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After Climate Despair

The dream of a global conversion to austerity has failed to stop climate change. Energy abundance is our best hope for living well with warming—and reversing it.

Matt Frost

The Italian Renaissance humanist Girolamo Fracastoro is best remembered for his allegorical poem about syphilis. But his interests were expansive. Around 1550 he wrote a letter to Alvise Cornaro, a nobleman skilled in hydraulics, worrying that a crisis loomed for the Most Serene Republic of Venice. The rivers of the region, stripped of trees to feed the city's growth, were filling the otherwise navigable channels of the lagoon with silt, forming pestilent marshlands and rendering the waterways impassable. At the same time, sea levels were falling. Venetians had known for centuries that their public health and maritime

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advantage depended on the precious lagoon, and the crisis had long preoccupied the republic's leadership. Fracastoro told Cornaro:

> This Lagoon must someday—only God knows when—dry out of sea water and become swampy, either from silt, or from the withdrawal of the sea from the whole bay, one or the other; I do not believe that any human power can oppose it.

Yet he exhorted Cornaro to action anyway. Fracastoro's idea was to flood the lagoon with fresh water. The plan was partially implemented but backfired, spreading muck across an even greater area. So the city then spent fortunes on diverting the silty rivers away from the lagoon and into the sea. Eventually, this strategy worked.

Like the siltation that worried Fracastoro and Cornaro, climate change is a slow, relentless environmental crisis, but one of far greater scale and complexity. Our challenge, however, is the same: to carry our thriving civilization into a future made perilously uncertain by the side effects of our own prosperity.

Each of us constitutes a link between the past and the future, and we share a human need to participate in the life of something that perdures beyond our own years. This is the conservationist—and arguably the conservative—argument for combating climate change: Our descendants, who will have a great deal in common with us, ought to be able to enjoy conditions similar to those that permitted us and our forebears to thrive.

But the dominant narrative of climate change, though it claims to be aimed at protecting future generations, in fact leaves little room for continuity. Preventing more than 1.5 degrees Celsius of warming above the nineteenth-century baseline, the latest aim of the Intergovernmental Panel on Climate Change (IPCC), will, as they put it, require "rapid, far-reaching and unprecedented changes in all aspects of society." Only a vanishingly unlikely set of coordinated global actions—an extraordinary political breakthrough—can save us from what the most pessimistic media portrayals describe as "catastrophe," "apocalypse," and the "end of civilization." Only by changing our entire energy system and social order can we preserve the continuity of our biosphere. And so climate politics has become the art of the impossible: a cycle of increasingly desperate exhortations to impracticable action, presumably in hopes of inspiring at least some half-measures. Understandably, many despair, while others deny that there is a problem, or at least that any solution is possible.

But we are not condemned to a choice between despair and denial. Instead, we must prepare for a future in which we have temporarily

failed to arrest climate change—while ensuring that human civilization stubbornly persists, and thrives. Rather than prescribing global austerity, reducing our energy usage and thereby limiting our options for adaptation, we should pursue energy abundance. Only in a high-energy future can we hope eventually to reduce the atmosphere's carbon, through sequestration and by gradually replacing fossil fuels with low-carbon alternatives.

It is time to acknowledge that catastrophism has failed to bring about the global political breakthrough the climate establishment dreams of, and will not succeed in time to avert serious warming. Instead of despairing over a forever-deferred dream of austerity, our resources would be better spent now on investing in potential technological breakthroughs to reduce atmospheric carbon, and our political imagination better put toward preparing for a future of ever more abundant energy.

The Futility of Dread

To their credit, climate mitigation advocates have persuaded the public that warming is happening and is a problem. According to a survey last year by the Yale Program on Climate Change Communication, American adults who believe that global warming is happening outnumber those who don't by a ratio of five to one. And 62 percent said they are either "somewhat" or "very worried" about warming. The journalists, researchers, and advocates who have worked to raise awareness of the problem have reason to congratulate themselves.

In the same report, however, we find this:

> Few Americans are confident that humans will reduce global warming. About half (49 percent) say humans could reduce global warming, but it's unclear at this point whether we will do what is necessary, and about one in five (22 percent) say we won't reduce global warming because people are unwilling to change their behavior. Only 6 percent say humans can and will successfully reduce global warming.

Is this pessimism just the next frontier for awareness-raising? With the public mostly persuaded that climate change is both real and dangerous, do advocates simply need to spread the word that a politically implemented solution is possible?

The bleak poll results may reflect a broad, if perhaps tacit, agreement that we have reached diminishing returns on dread. Even now that most Americans accept the dire predictions of scientists and journalists, their assent does not change the fact that we currently lack the institutional,

technological, and moral resources to prevent further climate change in the near term. The lay public has been taught to regard stabilizing the climate as an all-or-nothing struggle against the encroachment of a dismal future, and the bar for success is set high enough that failure is now the rational expectation.

We are perpetually on the verge of irreversible catastrophe—but we still have one last chance to save ourselves through some feat of collective self-denial. When scrutinized, this feat proves impossible. When we again fail to pull together and solve the problem, the consensus solution is to apply even more lurid panic in hopes of a more enlightened response. This combination of brooding pessimism and delusional optimism has not only failed, it has left us poorly equipped to imagine alternative responses.

Transformative utopian projects, like bleak visions of a miserable future, will always mobilize some activists and enthusiasts. But the dark romance of imminent disaster now informs even our mainstream climate debate—consider the spectacle of young activist Greta Thunberg excoriating world leaders at a United Nations summit in September, or the unfortunately named "children's climate crusade" for judicial regulation of fossil fuels. These sensational appeals have not led to the mass political realignment that would be necessary to impose decarbonization on citizens and energy industries. Severe penitential labors have occasionally appealed to small groups of religiously inclined people, but not to populations of increasingly individualistic and affluent modern societies. Predictions of collapse have successfully instilled pessimism—but not productive, coordinated transformation at a global scale. Human beings have a poor record of responding to existential threats by making sudden ameliorative changes to their behavior, or by "leveling up" to superior ethical frameworks.

A common reaction to "there is no solution" is "then there is no problem." No matter how persuasive the evidence of impending danger, most people find ways to dismiss or evade problems that appear insoluble. Attempting to build political support for impossible interventions by making ever more pessimistic predictions will not work; it will only leave us mired in gloom and impotence. This polarized fatalism will grow more extreme as opposing partisans, recognizing our dearth of practicable options, choose either glib denial or morbid brooding.

Missing the Target

We will not stop global warming, at least in our lifetimes. This realization forces us to ask instead what would count as limiting warming *enough*

to sustain our lives and our civilization through the disruption. There can be no single global answer to this question: Our ability to predict climate effects will always be limited, and what will count as acceptable warming to a Norwegian farmer enjoying a longer growing season will always be irreconcilable with that of a Miami resident fighting the sea to save his home. But because our leadership has approached climate change as a problem of coordinated global action, they have constructed quantitative waypoints around which to organize the debate.

The voluntary emissions targets proposed by the 2016 Paris Agreement aimed to keep global warming "well below 2 degrees Celsius above pre-industrial levels." The most recent IPCC report, from 2018, sets a more aggressive target of not more than 1.5 degrees. The report describes a number of scenarios of warming below and above the threshold, and because the recondite details overwhelm most audiences, these scenarios have become shorthand for "less disastrous" and "more disastrous."

The report goes on to describe various "mitigation pathways"—different combinations of changes in human activity that might keep warming below a certain level. The pathways that would limit warming to below 1.5 degrees are extremely ambitious: "Global net human-caused emissions of carbon dioxide…would need to fall by about 45 percent from 2010 levels by 2030, reaching 'net zero' around 2050." In other words, to reach the IPCC target, the world would have to cut its carbon emissions in half over the next decade and eliminate them entirely in a generation.

Some news sources portrayed 2030 as an official deadline for avoiding climate catastrophe. It is worth noting that the report's lead author, Myles Allen, has warned against this interpretation: "Please stop saying something globally bad is going to happen in 2030. Bad stuff is already happening and every half a degree of warming matters, but the IPCC does not draw a 'planetary boundary' at 1.5 degrees Celsius beyond which lie climate dragons."

More to the point, the atmosphere will almost certainly surpass 1.5 degrees of warming. The grim subtext of the report is that the time window in which we might have halted climate change through an internationally coordinated and democratically ratified regime of rationing and energy substitution, if it ever existed at all, has now passed.

The extreme unlikelihood that we will meet the target of 1.5 degrees becomes even clearer when we notice that doing so requires that we not only cut emissions radically, but at the same time remove enormous volumes of carbon dioxide already emitted. The report estimates that a

total of 100 billion tons must be removed by 2050. For comparison, the amount of carbon dioxide emitted globally from fossil fuels last year was around 37 billion tons.

For its projections on how to accomplish this enormous amount of carbon removal, the report assumes heavy use of a technology with the unwieldy name *bioenergy with carbon capture and storage*, or BECCS. With this technology, plants are grown and then burned for energy or processed into fuels like ethanol. Carbon emissions from power plants that burn biomass are captured and stored in permanent reservoirs. Because plants use carbon dioxide to grow, bioenergy with carbon capture and storage has "negative emissions"—meaning that it actually draws more carbon dioxide out of the atmosphere than it releases.

Bioenergy itself is already common today: Almost all gasoline sold in the United States contains a small amount of ethanol, typically derived from corn. But carbon capture and storage is far from widespread. According to a report released in March by the Global CCS Institute, there are only five operating BECCS projects in the world, storing just one and a half million tons of carbon dioxide per year. To meet the 1.5-degree target, the IPCC estimates that by 2050 the technology will need to store three to seven *billion* tons of carbon dioxide per year. The report's authors are well aware of the uncertainties about whether this scale is possible: "No proposed technology is close to deployment at scale."

Even were it possible to scale bioenergy and capture that quickly, doing so would have a major drawback: It would take up an immense amount of farmland. By one 2016 estimate, capturing enough carbon to meet even the 2-degree target by the end of the century could require devoting up to three million square miles of farmland to bioenergy crops—nearly the size of the contiguous United States.

So what if we prevent "overshoot"—that is, warming beyond 1.5 degrees—but without using bioenergy with carbon capture? A 2018 study in the journal *Nature Climate Change* that considered this option found that it would require sweeping transformations to all aspects of human life. These changes would include the universal adoption of a low-meat diet; producing most meat, eggs, and other animal proteins artificially, through in vitro cell cultures; reducing appliances to two per household, with tumble dryers eliminated entirely; a full transition to electric cars by 2030; and limiting global population to 8.4 billion by 2050, declining to 6.9 billion by 2100.

Overshoot is inevitable.

The Age of Overshoot

Admitting that we will fail to meet current targets does not mean we should stake out some new "acceptable" level of warming, or adopt a collective fatalism. Instead, we should explore possible futures outside the constraints of the IPCC's scenarios, and embrace new plans accordingly. As political scientist Roger Pielke, Jr. recently argued in the journal *Issues in Science and Technology*, "The failure of global climate policies to date suggests that new policy options should be explored—that we may need a significantly expanded policy envelope to begin to make satisfactory progress."

Expanding the climate options we allow ourselves to consider is easier said than done. The political and moral challenges are daunting. We will need to adapt to a warmer climate for perhaps decades to come, while at the same time preparing technological and policy solutions for a more distant future where we can finally claw our way back to lower levels of carbon and warming. At the same time, the stressors that a warmer climate will bring will be unequally felt across the globe, likely making our politics more divided and only dimming hopes for international coordination. We must finally abandon the empty hope of imposing equitable austerity via globally coordinated government fiat.

Furthermore, as we adapt to a warmer climate, complacency will be tempting, since we will likely not experience a sudden decline in global quality of life or biodiversity, and may be able to avoid the most dire disruptions. Changes will be slow, with many unfolding on a generational time scale, and with dramatically different impacts among populations. The misery that climate change is likely to cause, or is already causing, will be difficult to distinguish from deprivation as we already know it—the people most harmed, that is, will be the poor, who are already most vulnerable to natural forces. Even if there is a distinct moment of irrecoverable failure, or a tipping point that triggers the worst feedback effects, most people might not notice until it has passed.

Dale Jamieson, an environmental studies and philosophy professor, in his 2014 book *Reason in a Dark Time* makes an especially persuasive case for abandoning hope in the mainstream climate mitigation effort. He argues that our democratic institutions are not built to address the interests of those outside each polity's constituency, spatially or temporally. We do not have democratic mechanisms to account for the interests of non-citizens or of not-yet-living ones, nor do our ethical sensibilities easily help us connect our current consumption of fossil

fuels to the diffuse and time-lagged harms it causes. For these and other reasons, our political institutions have failed to arrest the use of fossil fuels.

In a hotly debated September *New Yorker* article titled "What if We Stopped Pretending," novelist Jonathan Franzen lays out the options once we accept that climate change will happen:

> If you care about the planet, and about the people and animals who live on it, there are two ways to think about this. You can keep on hoping that catastrophe is preventable, and feel ever more frustrated or enraged by the world's inaction. Or you can accept that disaster is coming, and begin to rethink what it means to have hope.

But unlike Jamieson, who counsels that we adopt virtues such as humility, temperance, cooperativeness, simplicity, and respect for nature, Franzen argues blandly that because above all we need "functioning" democracies and communities, "any movement toward a more just and civil society can now be considered a meaningful climate action." His list of what should count as a climate action happens to match the present priorities of American progressives: "Securing fair elections," "combatting extreme wealth inequality," "shutting down the hate machines on social media," "instituting humane immigration policy, advocating for racial and gender equality, promoting respect for laws and their enforcement, supporting a free and independent press, ridding the country of assault weapons—these are all meaningful climate actions."

That the proper response to a century-scale failure of global systems can be cribbed from a Berkeley yard sign in 2019 seems fortuitous. But Franzen's proposal rightly has the spirit of continuity: The ethics of a warmer world must not be a radical break in human history, but recognizable to people today. Whatever is good and necessary today will indeed continue to be good and necessary as our living conditions grow more stressful. And thinking about how to live well in the age of overshoot is more worthwhile than arguing over exactly how terrified we should be of IPCC benchmarks as we pass them.

The global failure to control emissions is not just a failure of political will or technological progress. Rather, it reflects the problem's inherent resistance to unambiguous characterization. Different observers can all adopt different conceptions of the problem, many of which are not mutually exclusive but remain practically or politically irreconcilable. For this reason, we will no more agree on some single new ethics than we will on the "correct" amount of atmospheric carbon dioxide.

Addressing the problem, then, must not mean the coordinated pursuit of a single solution but a perpetual process of decentralized negotiation and risk reduction. Our varied conceptions of climate change will never fully converge, and so the "correctness" of any approach is best evaluated not by whether it meets the latest IPCC target but by how well it affords broad political buy-in. Identifying alternatives to our current, failed approach to climate change requires identifying a more constructive set of ideas—practical, political, and sentimental. We will then be able to focus our resources on those interventions most likely to succeed.

The first step past our political impasse must be to reduce the moral content of our climate mitigation efforts, wherever possible replacing it with engineering challenges. Moralizing climate change, like in NBC News's recent call for anonymous "climate confessions," makes little sense outside of the Western cultural context. But a next-generation solar panel or nuclear reactor can be implemented anywhere.

This is not to suggest that because our politics have failed to arrest global warming we must somehow solve the problem outside politics, through voluntary commerce and innovation, while sovereign power recuses itself. On the contrary, our political efforts, domestic and international, must account for the lack of consensus, and should not presuppose sudden mass moral conversion or radical changes to our institutions. A successful politics for the era of overshoot will maintain continuity with our most enduringly human characteristics, appealing to our routine, unsophisticated self-interest as well as our loftier virtues. In the absence of a sweeping ethical revolution, a successful climate politics will look like a new variation on familiar methods, rather than a transformed social order.

Austerity vs. Abundance

What should motivate our response to climate change is what got us into this mess in the first place: our desire for the abundance that energy technology affords. Energy is the commodity that allows us to protect ourselves from the ravages of nature and to live distinctly human lives, and many of the benefits we enjoy today were made possible by the exploitation of fossil energy. Our children should enjoy greater energy abundance than us, not less.

But the mainstream climate establishment—the government officials, researchers, advocates, and journalists who sustain the consensus agenda represented by the IPCC—is bent on austerity. They demand that we

ration fossil energy consumption until zero-emission sources like wind and solar replace the fossil share of the global energy budget.

Discussions about climate change are also riddled with population anxiety. Lugubrious climate dread appears both as the idea that we should not inflict any more humans on this dying world and that we should not inflict this dying world on any more humans. For the most part, we no longer suffer from feverish speculation about runaway global population growth, since the population may peak anyway by the end of the century. Yet we still hear the old Malthusian idea that our limited energy resources will only be enough for everyone if there are fewer people to whom they must be handed out. Because the climate establishment views energy *consumption* as the problem, energy *consumers* must be on the negative side of the ledger—even if their welfare, or their grandchildren's welfare, is supposed to be the good being protected.

Wallowing in such unproductive thoughts contributes to the current stasis in climate mitigation politics. The question about children is susceptible to what some scholars call "identity-protective cognition," a phenomenon by which even cautious, analytical reasoning is motivated by the thinker's self-conception as a member of a particular group. For people who for whatever reason have decided against raising a large family, belief in ecological disaster and the need for austerity become a strong justification for their decision. Those with a desire for fecundity and abundance bristle defensively at the implications of energy austerity. And so the climate controversy tends to divide people based on their prior affinities, amplifying tensions between austerity and profligacy. Fear of catastrophic climate change, or glib dismissal of the danger, might express and reinforce underlying pessimism or optimism, respectively. Under these conditions, adversarial politics is unhelpful for exploring alternate solutions to global warming, as the issue will remain subsumed in the culture war Americans know and love.

Human survival at any scale depends on our ability to project ourselves into a future we recognize as continuous with us. When we don't, and instead resort to brooding, we also stop making the sorts of plans that might help us to avert the worst effects of what is to come. This estrangement we feel from the world our children will occupy is a modern condition that predates climate anxiety, but the consensus austerity framework for responding to climate change has made it more acute: It demands such a radical transformation of life that it becomes hard to imagine how the future would still be *our* future.

An alternate framework based on abundance would engage each of us as participants in the flow of human history, as the forebears of unknown

successors. It would complement even the doomsayers' calls for taking expensive measures today, since the benefits of mitigating climate change would apply to more people as the population increases. The number of future occupants of our planet is, or should be, the salient variable in any calculation of the long-term costs and benefits of climate change mitigation and adaptation measures. We can't know the economic return on any dollar we invest today in stabilizing the future climate, but we can model it as a function of, among other things, the number of our grandchildren's grandchildren. Our climate approach should presuppose that we are the benefactors of a burgeoning future population, not the progenitors of an ascetic cult formed to dole out a dwindling stock of resources. New sources of carbon-free energy would offer more value to more people than whatever new levers of social control we might invent to enforce a worldwide carbon-rationing regime.

A stronger focus on human utility does not discount the non-human biosphere: When we evaluate the natural world for its beauty or its diversity, we are still expressing human values, and those values are part of the civilization we hope to carry forward in time. For instance, the desire to protect coral reefs, one of the first casualties of global warming, can increase as more people gain freedom from poverty, allowing them to see the reefs' aesthetic and ecological benefits as worth spending resources to preserve.

An abundance framework is also aligned with our persistent human desire for comfort, and would lead us to reformulate our collective problem as one of scarcity, rather than prodigality. Instead of constraining our energy budget, we would look to a future in which a large, decarbonized energy capacity allows more people to enjoy the access to wealth and comfort that many of us take for granted. It would make little sense to leave cheap fossil energy underground in the name of future generations' well-being, only to also leave those descendants an energy-constrained world full of incentives to drill. To remove those incentives, they will need abundant energy.

Obviously, meeting the energy demand of a high-growth world would require new sources of carbon-free power in amounts beyond the IPCC's most optimistic scenarios. But we are already stuck hoping for a global political breakthrough. Technological breakthroughs are less far-fetched a solution. And a mass embrace of abundant energy is more realistic than sudden globally coordinated altruistic self-abnegation. Once we embrace abundance as a normative principle, it directs our attention and ambition toward the bets that, however long the odds, might actually pay off.

Embracing abundance means more than just a rhetorical or sentimental overhaul; it should change how we rank our policy and technology options. And gaining new energy sources would actually expand our options beyond the limited ones available to us now. Choosing abundance does not require that we first have all the answers for how to produce carbon-free energy, or how to reduce current levels of carbon dioxide. Rather, shifting our mindset from austerity to abundance will open up the political space necessary for imagining these answers and pursuing them.

Rethinking Adaptation and Mitigation

A larger supply of low-carbon energy would offer greater adaptive capacity, improve our ability to flexibly respond to still-unknown effects of global warming, and allow living standards in the developing world to continue rising. Economic development, of which energy is an essential component, remains the most robust form of adaptation for many people, since it affords them protection from natural hazards and the vagaries of a disrupted climate. No matter how zealously we panic in the developed world, the poorest populations will remain indifferent to their own carbon emissions as they try to improve their living standards.

Driving down the cost of low-carbon energy sources for the poor through subsidies and innovation is one way to reduce the carbon intensity of near-term economic development, rendering it more sustainable. Wealthier populations with access to affordable, low-carbon energy and with optimistic prospects for technological improvement would enjoy the luxury of magnanimity, of helping to temper climate-induced disruption.

New energy sources would also expand the range of mitigation options, political and technological, as the current options on offer are undesirable. Capturing and storing carbon is essential for the negative emissions needed to minimize overshoot, but we should find a way to use energy instead of land to capture carbon dioxide. This would not only allow us to avoid disrupting agriculture, but would obviate the need to discover and implement whatever new forms of social control a coordinated land-use regime would likely require.

Another set of problems applies to most geoengineering approaches, such as reducing warming by blocking part of the sun from space. There are many unknowns with these kinds of approaches, and potentially serious downsides. For example, they could reduce the amount of energy available for solar power and photosynthesis.

In the near term, we must accept that expanding our political capacity to regulate carbon dioxide depends on driving down the cost of carbon-free energy. Penalizing fossil-energy use can encourage research and development of alternatives, but panic alone will not engender a new democratic mandate for costly restrictions on emissions. Cheap, low-carbon energy can be an alternative to bureaucratic rationing or socially enforced austerity. If we are stuck hoping for a breakthrough, let us hope for one that further emancipates us from want rather than one that more efficiently imposes it.

Carbon as Waste

If we are to jettison the idea that carbon emission is a problem of human consumption, we will need a new framework for understanding what kind of problem it is. Klaus Lackner, a physicist at Arizona State University who researches air capture of carbon dioxide, is developing such a framework, which he calls the "waste management paradigm." As he writes in *Issues in Science and Technology*:

> Carbon dioxide is a waste product; dumping it into the open air is a form of littering. Dumping can be avoided or cleaned up with technological fixes to our current infrastructure. These fixes do not require drastic reductions in energy use, changes in lifestyle, or transformations in energy technologies. Keeping carbon dioxide out of the atmosphere is a waste management problem.

A waste management system for carbon would involve two main technical components: devices to capture carbon dioxide directly from the atmosphere, and sites to store the captured carbon in subsurface rock formations. Both components have been demonstrated in laboratory conditions: Lackner's own research focuses on artificial "trees"—devices that use natural wind passing over collector surfaces to passively absorb carbon dioxide from the air. Research into potential underground reservoirs has identified enough likely sites to store hundreds of years' worth of emissions. Existing carbon capture and sequestration technologies must be located at an emission source—typically, they draw carbon out of the exhaust gas at a fossil power plant. But they cannot capture carbon emitted far away—from cars or homes—or long ago—from centuries of human industrialization. A marked advance in direct air capture technology, or even steady incremental improvements to the devices that Lackner is developing, would be a breakthrough.

Lackner's waste management paradigm is an ideal complement to a climate politics that values continuity and abundance as normative principles.

> The focus on reducing emissions to address climate change has typically included with it a moral judgment against those who emit. Such a moral stance makes virtually everyone a sinner, and makes hypocrites out of many who are concerned about climate change but still partake in the benefits of modernity. A waste management perspective makes it unnecessary to demonize or outlaw activities that create waste streams.

Understanding carbon as a waste product allows us to place its removal at the very center of an abundant future. Unlike bioenergy, which requires agricultural land to get its negative emissions, a waste management system based on direct air capture and geologic storage requires energy.

Lackner suggests we treat carbon dioxide as the "metabolic by-product of industrial activities on which billions of people depend to survive and thrive." Instead of prohibiting its generation, we should apply ourselves to mandating and facilitating its disposal. This means that there would eventually be a need for governments to restrict the dumping of waste carbon, imposing the costs of removal and storage on the fossil fuel industry.

Imposing these costs would be equivalent to outlawing coal, which is already failing to compete with natural gas, even without a carbon price. This is not a free-market solution, and its details remain murky at this point. It would, however, be a policy with a successful precedent. Disposal of sewage and household waste are ordinary parts of civilized life, and carbon disposal could be as well. Adding another pollutant to the materials we pay to dispose of would be expensive and burdensome, and we naturally have less incentive to clean up carbon than sewage. But compared to the IPCC's hope for "rapid, far-reaching and unprecedented changes in all aspects of society," paying for removal of carbon pollution may be politically more viable, especially if the cost of low-carbon energy comes down.

A waste management approach does not require carbon emitters to integrate emission reductions into their own engineering systems. Waste disposal can be outsourced to specialists, and the infrastructure can be sited where geologic storage is available. The initial development of the technology would necessarily depend on financing from early adopters, just as the alternative-energy sector once relied on the enthusiasm of first movers who paid a premium to implement the new technology.

Carbon capture and sequestration has the benefit of permanently storing carbon dioxide in stable reservoirs, which the current market in carbon offsets cannot claim. Offsets have served as a popular way for

institutions to compensate for their emissions, but the track record of, for example, projects to preserve carbon in forest biomass shows that they have largely failed to deliver on their promises. Most offsets depend on natural processes that move carbon into the biosphere, where it remains vulnerable to being released again by natural causes or human intervention: Carbon stored in a stand of rainforest is only secure as long as logging is prohibited. Carbon capture and sequestration, on the other hand, removes carbon atoms from the atmosphere and returns them to the lithosphere where they were before we harvested them for energy.

While offsets are an attempt to manage the net flow of carbon in the atmosphere, geoengineering proposals would meddle with factors like solar radiation in an attempt to treat global warming symptomatically. But treating carbon as a waste product focuses our mitigation efforts on the root problem: the greenhouse gas itself. By treating the original cause of the problem, this approach is robust against other potential symptoms.

For instance, at high concentrations carbon dioxide can be harmful to humans. The U.S. Occupational Safety and Health Administration sets the safe limit for an eight-hour exposure to 5,000 parts per million. But some research suggests that decision-making performance can begin to decrease at 1,000 parts per million. Today the global level in the atmosphere is roughly 410, and without significant emissions reduction, some projections have it reaching a thousand or more in the next century. There is also evidence that our current levels of carbon dioxide are affecting the biosphere in ways other than increasing temperature: Plants appear to be producing higher amounts of sugar, diluting other nutrients.

Many skeptics of the climate change orthodoxy point out that there would be desirable aspects of a warmer world, like open shipping through the Arctic Ocean. Some still insist that increased carbon dioxide is not responsible for global warming. Even if that were true, there would still be ample reasons to keep the earth's atmospheric mix roughly consistent with what our ancestors and the organisms they lived with evolved to breathe.

Capturing Carbon

If the primary threat is too much carbon dioxide, then the primary task is the management of all carbon stocks, rather than simply of carbon flows into the atmosphere. This expands the scale of the problem. Disposing of waste carbon could be described as running the Industrial Revolution in reverse, since removing it from the atmosphere requires tremendous

amounts of energy. But this means that energy, and energy consumption, are no longer the problem, but are central to the solution.

Consider for example the direct air capture technology developed by, among others, the Canadian energy company Carbon Engineering. According to a design outlined in a 2018 paper, a prototype plant can remove one million metric tons of carbon dioxide per year at a price range of roughly $100 to $230 per ton. Powered by a combination of natural gas and electricity, capturing one ton of carbon dioxide requires burning 5,000 cubic feet of gas and using 366 kilowatt-hours of electricity.

These are daunting numbers. Remember that the IPCC pathways for not exceeding 1.5 degrees of warming would require removing three to seven billion tons of carbon dioxide per year by 2050. An abundant future would require even more energy and capture. So let us imagine a future in which we are using the Carbon Engineering design to remove 10 billion tons of carbon dioxide every year. That would require burning 50 trillion cubic feet of natural gas, roughly a third of global production, and using about 4 trillion kilowatt-hours of electricity, roughly what the United States now generates in a year. These energy requirements might decline as the technology matures, but the fact remains: Only very large new carbon-free energy sources, whether wind, solar, or probably nuclear, would allow us to clean up yesterday's carbon.

Carbon Engineering's pilot facility for direct air capture in Squamish, British Columbia

Although direct air capture may or may not ever be implemented at scale, the waste management approach to carbon dioxide offers a plausible goal for which we can begin to plan, and around which we can orient our technology, policy, and rhetoric. The future in which we have built a carbon-capture infrastructure, the energy sources to power it, and the policies to mandate it might be far off, but it is recognizable and feasible to strive for in a way that a global austerity future is not.

After Despair

We are stuck waiting for a breakthrough. The sort of breakthrough we await says much about who we are and where we hope to go. The consensus austerity view would have us hope for a moral breakthrough of penitential retrenchment. The abundance view would have us hope for a technological breakthrough to enable a flourishing future. One says that we have used too much energy, and our descendants should use less. The other implies that we have not devoted enough energy to capturing and storing carbon dioxide, and that we must leave our children and grandchildren as much energy capacity as possible to clean up our carbon waste.

Reframing carbon pollution as a problem of energy scarcity and waste management will not resolve our political impasse. There is no rhetorical trick that will convert entire populations to the expensive cause of carbon capture and disposal in the near term. But a future of abundant energy and improved technological options may offer hope for political progress, fostering agreement around mitigation by making it cheaper. Even though the domestic and global coordination problems will not be easily solved, prosperity could spur magnanimity better than anxiety has. Without prosperity, our technological options will remain weak and divisive.

Our mission must be to provide future generations with better technological alternatives than the ones currently on offer, which range from prohibitively expensive (like BECCS) to wildly reckless (like pumping sulfur dioxide into the stratosphere to block sunlight). We owe our descendants progress toward the long-deferred dream of energy "too cheap to meter," as Lewis Strauss, chairman of the Atomic Energy Commission, famously said in 1954. We owe them the tools with which to dispose of the waste carbon they will inherit. We owe them a better sentimental investment than morbid despair about the future they will occupy.

The policy measures we pursue in the near term should express the ethos of abundance and continuity. They should avoid emission cuts today that might limit wealth and technology options tomorrow. And they should

set us up to take the best advantage of whatever breakthroughs, technological or political, we might be fortunate enough to see in the coming years.

Some current mainstream climate proposals meet these criteria, and Americans can afford to implement them. For example, retiring coal-fired power plants will encourage the development of alternatives and will offer health and environmental benefits aside from carbon reductions. The U.S. government should stop leasing coal and oil reserves to private industry and should become a custodian of geologically sequestered carbon. Philanthropists interested in leaving carbon resources underground should be able to bid against energy companies for the rights to them. We should electrify our transportation fleet, build up our national power grid, and scale up next-generation nuclear power plants. Direct air capture technology, which generates low-carbon gasoline, diesel, and kerosene, can be used to replace some fossil fuels in the near term. If tomorrow brings us a political consensus to treat carbon dioxide as waste, the same technology can help clean it up. We must increase our public and private investments in energy research and development, and seek new sources of power that can be commercialized and deployed globally.

Meanwhile, we should continue to subsidize, through loan guarantees and other means, the deployment of proven clean energy technologies. The current generation of renewables might be supplanted by some abundant alternative, but for now, wind and solar both offer increasingly competitive alternatives to new coal-fired generation, and are likely to compete with existing coal soon. There is an opportunity to prevent the construction of new fossil fuel plants by accelerating the deployment of renewable alternatives.

Other policy approaches are less applicable to a strategic framework of energy abundance. "Weaning ourselves off nuclear energy," as Senator Elizabeth Warren proposes, is a fatuous idea even within the austerity framework, if the risks of climate change are as dire as predicted. Replacing already online, zero-carbon generation with wind and solar plants that require carbon-emitting construction and infrastructure overhauls will only dig us deeper into debt. In an abundance framework, the proposal becomes even more misguided.

Energy efficiency—an indispensable part of the current climate strategy—would seem less virtuous if we were pursuing abundance rather than rationing energy. *Carbon* efficiency will still be important in processes where fossil fuels have not been replaced, but only because it minimizes the direct problem: carbon emissions. A truly abundant energy source is, by definition, so plentiful that "wasting" it is impossible. We will know that we

are generating abundant energy when worrying about how much electricity the Chinese use seems as perverse as worrying about how much air they breathe. "Do more with less" is the ethos of austerity. "Do more with more" is the ethos of the abundant world to which we should aspire.

Though faced with the prospect of devastation, Girolamo Fracastoro, in his letter to Cornaro, at times became rhapsodic:

> I cannot remain silent before you, given the pleasure to think about something so beautiful and lofty. I first thought it necessary and inevitable that this Lagoon would end up without the sea's waters, and would become swampland. Then I realized how necessary it is, if possible, that this abundant and worthy city can defend itself—if it can face the sea's challenge—and remain as habitable and great and powerful as it is today.

Though Fracastoro's own engineering proposals missed the mark, it was thanks to his civic spirit, and that of his competitors, that the city of Venice prospered through the generations.

Like any ideal, a world of true abundance will remain forever out of reach. But as a guiding principle, it is superior to our shoddy utopia of abridged ambition. There is still time to step back and reimagine the civilizational challenge that is climate change. We can cultivate new ways of thinking about the risks and remedies before us. We can find new ways past our present impasse. We can stop gazing woefully into some imagined end of history and instead see ourselves as the generation that links our ancestors to our progeny. The choice we have faced many times before—despair or resolve—is ours again today.

Laguna di Venezia *by Anton Melbye, 1878*