land would be required: an area larger than India would be needed to offset less than a third of our current global emissions.[87] Therefore BECCS, together with growing demands for both food and biofuels, would create severe competition for agricultural land. Vast new networks of power stations, pipelines, pumping facilities, and injection sites would be needed, comparable in size to existing fossil fuel infrastructure. It is unclear if we could build this infrastructure in time to avoid critical climate thresholds.

Other proposals, such as ocean iron seeding and direct capture of carbon dioxide from the air, would be far more limited in impact and are likely to be non-starters.[88]

In a short period of time, these technologies have gone from being fringe ideas to forming the basis of most global plans for avoiding dangerous levels of warming. For example, most of the Integrated Assessment Models and mitigation plans issued by the Intergovernmental Panel on Climate Change include the widespread deployment of BECCS.[89] But these technologies are highly speculative as none have been commercially demonstrated, and there are important questions about achievable scale, unintended consequences, effectiveness, and costs. Therefore, the reliance on these technologies by policy makers in models and hypothetical plans represents an excuse for inaction and a serious moral hazard. Politicians are using these models and plans to avoid unpopular policies to rein in emissions in the near term and we, in the developed world, are implicitly using them to justify unsustainable, high-consumption lifestyles.

3. Our problems are growing faster than the solutions

If technology were going to solve our biggest problems, surely we'd be seeing the evidence by now. Yet atmospheric greenhouse gas concentrations are still increasing, not declining, and climate impacts are worsening. Likewise, we're seeing a plateauing (instead of a significant decline) in the global population growth rate; meanwhile, rapid population growth is widely regarded as contributing to political instability in a growing number of poor nations. And the rate at which plant and animal species are disappearing is increasing rather than diminishing.

Why aren't our technological solutions working? Do we just need to give them more time? Or do we lack the political will to fully implement them? To the extent the latter is the reason, it merely reaffirms the central point of this essay, since political will can be considered the societal mobilization of moral choice. But

techno-fixes may be failing us at a more basic level: there's evidence to suggest that we've reached the point where the technological solutions that have been proposed just aren't capable of maintaining the way we're currently living, even if we somehow mobilize the political will to massively deploy them.

Let's look again at the technologies we highlighted in the previous section.

Alternative energy

The broad consensus among energy policy wonks is that nuclear power does not hold much promise within the crucial next two decades.[90] Nuclear plants are slow and costly to build, and there are widespread concerns about radiation risk in the wake of the Fukushima reactor meltdowns. As a result, the global nuclear power industry is generally shrinking (though new plants are being built in China, India, and a few other countries).[91]

Other alternative energy sources (including hydro, geothermal, wave, and tidal power) are incapable of being scaled up to provide as much energy as society will need—though they could play complementary roles.

That leaves solar and wind as the best current candidates as major new energy sources. My colleague David Fridley and I recently published a book-length

analysis[92] of the opportunities and roadblocks in the transition to a mostly solar-wind energy economy. We found plenty of challenges, especially in adapting the sectors of society (mining, transportation, agriculture, and manufacturing) that currently use substantial amounts of energy in the forms of liquid and gaseous fuels. We also found that, while innovation is occurring in the field of energy storage, the need for storage will increase dramatically as the share of total energy that comes from sun and wind approaches 100 percent. Further, energy storage entails inherent inefficiencies.[93] Altogether, the rate of transition to renewable energy would have to accelerate to roughly ten times the current rate to achieve a fully renewable energy system in time to avert a climate crisis.[94]

The shift toward renewables will incur energy costs for the construction of new infrastructure, and in the early stages there will be no way to get all of that energy from solar and wind, so in order to avoid a pulse of emissions, we will have to shut down non-essential uses of fossil fuels throughout the economy during the transition.[95] Also, it's still unclear whether or at what scale a renewable energy system could be fully self-sustaining (i.e., powering all of its own inputs, such as mining and materials transformation) for decades and centuries to come.

The only way to minimize these problems is to dramatically reduce overall energy usage throughout society—a project that will require not just innovation, but also commitment and sacrifice.

Carbon capture and storage (CCS)

Official climate models in which the global surface temperature remains below 2 degrees C assume high levels of carbon capture and storage.[96] The scientists who construct these models have concluded that there is no other realistic way to reduce carbon emissions sufficiently, and fast enough, while maintaining economic growth. In effect, the only reason policy makers are seriously discussing extreme technologies like CCS and geo-engineering (whose drawbacks are discussed below) is that the project of shifting to alternative energy sources while maintaining economic growth is so daunting.

As discussed above, two main pathways for CCS are being explored: one starts with the capture of carbon emissions from coal-burning power plants; the other envisions growing enormous amounts of biomass, burning it, then capturing the carbon and burying it (BECCS).

> *The only reason policy makers are seriously discussing extreme technologies like CCS and geo-engineering... is that the project of shifting to alternative energy sources while maintaining economic growth is so daunting.*

While the technology to capture carbon emissions from coal-fired power plants has been tried and tested, today almost none of America's coal-fueled electricity-generating plants are equipped with CCS. The economics just don't work. Adding CCS to coal power plants is extremely expensive in terms not only of initial investment, but ongoing operations as well.[97] That gives the power industry little incentive to implement it in the absence of a substantial carbon tax.

Why would implementing CCS be so expensive? To start, capturing and storing the carbon from coal combustion is estimated to consume 12 percent to 35 percent of the power produced, depending on the approach taken.[98] That translates to not only higher prices for coal-generated electricity but also the need for more power plants to serve the same customer base. New technologies designed to make carbon capture more efficient aren't commercial at this point, and their full costs are unknown.

Further, capturing and burying just 38 percent of the carbon released from current U.S. coal combustion would entail pipelines, compressors and pumps on a scale equivalent to the size of the nation's oil industry.[99] And while bolting CCS technology onto existing power plants is possible, it is costly and inefficient.[100] A new generation of power plants would do the job much better—but that means

replacing 511 coal-fired current-generation plants, representing over 300 gigawatts of capacity.[101]

BECCS entails the same cost for pipelines, compressors, and pumps, but also requires vast tracts of farmland. In order to capture and bury enough carbon to make enough of a difference, immense volumes of biomass would be needed: by one calculation,[102] an area the size of India would have to be planted in fast-growing crops destined to be combusted in order to offset less than a third of our current carbon dioxide emissions. Setting aside so much arable land for CCS seems highly unrealistic given that more land will also be needed to grow crops to feed a larger human population.[103]

The prospects for carbon farming—using soil-building agricultural techniques to capture atmospheric carbon and sequester it[104]—are more favorable. Building topsoil would have many positive knock-on effects—yielding safer and more nutritious food, protecting biodiversity, and pumping less pollution into the environment. However, recent research has tended to support lower estimates for the potential of soils to take up carbon.[105] Further, carbon farming is not a singular new machine we can turn loose to solve our greenhouse gas problems; it is a set of techniques that will require significant changes to industrial agriculture—in effect, a re-thinking of the entire industry. While it's a shift that would carry side benefits,

it is not likely to take off without initiative, investment, effort, and sacrifice, supported by political will manifesting through regulations and subsidies.

Electric self-driving cars and Transportation-as-a-Service (TaaS)

While a report cited earlier claims that we are on the cusp of a rapid, inexorable trend toward the adoption of autonomous electric cars, it's worth noting that currently the rate of transition to electric cars is very slow. In 2016, over 88 million new light vehicles were built; 99.1 percent of them had internal combustion engines.[106] And while there's been progress in developing self-driving computer technology, questions about computer functionality (does your laptop work flawlessly under all conditions?), emergency situations, and legal liability still abound.[107] Further, while TaaS as a concept has shown growing popularity with Uber, Lyft, and similar businesses, its overall effect on car ownership is still relatively minor.[108]

It's undeniable that a rapid shift away from private ownership of gas-guzzling cars would reduce world oil consumption and greenhouse gas emissions. What's not clear is whether that shift can be driven rapidly enough by market forces alone so as to make a significant difference with regard to climate change.[109] It's also unclear what the unintended consequences might be. Some transportation analysts suggest that the widespread adoption of electric, self-driving cars and TaaS could result in more vehicle miles traveled per year per person, more urban sprawl, less public transit, less walking, less bicycling, and more clogging of side streets.[110] There may also be new risks associated with security and hacking.[111] It seems likely that, for this shift to solve more problems than it creates, a hefty dose of political will and well-guided personal choice will be needed. Our track record with unanticipated consequences from the adoption of the internal combustion engine doesn't inspire great confidence.

Solar radiation geo-engineering

Managing solar radiation with space mirrors or white roofing material wouldn't remove greenhouse gases from the atmosphere and therefore wouldn't reduce

other effects from these gases, principally ocean acidification.[112] Also, if it involved seeding the atmosphere or oceans with sulfur or other chemicals, geo-engineering on a large scale might have serious unintended consequences, such as significant changes to the hydrological cycle or ozone depletion.[113] Such effects might be cumulative or chaotic in nature, and hard to predict with existing models. Meanwhile, unless geo-engineering efforts were kept continually operating, regardless of the harmful side effects, climate change impacts being held at bay would immediately reassert themselves.

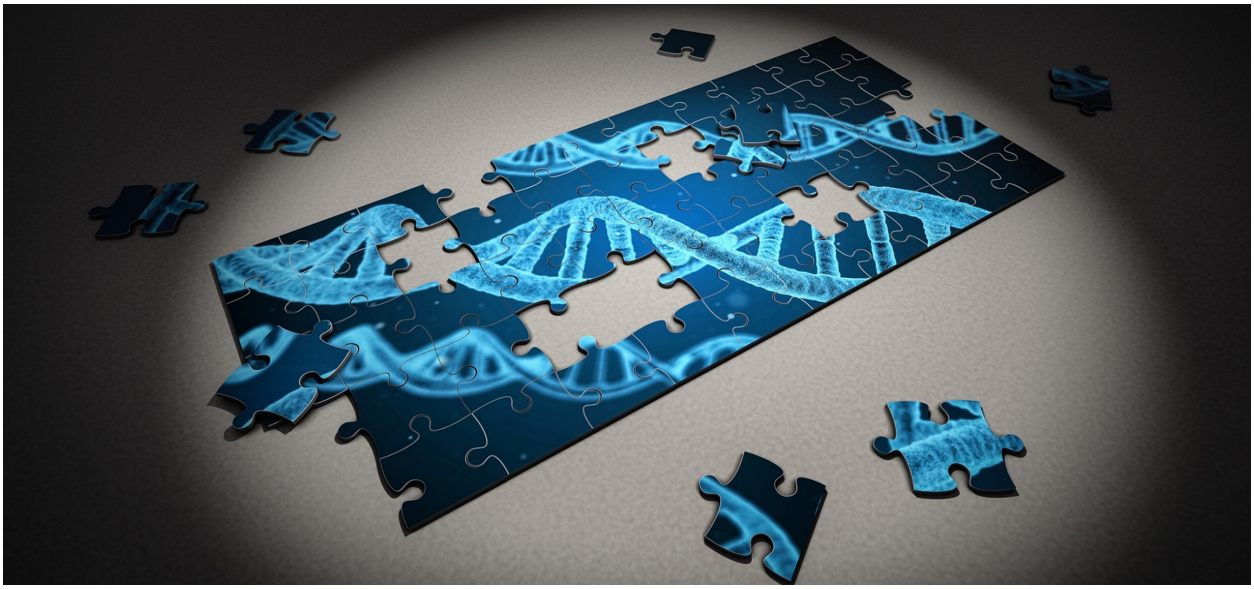
Among the most serious concerns raised by geo-engineering are questions about who would implement and control the technologies, and to whose advantage.[114] It is easy to envision scenarios in which wealthy nations that are in position to pay for geo-engineering efforts would design and control them to their particular advantage, and perhaps to the disadvantage to economic or political rival nations.

Agricultural biotechnology

So far, gene-splicing technologies have mostly been used to make crops immune to proprietary herbicides, with a resulting increase in herbicide usage and little change in crop productivity.[115] The first commercial applications of newer technologies are being targeted toward similar ends. Even if we can grow somewhat more food this way, is it worth spraying our fields with even more glyphosate, which the World Health Organization has found to be a "probable" carcinogen [116] that's also associated with collapsing populations of monarch butterflies?[117]

Big claims are being made for new gene-splicing technologies such as CRISPR, which could open the door to different kinds of potential food production improvements. But who would benefit from whatever "improvements" are actually achieved? Farmers? Consumers? Or giant agribusinesses? And who will decide how to allocate the risks, costs, and benefits?

There will certainly be risks and costs, as there are with all technological interventions. Unexpected effects can occur when new genes are added or existing ones are silenced.[118] Even with increased editing precision, the desired outcome may still prove elusive, since traits such as drought tolerance are associated with many genes and are also tied to complex interactions between the organism and its environment. Some of the agricultural applications of CRISPR being researched include ones that would alter the biology of insects and weeds, which could spread their edited genes rapidly through wild populations, possibly reshaping entire plant or animal communities in just a few years.[119] The prospects for side effects, such as upsetting food webs and facilitating invasions by other species, are as obvious as they are serious.



A review in *Nature* of CRISPR technology's applications in livestock breeding[120] noted that, while some potential uses may benefit poor farmers, this is "a rarity for editing research." The common goal in livestock gene editing is to generate higher-profit cattle, pigs, chickens, and sheep—which place small-scale, sustainable farmers at a greater economic disadvantage.

Genetic reconstitution of extinct species

It may be exciting to contemplate *Jurassic Park*-like projects reviving long-gone animals like the mammoth or the passenger pigeon. But bringing back a few individual plants or animals will be a meaningless exercise if these species have no habitat. Zoo specimens do not perform ecological functions.

Many scientists involved in extinct species revival efforts understand the need for habitat, and aim to revive species that could help restore ecosystems.[121] Still, it's important that we keep our priorities straight: *without* habitat, the revivified species themselves are only ornaments. Habitat protection is the real key to reversing biodiversity loss; species revival is just a potentially interesting afterthought.

Throughout the world, successful programs for biodiversity protection have centered on limiting deforestation, restricting fishing, and paying poor landowners to protect wilderness areas. Biologist Edward O. Wilson has recently proposed setting aside fully *half* the Earth's land and seas for biodiversity recovery; he estimates that doing so would reduce the human-induced extinction rate by 80 percent.[122] For a decade, a movement called "Nature Needs Half" has proposed virtually the same thing.[123] A recent article in *BioScience* argues that the audacious vision of Nature Needs Half is both necessary and feasible.[124]

It's a bold proposal that faces enormous political and economic obstacles. It is unimaginable absent widespread commitment not just of financial capital, but of moral strength as well.

There's a common thread here. The most promising solutions with the fewest likely negative side effects (such as carbon farming and ceding half the planet to wild nature) require the most from us in terms of changes in behavior and in systems—agricultural, transport, energy, and economic systems. That is, in effect, they imply moral intervention. On the other hand, the most "magical" of the techno-fixes (such as genetic engineering of crops or solar radiation geo-engineering), i.e., ones that require minimal behavior change or system change,

tend to carry the biggest risks. Perhaps the best candidate in the lot for a technological trend that can be driven mostly by market forces and still make a significant dent in one of our three make-or-break problems is the shift toward electric, self-driving vehicles and TaaS (a recent headline notes that "10 percent of Americans trading in a car plan to use Uber and Lyft instead of buying a new one"[125]). But even in the best case imaginable, in which this suite of technologies dramatically lowers our oil consumption without any serious unintended consequences, it would by itself hardly be a complete solution to our triple dilemma. The implication, again, is that while technology can sometimes help us solve our problems, we can really turn the tide only by leading with moral choice and behavior change.

* * *

Beyond the specific caveats attached to each of the technologies discussed above, we are confronting three more general challenges that should make us skeptical about the prospect for a century of technological solutions:

Insufficient investment capacity

Today, most nations can't even afford to maintain much of the infrastructure they already have in place, much less do they have the means to deploy most of the above solutions at the scale needed in order to deal with our three big problems of climate change, overpopulation, and biodiversity loss. While it may theoretically be possible for governments to fund massive new programs (such as CCS, nuclear power, or geo-engineering) through deficit spending, this would be problematic given enormous existing levels of government debt throughout the world.[126] Many shifts in energy usage technology that will be needed to support the transition to all-renewable energy will require households to invest in new machines (electric cars, electric heat pumps to replace furnaces, electric induction cooking stoves to replace gas stoves, solar hot water systems), but most households are likewise drowning in debt.[127]

Diminishing returns

The rapid, unprecedented technological transformation that roiled the twentieth century depended upon conditions that cannot be expected to continue. These included the rising availability of cheap energy, plentiful raw materials, fast-growing economies, and the capacity to generate enormous amounts of investment capital. So far, it appears that this century will present a very different set of conditions, including constrained amounts of available energy, depleting raw materials, stagnant economies, and mountains of debt.[128]

Many economists have pointed out that the global economy is generally slowing, and they even have a name for the phenomenon: "secular stagnation."[129] A few economists have explicitly tied this slowing of growth to the well-known phenomenon of diminishing returns.[130] From a macroeconomic standpoint, diminishing returns appear as each new increment of economic growth produces higher levels of environmental and social costs (i.e., externalities), which can begin to exceed benefits delivered; this is a situation economist Herman Daly calls "*uneconomic* growth."[131]

Unintended consequences

Finally, there is the problem of side effects, which seems to plague all technological solutions.[132] Many, if not all, technologies discussed above will have their own negative consequences that, in a few cases, may be as serious as the problems they're intended to solve. Even solar and wind power, whose climate impacts are far lower than those of the fossil fuels they may replace, imply environmental risks and costs, including resource depletion and pollution associated with raw materials extraction and the manufacturing, transport, and installation of panels and turbines.

In focus: Feeding nine billion people

A growing global population and changing dietary preferences[133] are driving the urgent need to produce more food. Under present trends, at least a 50 percent increase in the food supply will be needed to meet the needs of a global population of more than 9 billion by 2050.[134] However, current international plans and policies for achieving this goal are seriously flawed: they rely on hazy expectations of technological solutions that may not work, and ignore likely unintended consequences. Further, these plans have yet to deal with existing food supply issues: 800 million are still undernourished, contributing to the deaths of 3.1 million children each year,[135] while the environmental impacts of agriculture are substantial and worsening.

The United Nations Food and Agriculture Organization (FAO) proposes to feed 9 billion by essentially following the path of the Green Revolution of the 1960s and 1970s.[136] But by the FAO's own assessment, this kind of high-input, resource-intensive farming will not deliver sustainable food production without a major institutional transformation in farming methods.[137]

Moreover, crop yields and the overall productivity of the food system are not keeping pace with the rates required to feed our projected population.[138] The World Resources Institute finds that FAO projections for productivity growth are largely unrealistic, as new technologies are incapable of matching the yield growth seen during the Green Revolution. Today, most of the world already fully exploits nitrogen fertilizers, irrigation (where enough water is available), and scientifically bred seeds.[139] Emerging biotechnologies, including controversial genetic modification techniques, are often portrayed as the silver bullet for future food systems despite well-documented risks and downsides, such as the dislocation and impoverishment of small-scale farmers, harmful ecological interactions, and herbicide proliferation.[140] Also, there is little indication that these technologies have meaningfully increased crop yields in recent years.[141]

The only other significant path to increasing food output—expanding the global area under cultivation—faces severe constraints from limited resources and steeply rising ecological impacts, including the irreversible loss of biodiversity.[142] The environmental pressures of the global food system are already immense: 5.2 million hectares of forest are lost each year; 85 percent of fish stocks are over-exploited; and agricultural carbon dioxide emissions have risen more than 40 percent since 1990.[143] Expansion of existing farming practices will lead to greater competition for natural resources, higher greenhouse gas emissions, and more land degradation.[144] Meanwhile the *effects* of climate change are expected to exacerbate land competition and environmental impacts in most world regions.[145]

The status-quo policy bureaucracy is creating the opposite of food security. There are obvious places to intervene in order to change direction: we can de-commodify food, assisting those in need and providing essential community resilience. Food waste can be drastically reduced (between 30 percent and 50 percent of all food produced globally is wasted).[146] And diets can be shifted away from resource-intensive animal products. But we have to go further still: we need holistic, precautionary assessments prior to the introduction of new agricultural technologies, and we need to resist industrial intensification by reclaiming and localizing food systems. These vital steps represent a transformative change in the way we relate to food, the environment, and each other.

4. The inequality problem

In the Introduction, I promised to return to the problem of economic inequality. This was not included in the three-item list of humanity's basic challenges in section 1 because it is not a problem for which a specific technological solution has been proposed. Clearly, reducing economic inequality demands some degree of moral action, political will, negotiation, and sacrifice of advantage. To avoid direct moral engagement with the issue, policy makers often simply assume it will eventually disappear due to three technology-led trends—economic growth, demographic transition, and decoupling—to which I will return in a moment.

It is important to note that inequality, like the other problems we've been discussing, is worsening: while absolute poverty has been reduced worldwide in recent decades, wealth is concentrated in fewer hands today than ever before.[147] Further, as social problems tied to economic inequality proliferate and deepen, they tend to absorb our attention to the point that we lose sight of the ecological

conditions that contribute to them—such as climate change and overpopulation.[148] In other words, it is a very serious problem—as serious in its own way as the three-make-or-break global dilemmas mentioned in section one. And adding it to the mixture complicates our situation still further.

Worldwide, policy makers seemingly must do four things at once in order to keep social and ecological chaos at bay: (1) reduce economic inequality, (2) accommodate a growing global population, and (3) reduce human impacts on the environment (notably climate change and biodiversity loss), all while (4) growing their economies. Yet from a practical standpoint, the second aim is at odds with the first and the third: a growing population tends to increase (not reduce) environmental impacts, and it also makes programs designed to reduce economic inequality more difficult to fund, because a constantly increasing number of people must be served by those programs. Meanwhile, a larger economy is overwhelmingly likely to have a larger throughput of energy and materials, putting (4) at odds with (3).

The contradictions are stark and unavoidable. But there is remarkably little discussion about them among either policy makers or the general public. That's partly because of policy makers' habit of assuming that the technology-related trends mentioned above somehow can eventually make inequality, and the contradictions just mentioned, disappear. Let's examine each of the three trends to see whether they are indeed capable of reversing the current drift toward greater economic inequality.

Economic growth

Economic growth is widely regarded as a tonic for every social ill. Since the administration of John F. Kennedy, economists have delighted in equating economic growth to "a rising tide that lifts all boats." That's an encouraging metaphor, but the trouble is that the tide tends to lift the yachts while swamping the canoes. And how helpful is a rising tide if it threatens to undermine the life-supporting capacity of planetary systems? Despite all the evidence that the global

economy already consumes too much, economic growth, measured in terms of GDP, remains the centerpiece of policy, at every governmental level and in every nation.[149] Yet, as already pointed out, worldwide economic growth is generally slowing, not accelerating. Even if policy makers want more of it in order to make social problems associated with inequality go away, beyond a certain point they cannot summon growth at will.

Henry Wallich (1914–1988), an American economist and central banker once said, "Growth is a substitute for equality of income. So long as there is growth there is hope, and that makes large income differentials tolerable."[150] If Wallich's quote is true, then so is the reverse. Greater equality of income is a substitute for growth, and it's an indispensable one, given the economy's expansion beyond biophysical limits.

Demographic transition

Demographic transition is a shift, observed over the past century in many countries, from high birth and death rates to lower birth and death rates (and slower net population growth) as those countries became more industrialized and urbanized[151]—i.e., as they adopted more sophisticated technology. With industrialization and economic growth, the problem of rapid population growth appears to solve itself.

Although addressing the inequality problem could help solve our population dilemma, it also could unintentionally increase overall consumption levels. When currently poor people become wealthier, they tend to spend most of their income gains on consumption, whereas wealthy people tend to withhold more of their income for savings and investments.[152] Since both demographic transition and economic growth imply rising GDP levels (and hence rising overall levels of consumption of materials and energy), appealing to these trends makes it more difficult to reduce environmental impacts like climate change and species extinctions.

Decoupling

The only solution to the conundrum is to *decouple* GDP growth from energy usage and resource consumption—to do more with less. Decoupling comes in two strengths: mild-strength (or *relative*) decoupling, which implies using less energy and stuff for each unit of economic growth; and high-strength (or *absolute*) decoupling, which implies reducing the total use of resources even as the economy continues to grow.[153] Almost all economists and policy makers believe that relative and absolute decoupling will be inevitable features of further technological innovation. Thus, decoupling is the main key to banishing the contradiction inherent in trying to resolve inequality, population growth, and rising environmental impacts.[154]

Unfortunately, it turns out that decoupling has been oversold. A recent paper in *Proceedings of the National Academy of Sciences*[155] showed that even the relative decoupling that most economists believe industrial nations have already achieved is actually the result of false accounting. Other researchers have come to essentially the same conclusion.[156]

Without decoupling, the contradiction between reducing inequality on one hand, and resolving our environmental problems on the other, remains firmly in

place. Worse still, it turns out that "demographic transition" is really just a theoretical construct that doesn't fit the data evenly and doesn't necessarily have much predictive value.[157]

As I pointed out in the Introduction and will reiterate, technology can help at the margins. Just one example: There are still millions of people throughout the world for whom lighting is a luxury, and for whom the only alternatives are kerosene, candles, or fire, all of which come at a cost in terms of both money and air quality. The solution could be a solar light—a small solar panel integrated with a battery and an LED bulb, supplying several years' worth of light at zero operating cost. An international charity, SolarAid, has teamed up with Chinese solar company Yingli, and UK design firm Inventid to produce and distribute thousands of solar lights in nations like Malawi, Uganda, and Zambia.[158] These cheap light sources improve lives while also reducing climate impacts.

There are more happy, clean-technology and appropriate-technology stories like this to be told.[159] But adding them all up doesn't come close to solving our equity, climate, population, and biodiversity problems. Doing so will still require hard choices and intense work.

Inequality is not a mere technical glitch. Reducing it within nations generally requires redistribution via progressive taxation and social welfare programs. Reducing wealth inequality *between* nations will entail powerful countries giving up trade and military advantages.[160] Redistribution can only be achieved with negotiation and willing sacrifice. It is a moral imperative, and pursuing it requires moral action—which, in our current circumstances, must somehow at the same time reduce rather than exacerbate critical environmental dilemmas.

In focus: Labor-saving technologies

When doing chores around the house, most of us would choose a leaf-blower over a rake, a power drill over a screwdriver, or a dishwasher over a scrubbing brush (if we're wealthy enough to have the mechanized option). This is understandable—these devices allow us to do the job more quickly and easily. And taken together, they arguably provide a higher material standard of living. While these choices may seem mundane, the gradual automation and mechanization of the household has profoundly shaped our lives in ways we often don't notice—and not always for the better.

We naturally assume that household machines and appliances save us time. They do, in a way, but several studies have shown that rather than doing the job with time to spare, domestic technology tends to increase our expectations of what is normal.[161] More elaborate meals, cleaner laundry, and bigger gardens are now required in order to keep up appearances. And the expectation of owning a full assortment of gadgets, all periodically updated, likewise keeps us on a competitive status treadmill. We often end up doing what is not really needed, while spending more money and consuming more resources.

Meanwhile the reduction in physical activity that these household technologies enable—aided by their counterparts in the workplace—is impacting our health. On average, we each burn several hundred fewer calories per day, and this helps partly explain the increase in obesity in the U.S. and other wealthy countries.[162] Furthermore, as mass-manufactured products have become cheaper, more intricate, and more difficult to repair, the self-reliance and do-it-yourself attitude of previous generations have been replaced by a throwaway culture. There is even reason to believe that domestic technology and the way we use it have contributed to the decline of community and embedded gender inequality in the home.[163] Clearly, the convenience that these devices afford comes at a steep cost.

In the wider economy, the tendency of technological advances to suppress wages and raise unemployment has been known for a long time.[164] New technology diminishes the role of labor in production, which eliminates jobs and creates a more skewed distribution of income. This process is accelerating, with looming consequences—as Elon Musk, Bill Gates, and Stephen Hawking have all recently observed.[165] Until recently, this trend was mitigated by cheaper products and by the creation of new jobs in nascent industries.[166] However, with automation now increasingly being driven by artificial intelligence and robotics, the number of jobs being created is likely to be outpaced by the number destroyed.[167] We may need to rethink deeply held assumptions about livelihoods, and the ultimate goals of our economic system.

In our own lives, we can deliberately choose how much to rely on technology. We can live more simply, and enjoy stronger community bonds, better health, more equality, and greater self-reliance as a result. As communities, we can support tool libraries, co-ops, not-for-profit organizations, community supported agriculture and the gift economy—taking back some control of employment and production as a result. We can invest in re-training for workers affected by automation, and should seriously consider approaches such as work sharing or even a universal basic income.

5. Why we rely on technology so much, in imagination as in daily life

The central assertion of this manifesto is that humanity can't solve its biggest collective problems with technology alone. Some readers might see this as a straw-man argument: after all, no one is claiming that technology is an autonomous god-like entity that can overcome these challenges all by itself; everyone agrees that people design, make, and use machines, and are ultimately responsible for the consequences. But, in effect, all of us—ordinary citizens as well as policy makers—are increasingly adopting a quasi-religious faith in technologies to solve climate change, overpopulation, and species extinctions, and are appealing to technology-led trends (economic growth, demographic transition, and decoupling) to somehow banish hard choices having to do with inequality. To the extent that machines *can't* deal with a problem, we prefer simply to ignore it. We've already seen that this is a failing strategy. But if so, why do we keep stubbornly pursuing it?

In the Introduction, I noted that technology has a history of success (un–intended consequences aside), especially in the last century. Machines really accomplished wonders. But there's much more to our devotion to the techno-fix than that. Our deep faith in technology has social, psychological, and even genetic roots.

In his 1980 book *Overshoot,* sociologist William Catton, Jr. described modern technologies as prosthetics, or detachable organs (i.e., extensions of our inherent capabilities for motion, computational thought, etc.) that make us more powerful.[168] Clothing is a prosthetic technology that empowers us to live in cold climates. A jackhammer is a prosthetic extension of our fist that empowers us to break up rock or concrete. Catton called Homo sapiens "the prosthetic animal" and noted wryly that "when an airline pilot with thirty-three years of flying experience refers to the familiar act of buckling his cockpit seatbelt as 'strapping a DC-8 to my waist,' it is clear that even a modern jetliner can be seen as an elaborate prosthetic device."

Naturally, we want power. Every organism does.[169] Those species that best mobilize power in order to obtain food, evade predators, and reproduce successfully manage to survive. Since prosthetic technology gives us power over our environment (and often over one another), it's natural for us to want more of it.

Among organisms, status serves as a way of minimizing the costs of competition. Animals compete for mates and food, but competition carries costs. Signals of status establish which individuals are more or less likely to be successfully challenged, so overall there is less energy wasted in competition.[170] Tendencies among modern humans to acquire technological status symbols—expensive cars, clothes, houses, and electronic devices—are therefore deeply rooted in evolution.

Also, our brain chemistry evolved to aid our survival: the neurotransmitter dopamine, for example, gives us a slight "high" in response to anything we notice in our environment that is out of place or unexpected and that might signal a

potential threat or reward.[171] But addictive substances and behaviors can hijack the brain's dopamine reward system. Addictions to acquiring or using certain technologies are hard to overcome because they are reinforced by our innate brain chemistry. They can be as hard to defeat as a drug dependency. As we surround ourselves with more technology, our environment becomes filled with potential dopamine reward system hijackers.

There are also socioeconomic roots to our fascination with the techno-fix. At one time, most humans directly depended on hunting and gathering, and later on crops and weather, for their survival. Now, largely thanks to technology, most humans live in urban settings where they directly depend on jobs, investments, banks, and stores—the *economy*. Technology drives the economy, and we naturally want the economy to thrive. To do so, it needs to grow: it constantly requires higher profits to produce more jobs. Fixing our problems with technology may lead to economic growth; addressing those problems with behavior change and moral choice usually doesn't.

So, it's *understandable* that we would appeal to technology to address as many of our problems as possible. But that doesn't make it *wise*. Tellingly, many of the people who are most directly familiar with specific technologies are most careful to shield themselves from those technologies' side effects. In his book, *Irresistible: The Rise of Addictive Technology and the Business of Keeping Us Hooked,*[172] author Adam Alter tells how Steve Jobs kept his kids from using iPads and iPhones, and many other IT (information technology) moguls also severely restrict their children's use of portable electronic devices. Similarly, many Midwestern farmers who make a living growing genetically engineered crops using pesticides and artificial fertilizers feed their own families from an organic garden next to their house. And many medical doctors insist on forgoing invasive end-of-life technological interventions for themselves,[173] even though much of their professional income is derived from recommending and providing such interventions for others. What have these people figured out that others haven't? And if they've figured it out, why can't the rest of us?

In focus: Electronic, hand-held devices

At home, in the office, at social gatherings, and even when we're out in nature, we're often glued to the screens of our hand-held electronic devices. As of 2015, 64 percent of American adults owned a smartphone, up from 35 percent in 2011.[174] On average, we check or touch our phones 150 times per day.[175] Alongside this trend, and helping drive it, is the meteoric rise of social media: around one third of the world's population were active users as of 2016, with average annual increases of 10 percent.[176] Electronic devices and online platforms are quickly becoming indispensable both socially and professionally. Nearly half of smartphone owners now say they "couldn't live without" their devices.[177] They bring obvious benefits, allowing us to connect, share, organize, and discuss with others across spatial and cultural boundaries. But is there a dark side to this fundamental change in the way we communicate?

Overuse and addiction are real and growing problems.[178] Social media are carefully designed to maximize usage and create more traffic for advertisers[179]— a subtle form of mind-control. We aren't all equally affected, and the quality of online interactions plays a key role. Vulnerable groups include children and adolescents,[180] people with existing social problems[181] and low self-esteem,[182] and individuals who may tend to replace or diminish real-life relationships in favor of online ones.[183]

These unhealthy patterns can lead to serious practical consequences, including loss of mental focus, technology-related information overload or "technostress,"[184] and even lower job and academic performance.[185] Emotional and psychological impacts are also common, often tied to harmful social competition and anxiety caused by frequent comparisons of our lives to others;[186] declines in the self-reported number of close friends; depression and lower life satisfaction;[187] and family stress.[188] Also worrying are the potential health impacts of long-term, chronic use of these devices—from decreased exercise, if not from cumulative exposure to electromagnetic radiation. The long-term health impacts of the latter are still uncertain, but the frequencies emitted by mobile phones have been shown in the lab to have potentially harmful biological effects.[189]

So, what can be done to temper the downsides of the rise of smart devices and social media?

- Develop personal autonomy at home and work by building healthy self-esteem (without looking to social media for this).
- Promote non-consumerist values in your children, and value your real-world relationships.
- Promote moderation in your use of these technologies: it's as simple as taking time to shut down your computer, put down your phone, and have a conversation, sing a tune, cook a meal, watch the sunset, or observe a non-human animal.
- Go on a computer and phone fast one day a month, or one day a week if you can manage it.

Collectively, we must raise awareness, particularly among the most vulnerable groups, of social media's antisocial side effects. Also, we should consider supporting efforts to identify and reduce local electronic pollution, to reduce cell phone usage by children, and to ban sales of smart phones for children under the age of thirteen.

6. Denying limits leads to moral atrophy—and catastrophe

The three core problems we have been discussing all relate to limits. Climate change is the consequence of our exceeding the limit of the atmosphere's ability to absorb wastes from industrial processes. Population growth presses against the limits of the environment's ability to yield food and natural resources. Species extinctions result from humanity's stealing limited ecological space from other organisms. Inequality is about limits too: our political and social systems appear to strain beyond their limits when some people have vanishingly little, while others wallow in wealth far in excess of their ability to enjoy it or put it to any practical use.

In essence, these are all old problems, as we have seen. Population pressure, inequality, and environmental impacts have plagued every human society from time to time.[190] Technology has changed the scale of our problems, but it hasn't really changed the essential nature of the problems themselves. In recent decades,

fossil-fuel energy—channeled through thousands of new technologies—enabled us to expand some critical limits. We grew more food per unit of land. We increased the speed of information sharing to near the speed of light. We reduced the cost of basic commodities with resource-extracting machines that could catch fish, fell trees, and mine ores at speeds and in quantities never before imaginable. Partly as a result, technology assumed the guise of an all-purpose genie to which we could appeal in order to evade uncomfortable moral and philosophical questions about limits, questions whose only genuine answers entail—as they always have—negotiation, behavior change, and willingness to give up some degree of power and advantage.

Before fossil fuels, and before the technological revolution they fueled, we were *forced* to confront and adapt to limits. We codified lessons about limits in a set of virtues (sufficiency, modesty, thrift, generosity, and self-control), and vices (greed, selfishness, envy, and gluttony) that were held similarly by people everywhere, in very different and distant societies. Lately we have come to believe that technology makes these virtues and vices at least partly obsolete. We are encouraged to want more, consume more, and waste more because the economy demands it. But doing so doesn't make us better people; it usually does just the opposite. By abandoning those old virtues and ignoring those vices, we merely become more dangerous to ourselves, one another, and our environment.

Technology assumed the guise of an all-purpose genie to which we could appeal in order to evade uncomfortable moral and philosophical questions about limits, questions whose only genuine answers entail—as they always have—negotiation, behavior change, and willingness to give up some degree of power and advantage.

Environmentalists once appealed to the virtues of sufficiency and self-control, and warned against the vices of greed and gluttony. *Use less*, they admonished; have

fewer children; reuse, repair, and recycle. However, in recent years some environmentalists have despaired that the effort of persuading humanity to be more ecologically virtuous wasn't working. It's an ineffective message, they concluded. It is too dreary; it doesn't offer enough hope. And so, some have declared themselves "eco-modernists"[191] and now happily claim that technology will solve our problems without our having to tire our withered ethical muscles. To be fair, many eco-modernists and their organizations cling to this cheerful pitch because they don't see how moral choice could work at this late moment to address the enormous and growing problems of climate change, species extinctions, and overpopulation. They may be right that the challenge now exceeds our collective capacities for sacrifice and negotiation; but even if it does, we should know that techno-fixes aren't up to the task either. And that leads us to a dark prospect.

There is a presumption underlying this entire manifesto: that "we" (meaning humanity in general) want to maintain civility, peace, and cooperation. Thus "we" are all invested in solving climate change, inequality, species extinctions, and overpopulation—if not with technology, then somehow. But there is another way to deal with all these problems: make sure someone else pays the price, as a result of ruthless competition for shrinking ecological carrying capacity. The longer unsustainable population and consumption trends remain unaddressed, the greater the number of us who will drift toward the view that the project of maintaining global civility is not worth negotiation and compromise. If compromise involves giving up goods that we sense are already becoming scarcer, then why not instead play a blame game and prepare to fight for what's left of Earth's dwindling resources?[192] Perversely, the resulting mad scramble would almost certainly be framed as a "moral" response to the situation, since it would be rooted in the drive to protect one's own tribe from the threat of others.

The implications are truly and utterly apocalyptic. There will be a point of no return, beyond which the sacrifices required in order to regain a condition of ecological sustainability become just too great to endure, and preserving present

advantages becomes just too great a priority. We are fast approaching that point. This manifesto is actually a hopeful document, in that it assumes we still have some time. But we should not assume we have much.

For now, most of us at least give lip service to global civility. But actually, maintaining that civility implies much more than just hoping that CCS will solve climate change, or that more automation will reduce economic inequality (rather than worsening it, which is far more likely).

In focus: What is sustainable development?

The rising global population requires not only increased provision of food, shelter, and the basics to sustain life, but also the means to address crippling poverty. Studies suggest that over half of the world's people currently have insufficient income to lead lives consistent with fundamental human rights.[193] However, humanity's consumption footprint is already unsustainably large, exceeding what the planet can provide long-term by a margin of 60 percent.[194] And averting catastrophic climate change will require the world to implement immediate reductions in greenhouse gas emissions. The contradiction is plain. Attempts to reconcile climate constraints with the need to lift the global poor out of poverty, hampered by misleading notions of global development, are stumbling into serious moral dilemmas. This is now epitomized by the United Nation's Sustainable Development Goals (SDGs), which claim to be "a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity,"[195] but in reality, are unlikely to achieve their intended aims.

Clearly, this impasse is the result of excessive consumption on the part of the world's wealthy minority, rather than efforts to meet the needs of impoverished multitudes.[196] The top one percent of emitters in the United States emit around 2,500 times more CO_2 than the bottom one percent globally.[197] In this context, it is both practically questionable and morally dubious to imply that market-centric growth imperatives embedded in the SDGs offer the best way forward, instead of a drastic transformation of unsustainable lifestyles in rich nations. In effect, the SDGs intentionally seek to shift responsibility from the powerful to the powerless and serve to lock in the existing model of highly unequal growth-based development. Analyses have shown that at present rates, this strategy would take over 200 years to eliminate poverty and would result in a global economy 175 times its current size.[198] Despite such obvious flaws and mounting critiques,[199] economic development policy remains enslaved to a broken ideology.

The Integrated Assessment Models (IAMs) used to chart a course for the future of development are becoming increasingly divorced from reality. For example, a recent study[200] of the widely-used IMAGE 3.0 model found that a growth-based sustainable scenario over the 21st century requires highly optimistic assumptions regarding such factors as renewable energy, dietary change, education investment, and fertility. In particular, both energy intensity and carbon intensity would need to decrease at rates out of step with historical trends, by unknown technological means and against a well-known tendency towards diminishing returns. Even so, such a scenario still leads to warming of 3°C by 2100, beyond the level accepted as "safe" by the international community, and relies on the widespread deployment of climate-altering technologies that do not yet exist (as discussed in more detail in the sidebar on Geo-engineering). The numbers simply don't add up.

Sooner or later those of us in the wealthy nations will need to face the fact that there's no escape from downshifting our lives and learning to live within the limits nature imposes. Externalizing responsibility to non-existent technology can only extend and worsen our situation.

7. What we must do

How do we actually initiate a collective moral conversation about moving beyond illusory techno-fix solutions, and begin the processes of negotiation and behavior change? For the conversation to happen, we need three things: some assurance that such a conversation is possible and can achieve the needed results; the social and cultural space for that conversation to occur; and the will to have it. In addition, some inspiring examples might be helpful.

* * *

First, conversations about limits are perfectly natural, and we are indeed capable—genetically as well as culturally—of having them and acting on them. Over countless generations, human societies learned to tame biologically rooted reward seeking with culturally learned behaviors geared toward self-restraint and empathy for others. Prudence, thrift, and the willingness to sacrifice on behalf of the community are evolved functions of the neo-cortex[201]—the part of the brain unique to mammals—and are both rooted in evolutionary imperatives and also

learned by example. Traditional human societies expended a great deal of effort to provide moral guidance, often through myths and stories, to foster pro-social behavior and to avert ecological overshoot.[202]

Since the advent of consumerism, we have cast aside some of those stories in order to stoke economic growth. Consumerism has promoted greed and individualism, and blinds us to the environmental consequences of overconsumption. After decades of consumerism, it is difficult to rapidly change people's tendency to want *more*. However, it is possible to redefine what "more" means. We can choose to measure success in terms of relationships, community solidarity, meaning, and shared experiences rather than the mere acquisition of things.

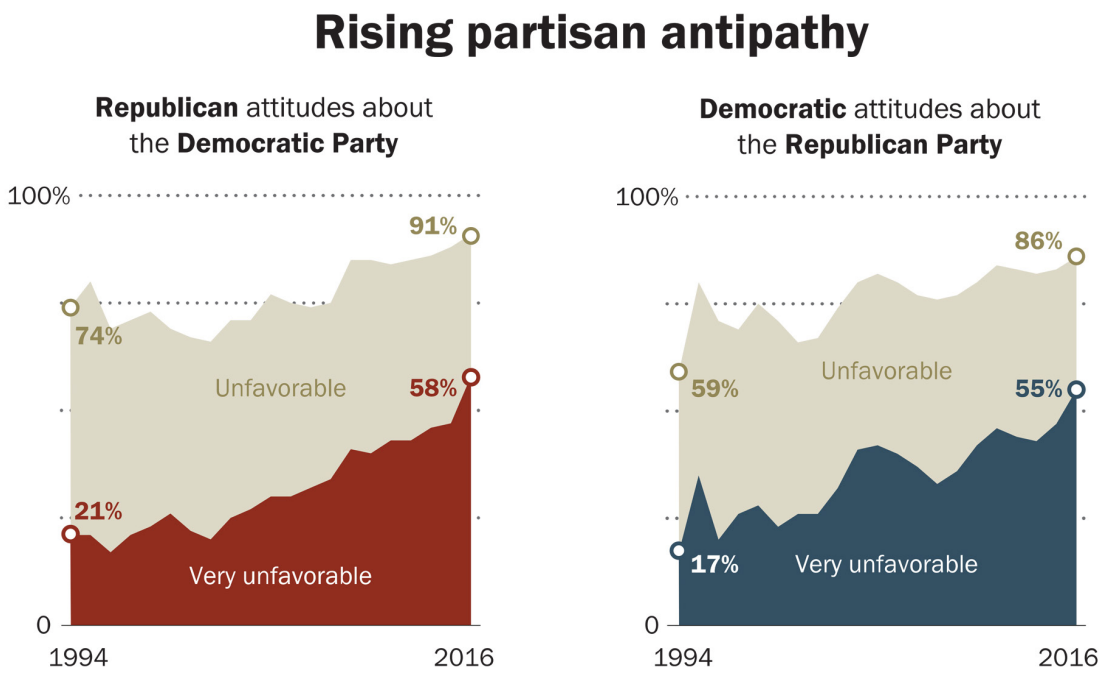
In promoting pro-social behaviors that benefit the integrity of the natural world, it is important to work *with* human nature—the selfish as well as the cooperative parts. While we are deeply social creatures who need social relationships to thrive—relationships that require giving and reciprocity—we are also driven by status and reward. We can harness both of these aspects of ourselves—the competitive and the cooperative—by creating new cultural stories (and reviving old ones) in which high status and reward are attached to habits and behaviors that promote healing, sharing, giving, creating, growing, conserving, and thriving within constraints. We can also rewire our brains to some degree through the formation of new habits, but that requires setting intentions and sticking to behaviors that may at first seem unfamiliar and even uncomfortable.

Part of the challenge we face is that our society's customary sources of moral guidance—political and religious institutions and their leaders—have come to believe in the need for unsustainable growth. Not only does government encourage us to consume more commercial products, but some religions also insist that we have big families and forgo contraception. Those messages undermine our survival prospects and we must challenge them with common sense and moral persuasion.

* * *

The public space in which difficult conversations about values and limits can occur is getting both crowded and scarce. In the twentieth century, journalism could change minds, institutions, and behaviors. For example, *The Jungle*, a 1906 novel by Upton Sinclair, alerted the public to unsanitary practices in the American meatpacking industry, resulting in public outcry that led to reforms. Similarly, *Silent Spring* by Rachel Carson (published in 1962) changed public attitudes about pesticides and led to the banning of DDT. In the early days of television, broadcasts by Edward R. Murrow helped bring down the unscrupulous, red-baiting Senator Joseph McCarthy.[203]

Today it's more difficult to imagine a single journalistic voice having such impact. In the decades immediately after World War II, information traveled via books, newspapers, magazines, radio, and television. Most Americans got their nightly news from one of three sources. Now we have hundreds of cable channels instead of just a few TV networks; but more importantly we have the Internet—a powerful information technology that in some ways subsumes all the others. In its wake, the media have morphed into a giant echo chamber—or series of them. British humorist Stephen Fry calls this development, "The ghettoization of opinion and identity . . . apportioning us narrow sources of information that accord with our pre-existing views, giving a whole new power to cognitive bias, entrenching us in our political and social beliefs, ever widening the canyon between us and those who disagree with us."[204] Without universally trusted news and commentary, we are in effect becoming re-tribalized, much as communications technology guru Marshall McLuhan foretold back in the 1960s.[205] One subgroup's hard scientific data is another's "fake news."



Political polarization in the United States is nothing new, but the degree of distrust and even outright hostility has grown to extreme levels, according to surveys conducted by Pew Research Center. Source: Pew Research Center, Partisanship and Political Animosity in 2016.

The social space for moral conversation and negotiation has a name: *politics*. It's in the political arena that social groups vie for power and negotiate the allocation of common resources in order to solve problems—including environmental problems like climate change. With the ghettoizing of information, politics has become hopelessly corrupted and polarized—most notably in the United States. Under these circumstances, the prospects for needed but difficult collective societal conversations about climate, population, and biodiversity might seem hopeless.

Nevertheless, space for such conversations still exists at the local level. Think of a spectrum of action ranging from the individual level at the bottom, ranging up to national and global levels at the top. Though action is needed at the national and global levels, the local community provides a "sweet spot" for discussion and engagement. Within the community, we interact with one another directly and can challenge one another's beliefs. Personal action within the community is more likely to be driven by genuine moral commitment than by stereotyped national

political messages (though the latter certainly do intrude into local politics). And it's at the community level where those who are affected by policy have the greatest ability to shape policy.

Effective action can entail running for local office, or engaging with local officials on issues having to do with land use, development, housing, building regulations, and transport planning. Beyond the formal machinery of local politics, one can create opportunities for public education by organizing lectures, study groups, and film showings. Local chapters of organizations like Transition Initiatives[206] and Business Alliance for Local Living Economies (BALLE)[207] can also provide venues for conversation and action. As minds are changed within the community, an opening is created for more national- and global-level consideration of topics that may previously have seemed off-limits.

Conversations require both listening and speaking skills. In a polarized political environment, one skill particularly needed is the ability to convey meaning and concern while avoiding charged rhetoric and loaded words; another is the ability to impart knowledge without making the listener feel stupid or wrong.[208]

* * *

The will to confront our pressing problems exists. People across the political spectrum are worried about the future and want to see environmental and social problems solved. But we must find ways to mobilize that will, ways that actually result in behavior change. The old values survive. But we must take individual and collective action rooted in those values.

Since the 1970s, environmental organizations have played an important role in motivating values-based individual and collective action. These organizations' founders understood that overpopulation and environmental damage are essentially moral problems, and so they crafted messages designed to raise awareness and shift collective behavior. Some of those messages were inevitably perceived as hectoring, shaming, or frightening. But, at least up to a point, they worked.

Somehow, we must amplify that effort and make it much more effective. That will require environmentalists to return to their first principles. Eco-modernists have said, in effect, that with regard to efforts to change collective behavior, "We tried that in the '70s and it didn't work." However, to the extent a moral message was tried, it *did* work. Efforts to change policy and behavior resulted in cleaner air and water, a slew of effective regulations, and the adoption of new habits by tens of millions of people in industrial societies.[209] Population organizations, by promoting family planning and the raising of women's status in tradition-bound societies, managed to help reduce the global population growth rate.[210] True, earlier generations of environmentalists didn't accomplish enough, but it is wrong to think they achieved nothing at all.

A reinvigorated and refined moral message is needed to confront a new reality. Whereas environmentalists at first merely issued warnings of eventual consequences, we now see consequences at our doorstep; meanwhile warnings are graver, more specific, and grounded in abundant data. While environmentalists formerly labored to wake citizens from a stupefied consumerist trance, the option of remaining in that somnambulant condition is now available to fewer and fewer people as economic growth falters and inequality worsens.

The message needed today is one that helps masses of people come to terms with a rapidly changing world in which inequality and climate change are increasingly linked. That message must be directed especially toward young people, who are entering a world already full of humans and their industrial wastes, one that is also rapidly emptying of species and resources. It is already clear that millennials' priorities are different from those of their parents and grandparents: millennials are uninterested in car ownership; they want experiences instead of things.[211] What they need is a way of understanding the moral challenge of our time, and opportunities to act on that understanding.

* * *

In addition to dealing with our problems related to climate, population, habitat, and inequality head-on, achieving a condition of sustainability will also require us to develop a healthier relationship with technology. Today's biggest technology trends—the growth of the "internet of things" (IoT), robotics, and artificial intelligence (AI)—will make fortunes for inventors and venture capitalists, and could change our lives for the better in some ways. But they will also likely pose serious threats to employment, privacy, security, and civil liberties. We may be heading toward Schumpeterian "creative destruction" (or, to use the current corporate buzzword, *disruption*) on a scale none of us has bargained for.

How can we do a better job in the future, than we have done so far, of weighing technology's costs and benefits? Too often our fascination with technology has overwhelmed our better judgment. To keep that from happening even more as IoT, robotics, and AI converge, we must learn to guide technology's design, adoption, and use with a robust discussion of ends and means.

Ends: What is our goal as a society? Is it just endless growth and ever-increasing wealth—or shall we aim instead for general well-being within the limits imposed by our mortality and our environment? Do we wish to be a virtuous and happy society, or merely a powerful one?

Means: What means are appropriate to accomplish the ends we choose? What scale of technological intervention will accomplish what we require, without creating a massive infrastructure that ends up reshaping our priorities to support its own maintenance and proliferation (as the automobile, for example, has done)? What scale of environmental impacts is acceptable? There are two things we should especially watch for: means that degrade the options of others, including those of future generations (e.g., by depleting resources, polluting the environment, or eroding biodiversity); and means that degrade *us*—morally or otherwise (example: by enticing us to stare into screens all day instead of interacting directly with our natural environment and with flesh-and-blood people). The notion that all technologies are neutral is naïve: each embodies an agenda, and that agenda may or may not align with the priorities and values of a majority of citizens.

Developing a healthy relationship with technology will require national technology assessment protocols. We must put public effort into foreseeing and measuring each technology's impacts on environment, human health, psychology, and society. And we must do this before that technology's widespread adoption. Some new technologies or their applications may deserve to be banned outright. Technology assessment is already happening on a small scale: several governments (Switzerland, Austria, Germany, Denmark, the European Parliament) have institutes or departments for technology assessment to inform government regulatory decisions.[212] (The United States Congress created the Office for Technology Assessment in 1972; over the years it published hundreds of useful and insightful reports. A budget-cutting Congress abolished it in 1995.)

At the same time, we must encourage one another to adopt personal habits of reflection with regard to the choice and use of technologies. We should each find ways to limit our screen time; we should think carefully about our choices regarding land transport and about whether and how much to fly; and we should give morality a place in our food choices—whether to eat meat and how much of it, and whether to eat organic or conventionally grown foods.

As members of communities, we should also maintain the keen awareness that these kinds of personal moral choices are more readily available to middle-class households than to low-income families, who may not have the option to eat organic, local foods or to buy an electric car. We should therefore work within our communities to expand the possibilities for ethical choice to all people.

* * *

It may be helpful to survey some encouraging examples in which morally motivated action is working to address our three big problems.

Climate

The best success stories about action to combat climate change rarely emerge from national capitals; they come instead from places like California—especially communities like Sonoma, Marin, and Monterey Counties, where citizens banded together to create their own nonprofit electric utility companies[213] dedicated to expanding renewable energy; from Amsterdam and Copenhagen, cities committed to minimize the role of the automobile;[214] and from villages in Africa where cheap solar cells and LEDs are reducing the burning of biomass for light. Many cities have adopted 100 percent clean energy goals that are far more ambitious than commitments by their national governments.[215]

Population

Thailand launched a government-sponsored family planning program in 1970. It included public messages about the benefits of family planning; provision of a broad array of contraceptives without prescription; and distribution by nurses, midwives, and even shopkeepers within communities. By the late 1980s, the nation's average lifetime number of births per woman had dropped from about seven to below the "replacement-level" of 2.1. A cost-benefit analysis estimated that Thailand's program prevented 16.1 million unintended births between 1972 and 2010, saving the government $11.8 billion in social service costs, or $16 for every dollar invested in the program.[216]

Iran began a national family planning program in 1967, and as a result, the nation's lifetime number of births per woman fell by nearly two children—from 7.7 in 1966 to around 6.0 in 1976. However, soon after the 1979 revolution, the family planning program was dismantled. As a direct result, the fertility rate rose to 7.0 in 1980, and the rate of population growth jumped to 3.6 percent annually. Voices of concern inside and outside of government forced a change in population policies in the late 1980s. The Iranian government, with the support of Muslim religious leaders, reinstituted its national family planning program. The proportion of married women of reproductive age using contraception increased from 37 percent in 1976 to 73 percent in 1997, and the average lifetime number of births per woman declined from 6.8 in 1984, to 5.5 in 1988, to 2.8 in 1996, and finally to 1.9 in 2012.[217]

Many other countries with successful family planning programs and low fertility rates include Bangladesh, Colombia, Indonesia, Tunisia, Turkey, and Vietnam.[218] China, with its one-child policy, is a special case in that its family planning program is not voluntary. The experience of other countries shows that coercion is not necessary.

Some of the most effective work to reduce unsustainable population growth is being led by Population Media Center,[219] which enlists creative artists in countries with high population growth rates (which are usually also among the world's poorest nations) to produce radio and television dramas featuring strong female characters who successfully confront issues related to family planning. This strategy has been shown to be the most cost-effective and humane means of reducing high birth rates in these nations.

Species conservation

At the center of successful biodiversity programs is the steady expansion of national parks and nature reserves (including marine protected areas), as well as efforts to slow deforestation, limit bad projects (big dams, mining, etc.), and restrict fishing. Conservation organizations, including the Nature Conservancy[220] and the

World Wildlife Fund,[221] and government agencies (using legislation such as the U.S. Endangered Species Act), work to rescue animals and plants on the brink of extinction. Meanwhile, national parks and wilderness areas help preserve habitat.

Efforts to help forests migrate in response to climate change, to remove invasive species from island ecosystems, and to re-populate ecosystems with native species are ongoing in many nations.[222] There are many individual success stores (Amur tigers, the gray whale, the southern white rhinoceros, the mountain gorilla, and other endangered animals have been saved from extinction—for now), however, only the protection of habitat on a massive scale will prevent future losses of plant and animal species on a terrifying scale.

Inequality

International development agencies typically aim to address inequality by way of bank loans for infrastructure spending, hoping to nudge poor nations toward the ultimate goal of becoming urbanized societies with a large middle class and a consumer economy. But in a few South American nations—notably Ecuador, Peru and Bolivia—a new social movement is taking a different developmental path altogether.[223] "*Buen Vivir*," Spanish for "good living" or "living well," draws from indigenous ideas and attitudes to promote a way of living based on a mutually respectful, interdependent coexistence between humans and nature. It refuses to measure well-being in terms of dollar incomes and advocates de-growth of the high-energy economies of the industrialized world.

* * *

If we do all of the things suggested here, can we turn the tide and avert ecological catastrophe and social turmoil? There's no guarantee. But if we continue on our present path, no magic machine will be able to prevent current trends from converging into an unprecedented ecological and human crisis. Nor can national governments by themselves save the day: they are too invested in the current growth-based model of development, and in many cases too politically polarized to be capable of managing such a profound change of direction. Our only real

hope is to join together as individuals, as households, and as communities to weave a new fabric of cooperative action rooted in deep and ancient values. That means deliberately choosing to live in a world that is sustainable and equitable, by following such a world's inevitable and inherent rules.

Becoming better people in a better world: there's no app for that. The good news is, we don't need one. It's a potential that already lies within us, ready to be re-awakened.

8. What you can do right now

Each of us needs to take responsibility for addressing climate change, overpopulation, and biodiversity loss. You can start right now—just choose where to start: from a place of personal growth, within your community, or take it all the way to the national or global levels.

GOAL / SCALE	Climate Stability	Right-sized Population	Biodiversity Conservation	All Three Goals
Personal	Ditch the screen and reconnect with the people in your life. Take the **pledge to unplug**.	Talk with friends and loved ones about family size. Read **this article** or Bill McKibben's book ***Maybe One*** for ideas on how to start a conversation.	Turn your yard, balcony container garden, schoolyard, or work landscape into **Certified Wildlife Habitat**.	Learn how to build resilience in your own community. Take the **Think Resilience online course**.
Community	Host a **Turn21 event**. It's time we grew up and treated the planet and each other with respect.	**Support** your local Planned Parenthood Health Center or step up to become a **Planned Parenthood Defender**.	Take part in some citizen science, and help track wild bird populations. Participate in the **Christmas Bird Count**.	Shift the way your friends and colleagues think about the issues we face. **Organize a discussion group** for the Think Resilience course.
National / Global	Support **Barefoot College** and/or **Solar Aid**, who meet people's needs while reducing emissions.	Support the **Population Media Center** and change lives by changing the story.	**Volunteer with the Land Trust Alliance** to protect and conserve natural habitats.	Share **this manifesto** with 10 people. Include your local, state, or national representatives.

Appendix

Resources for further reading

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Page 12: Artist's rendering of a hyperloop in a futuristic city, via Carnie Mellon University, http://www.cmuhyperloop.com/#vision.

Page 14: Self-driving Google cars, via Medium.com, https://medium.com/@willswan/why-i-will-never-buy-a-self-driving-car-out-of-choice-134d221bb9fe.

Page 16: Mammoth baby studied by scientists at Natural History Museum in London, via Agence France-Presse, http://www.ibtimes.co.uk/lyuba-42000-year-old-baby-mammoth-arrives-natural-history-museum-london-1449267.

Page 19: Still from "The Sorcerer's Apprentice" in the 1940 Disney movie *Fantasia*.

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Page 57: Typewriter key, via Pixabay, https://pixabay.com/en/typewriter-black-white-1156826/.

Endnotes

All internet addresses are current as of August 2017 unless otherwise indicated.

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