



A Plan to Save the Future from Extinction,
Climate Change, and Pandemics

Half-Earth Socialism

Troy Vettese and Drew Pendergrass

'An exercise in democracy few books have dared to undertake'
—Andreas Malm, author of *Fossil Capital*

Half-Earth Socialism

Half-Earth Socialism

*A Plan to Save the Future
from Extinction, Climate
Change, and Pandemics*

Troy Vettese and
Drew Pendergrass



VERSO

London • New York

First published by Verso 2022
© Troy Vettese and Drew Pendergrass 2022

All rights reserved

The moral rights of the editor and authors have been asserted

1 3 5 7 9 10 8 6 4 2

Verso

UK: 6 Meard Street, London W1F 0EG
US: 20 Jay Street, Suite 1010, Brooklyn, NY 11201
versobooks.com

Verso is the imprint of New Left Books

ISBN-13: 978-1-83976-031-0
ISBN-13: 978-1-83976-032-7 (UK EBK)
ISBN-13: 978-1-83976-033-4 (US EBK)

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data

A catalog record for this book is available from the Library of Congress

Typeset in Sabon by MJ & N Gavan, Truro, Cornwall
Printed in the UK by CPI Group

To our parents

Contents

Introduction

1. Binding Prometheus
2. A New Republic
3. Planning Half-Earth
4. News from 2047

Epilogue: An Epoch of Rest

Acknowledgements

Appendix

Notes

A map of the world that does not include Utopia is not worth even glancing at, for it leaves out the one country at which Humanity is always landing. And when Humanity lands there, it looks out, and, seeing a better country, sets sail. Progress is the realisation of Utopias.

–Oscar Wilde

We enter into Utopia's proper and new-found space: the education of desire. This is not the same as 'a moral education' towards a given end: it is, rather, to open a way to aspiration, to 'teach desire to desire, to desire better, to desire more, and above all to desire in a different way'.

–E. P. Thompson,
quoting Miguel Abensour

Introduction

Is it so incomprehensible that the people today cry out for utopias, for powerful presentations of their future fate?

–Otto Neurath

Looking Backward: 2047

In the autumn of 2029, after many years of ravaging the cities and hamlets of poor nations, climate change proved itself capable of bringing even the heartland of global capitalism to its knees. Swollen by the unseasonably warm waters in the north-west Atlantic, a hurricane of unprecedented ferocity left an arc of destruction from Washington, DC, to Boston.¹ Powerful storm surges deluged coastal towns and strong winds downed power lines, leaving 30 million people in darkness for weeks. As emergency crews dug through the rubble, even the most fanatical Republicans could no longer deny the effects of climate change. A consensus, reached in a candle-lit session of Congress, was not to decarbonize the energy system, but rather to deploy a radical and untested technology called solar radiation management (SRM) to ensure such a calamity would never again befall the United States.

The government contracted a start-up, spun from an Ivy League laboratory, to douse the heavens with a sulphuric mist. High-flying military jets were retrofitted to dump a payload of atmosphere-altering sulphur into the stratosphere. The resulting ‘stratoshield’ of reflective aerosols blocked out the sun by a carefully calibrated fraction and reduced global temperatures to pre-industrial levels within a few years. Respectable opinion conceded that while it was tragic that SRM caused a slew of poor harvests in equatorial countries and the additional atmospheric sulphur killed thousands of people every year, on the whole, the benefits surely

exceeded the costs.² Rather than seeing SRM as a dangerous and desperate measure, optimists portrayed it as a demonstration of American statesmanship, technology, and entrepreneurial pluck.

Soon, however, the costs of the SRM programme became impossible to overlook. A pernicious development was the sulphuric aerosols' steady erosion of the ozone layer – a protective shield upon which all earthly life depends. The geoengineers assured the public that an ozone-neutral aerosol would soon be found. They experimented with diamonds and engineered nanoparticles, and for a time they were especially excited by calcium carbonate because its alkalinity appeared capable of reversing the ozone layer's acidification.³ Unfortunately, the complex chemistry of the atmosphere meant that the calcium carbonate unexpectedly catalysed a reaction that actually left the ozone hole bigger than before.⁴ By the 2040s – more than a decade into the SRM programme – there was still no long-term solution to the problem. At this point SRM could not simply be switched off, because the high concentrations of greenhouse gases would heat the atmosphere all at once in what scientists called 'termination shock'.

While the threat to the ozone layer lingered on the horizon, SRM's disruption of various global weather systems was a clear and present danger. The most worrying was the weakening of the monsoon, which threatened the livelihood of tens of millions of Indian farmers. Through diplomacy and generous restitution, Washington managed to talk Delhi out of its threats to shoot down the American SRM fleet, but it was uncertain whether a similar agreement could be brokered with Moscow or Beijing if those governments confronted an SRM-induced disaster. Washington, however, cared little about what non-nuclear powers thought of the stratoshield, having implemented it roughshod over objections from other countries in 2029. American unilateralism in SRM research dated back to the late 2010s, when a coalition of African and low-lying island nations repeatedly tried to bring SRM under an international authority, such as the UN Environment Programme or the Montreal Protocol (a treaty which protects the ozone layer). The US had vetoed these motions to keep SRM unregulated; geoengineering, it seems, had always been a form of planetary class war.⁵

To ward off accusations of climate imperialism, geoengineers claimed that SRM was actually in the interest of poor nations.⁶ SRM, according to

this argument, lowered poor countries' risk premiums for 'catastrophe bonds', an exotic financial instrument hawked by Wall Street bankers keen to greenwash their portfolios. In this way, the geoengineers believed, the market could bridge the divide that separated the Global North and South. There was an opportunity to test this market solution soon after the 2029 deployment began, when unprecedented droughts wracked West Africa. Yet these crises usually did not meet all the conditions laid out in some contracts, leaving cash-strapped governments struggling to respond.⁷ Even when bondholders did pay out, the money often came too late to aid relief efforts, nor could it buy back ecosystems that had deteriorated under the new SRM regime.⁸ Such experiences contrasted sharply with SRM's impacts in the core capitalist states, where quotidian life continued more or less as normal save for the nearly permanent overcast weather. Even then, many saw blue skies as an inevitable casualty of modernity, much like electrification's extinction of starry nights a century before.

SRM marked the beginning of the end for the environmental movement. With chemicals partially blocking the energy source for solar panels, investors panicked and funds for renewable infrastructure crashed in the early 2030s, sparking an unexpected renaissance for the high-cost, environmentally destructive 'nonconventional' oil sector – tar sands, fracking, and deep-sea rigs. Indeed, far from being curtailed, total petroleum production was on track to reach 116 million barrels per day by 2040, some 16 per cent more than in the early 2020s.⁹ With the stratoshield in place, the imperative to abolish the fossil-fuel industry slackened. While SRM returned a measure of climatic and economic stability (if only in the rich North), this new global thermostat proved unable to reverse the decline of the biosphere. The macabre drum beat of habitat loss and extinctions continued unabated. Ecologists despaired at the disappearance of countless species whose life cycles were disoriented by the syncopated seasons and shocks of freak weather. Unabated carbon pollution threw off the ocean's chemistry to the point where only the hardiest creatures could survive in the vast acidic wastes. Sulphuric aerosols created acid rain that poisoned forests and lakes, undoing one of the great triumphs of environmental activism during the 1980s.

In sum, these events spelled a strange defeat for the environmental movement – strange because for decades it had won victory after victory. With millions demonstrating in the streets for climate justice in the 2010s,

environmentalist parties took power in regional and national governments around the world in the 2020s, allowing them to finally realize their dream of ‘green capitalism’. For example, carbon pricing, which covered only a fifth of global emissions in 2020, increased to half by 2030.¹⁰ Unfortunately, the median price only rose from US \$15/tonne to \$40 (translating to a mere \$0.36 a gallon at the pump). This fell well short of the more stringent targets set by the Intergovernmental Panel on Climate Change (IPCC), ranging from \$135 to \$6,050/tonne (i.e., topping out at an extra \$53.24 per gallon of gasoline).¹¹ The greens were more successful in implementing new global standards that ended up doubling the rate of energy efficiency growth between 2017 and 2040. Yet, such improvements were counteracted by total energy demand growing even faster.¹² Relative gains matter little on a finite planet. Proponents of ‘green’ cars (electric, fuel-cell, or hybrid) faced a similar set of contradictory trends. These vehicles made up a fifth of the global fleet in 2040 and 30 per cent of new sales – a real achievement – but because people were buying and driving cars at higher rates than ever, the total amount of oil guzzled by personal transportation barely budged.¹³ One major reason for this was the failure of green governments to reduce the demand for cars through increased urban density and public transportation. In 2040, wind and solar only made up 4 per cent of the energy system despite being the fastest-growing sources of power generation, while fossil fuels maintained a diminished but still commanding 76 per cent share.¹⁴ The problem was that the greens mistook slowing down the pace of the environmental crisis for victory, rather than merely a defeat postponed.

After decades of environmentalists’ championing ‘win–win’ solutions for both business and nature, it became clear that making unprofitable decisions was where true freedom lay. The ‘free’ market forbade shutting down fossil-fuel firms, implementing energy caps, and building large-scale renewable-energy infrastructure. Private utilities fiercely resisted the latter because they dreaded the renewable energy–induced ‘death spiral’: when too many people installed their own solar panels, utilities lost customers and were forced to raise prices, which in turn led to further shrinking of their market share. What’s more, these new consumer-producers destabilized the grid by selling excess energy on windy or sunny days. Utilities responded by lobbying hard against ‘feed-in tariffs’ and licences

for renewable energy production.¹⁵ Even if governments managed to overcome such resistance, the variability of wind and sun coupled with insufficient energy storage meant that disruptions in the energy supply were inevitable.¹⁶ Imposing such inconveniences was political suicide in the Global North, even if brown-outs had long been common in the South.¹⁷ The whole premise of ‘green capitalism’ was that environmentalists would only make minimal demands of firms and consumers in order to gain their support – but how could the world’s greatest problem be solved by such modest means?

Such political reticence extended, with perhaps the direst consequences, to the meat question. Environmentalists had long been loath to raise it in fear of losing support, but this proved a grave miscalculation. While ocean acidification from carbon pollution and the new SRM programme pushed many species to extinction, the greatest butcher of global biodiversity was the livestock industry.¹⁸ Despite constituting only a few percentage points of global GDP, animal husbandry ravaged countless wild ecosystems to sustain captive life in its teeming billions. Meat production doubled over the three decades before 2047, with devastating costs to local environments and the global climate.¹⁹ This future was supposed to have been averted by entrepreneurial scientists and ethical firms purveying ‘clean meat’ (lab-grown or plant-based), but while this new market grew significantly, just as with electric cars and the renewable energy sector, it could not solve the problem by itself. The market could sell both the poison and its antidote, but it cared little about the right ratio of the two.

As a planetary force comparable to the fossil-fuel industry, the livestock sector generated repeated shocks in the world system over these bleak decades. Million-animal operations were hothouses of zoonotic illnesses, and small-scale outbreaks occurred almost constantly: *E. coli* (including the dangerous STEC O104:H4 strain), Q fever, and salmonella contaminated water, air, and food.²⁰ However, these crises were mere pinpricks compared with the civilizational laceration of the avian flu pandemic of 2035, some three decades after the first instance of human-to-human transmission. Given that the virus’ victims suffered a mortality rate of 60 per cent, containing the global death toll to only 200 million seemed a pyrrhic victory of sorts.²¹ After this *annus horribilis*, there were calls to drain disease reservoirs within wild animal populations through intentional

extinctions.²² This was seen as more expedient than asking people to give up meat and expand nature preserves to act as cordons sanitaires, although public health experts had been advocating such a programme since the early twenty-first century.²³

It was difficult to prise the environmental and economic catastrophes apart during these years. The inexorable rise of factory farming wiped out the remnants of the world's 10,000-year-old peasantry. With little industry to absorb this displaced class, the share of humanity living in slums more than doubled between the early 2020s and 2047 to 3 billion people.²⁴ Inequality, automation, and low rates of economic growth meant that by 2040, some 24 per cent of the world's population was reduced to involuntary indolence, a fourfold increase compared with the mid-2010s.²⁵ By 2050, the richest 1 per cent had funnelled 39 per cent of the world's wealth into their pockets, dwarfing the 27 per cent held by the global middle class (i.e., the middle two-fifths of humanity), let alone the scraps held by the bottom billions.²⁶ Inequality had environmental consequences too, as the top 1 per cent emitted *twice* as much carbon as the bottom half of humanity.²⁷ In the mid-2030s, the first trillionaire emerged: a Chinese tech mogul narrowly beat an American rival to become a modern Croesus. Geoengineering made small but still substantial fortunes for the scientist-entrepreneurs, who cashed in on the IPO of their start-up soon after the stratoshield was put in place. Conspiracy theorists who saw SRM as poisonous 'chemtrails' ensured that the geoengineers enjoyed little peace; some were even assassinated.²⁸

Although much of the natural world had been transformed into a factory farm, a suburb, or a garbage dump, the market's control over the biosphere remained far from complete. SRM best revealed the gulf that lay between mastery and unintended chaos. Even after years of study and implementation, the geoengineers still hadn't fully grasped the hyper-complexity of the Earth system that spanned living creatures, the oceans' slow churn, and a vast, turbulent climate. They confronted this challenge with complacency rather than humility in the face of what they did not – and indeed could not – know. In the decades leading up to 2029, the geoengineers did not bother to collect much baseline data or build detailed models.²⁹ In this way, their actions belied what some philosophers of science had suspected: that small-scale SRM experiments could never

capture what implementation would be like due to the complexity of the Earth system.³⁰ In this post-experimental era, action replaced knowledge.

In the 2030s, the material and political threat posed by climate change to the prevailing order peaked and subsided. The fact that scientist-entrepreneurs and their generous philanthropic backers overcame the climate crisis through SRM seemed to vindicate faith in the market. Fossil-fuel companies, conservative think tanks, and economics departments, after all, had been among the earliest supporters of geoengineering.³¹ That conservative coalition, which had cultivated this crisis of environmental catastrophe and inequality since the mid-twentieth century, remained dominant a century later. Despite briefly tasting power, the environmentalists accomplished little because they never elucidated how the various facets of the environmental crisis – climate change, pandemics, and mass extinctions – were interlinked; nor did they articulate what a post-crisis society might actually look like. The ruling class had long been clever and ruthless, but they were also fortunate to face such hapless opponents.

The View from Mont Pèlerin

How can this dystopian future be avoided? Environmental collapse and feudal levels of inequality are not inevitable. Although the biosphere is certainly in dire shape, there is still time to reverse its decline and simultaneously create a just society. The purpose of this book is to outline the material conditions of the current ecological predicament and show how it can be transcended by providing new ways of conceiving the relationship between the economy and the environment. While at times our proposals may seem outlandish – our book, after all, belongs to the utopian tradition – they are meant to encourage those on the Left and in the environmental movement to take seriously the challenge of not merely surviving the next century but creating a better society within a wilder and stabilized biosphere.

Our thought experiment of the decades leading up to 2047 reveals the inadequacy of mainstream environmentalism. We tried to be fair by assuming the rapid uptake of carbon markets, renewable energy, and electric cars, and show how these measures would still fail to prevent a global ecocide by mid-century. It is not enough if the market for ‘clean

meat' or renewables grows quickly – their environmentally deleterious competitors must also contract, and this is unlikely to happen if environmental policy is guided by price signals. Indeed, our survey shows that it is not so much the monetary value or rate of growth that matters, as it is the physical composition of the global economic metabolism: How much land are we converting from forest to pasture? How much energy are we using, what are its physical properties, and how is it generated? How should we allocate necessary but environmentally costly resources such as steel and concrete?

Why, then, is politics outsourced to the market, an institution that clearly cannot address the environmental crisis? This question forces us to confront the market's high priests: the neoliberals. In 2047, they will not only celebrate the centennial of their movement's birth but likely be in a strong position to enjoy a second century of intellectual, political, and economic hegemony.

The epithet 'neoliberal' is often a grenade lobbed with the pin attached, because this explosive term is rarely understood by those hurling it. To grasp this controversial and murky ideology, it helps to return to the moment of its genesis as a self-conscious movement. On 10 April 1947, thirty-nine European and American intellectuals congregated at the Hotel du Parc, a luxurious Swiss establishment perched upon Mont Pèlerin.³² Those attending this first meeting of the Mont Pèlerin Society – an organization that still exists – sought to reinvent liberalism for an age when the market was everywhere in retreat. The Great Depression, World War II, and the post-war welfare state made clear that classical liberalism's faith in laissez-faire was obsolete. Departing from their eighteenth-century tradition, the neoliberals recognized that markets were hardly natural but rather needed nurturing and protection by a strong state. Markets deserved such care because they could concentrate knowledge diffused throughout society into the metric of price. The conference's impresario, Friedrich Hayek, saw the price system as a mechanism not merely for exchanging goods but also 'for communicating information'.³³ Markets allowed people to act rationally as individuals without full knowledge of *why* prices change, which meant that society's 'optimal ignorance' was surprisingly high.³⁴

While we disagree with the neoliberals' belief in the all-knowing market, we admire their commitment to simple and powerful axioms. If, as they claim, the market produces knowledge better than other institutions – such as science or central planning – then it follows that all of society and nature should be set to the logic of the price system by a neoliberal state. This philosophical shorthand allows neoliberals to diagnose the ills of the world and to propose a slate of prescriptions.³⁵ It allows them to *act*. We believe that environmentalists and socialists need a similar shorthand to regain political momentum. Thirty-four years ago, Stuart Hall proposed 'learning from Thatcherism' because neoliberals had demonstrated how 'good ideas ... don't fall off the shelf without an ideological framework to give those ideas coherence.'³⁶ In many ways, our political philosophy is crafted in the mirror image of neoliberalism because we similarly focus on questions of knowledge and the role of markets in society. Through this intellectual exchange, we have devised a few principles to provide the basis of what we call Half-Earth socialism.

The concept of Half-Earth comes from E. O. Wilson, an entomologist whose research has shown the need to rewild half of the planet to staunch the haemorrhaging of biodiversity. While global warming, poaching, and invasive species decimate flora and fauna, Wilson stresses that the greatest driver of extinction remains habitat loss.³⁷ So, why is it 'Half-Earth' and not a quarter or three-fifths? Early on in his career, Wilson and his colleague Robert MacArthur discovered a simple mathematical relationship between land area and biodiversity. In their study of island biogeography, they found that the number of species was roughly proportional to the fourth root of the area.³⁸ This meant that, all things being equal, there were fewer species on small islands than on large ones. Decades later, Wilson realized that nature preserves were the terrestrial equivalents of islands. As 15 per cent of the world's land area is presently protected (plus a measly 2 per cent of the ocean), only half of all species will survive the Sixth Extinction.³⁹ To create a global ark able to protect 84 per cent of species, then 50 per cent of Earth needs to be protected ($0.5^{0.25} = 0.84$).⁴⁰ Such costly but necessary ecological stewardship would yield many other benefits, such as sequestering atmospheric carbon in rejuvenated ecosystems and creating buffers to prevent the emergence of new zoonoses.⁴¹ Yet Wilson fails to see that Half-Earth must be socialist if it is

ever to exist. Such an enormous reform would quickly run up against entrenched economic interests, from mining firms to ranchers, many of whom would be willing to bloody their hands to protect their bottom line.⁴²

As we sketch what Half-Earth socialism might look like, we strive to carefully account for what is necessary and feasible, even if such things are hardly politically expedient now. If Hayek had circumscribed his political aims with the political realities of 1947, we would not be living in a neoliberal society today. Nonetheless, our utopian imagination is constrained by quite conservative parameters derived from the scientific literature on energy production, land use, planning, and ‘planetary boundaries’. Much of the book is dedicated to debunking panaceas beloved across much of the political spectrum, such as nuclear power, geoengineering, ‘green growth’, and carbon capture and storage. We train an equally sceptical eye on the solutions proposed by the demi-monde of Brooklyn socialists to the alpine eyrie of Davos’ philanthropist kings (it’s not clear why Swiss hotels are so attractive to megalomaniacs). While our book critically engages with neoliberalism, it also confronts the delusions of the political centre and Left.

This book’s purpose, however, is not primarily to criticize the present but to posit a countervailing positive vision for the future. We survey the present crisis and detail how an eco-socialist alternative might work in practice. Our framework draws on ecology, energy studies, epidemiology, cybernetics, history, mathematics, climate modelling, utopian socialism, and, yes, neoliberalism. This is not to say that we have drafted the only possible solution for everything that ails the world today; this is merely a start, a provocation, for a broader but more serious discussion about life after capitalism. We want to ask the hard questions about politics in an age of ecological collapse: What is socialism? How does socialist democracy work? What does a truly environmentally stable society look like? How could an eco-socialist coalition take power? How would local, national, and global levels of government interact? Half-Earth socialism’s tension between utopianism and practicality allows us to create a framework commensurate with the scale of the task at hand but is simultaneously realistic enough to provide the basis for socialism in our lifetime.

From 1989 to 2047

Neoliberal hegemony has endured so long because its opponents have repeatedly let crises go to waste. The Great Recession of 2008 left Alan Greenspan (a former Federal Reserve chairman and card-carrying member of the Mont Pèlerin Society) so disoriented that he confessed his ‘mistake’ in trusting the market to guide financial actors rather than relying on direct regulation.⁴³ The catastrophic SARS-CoV-2 pandemic was an even greater disturbance to the neoliberal order, but neither environmentalists nor socialists secured significant gains.

By contrast, the neoliberals were well prepared intellectually and organizationally to attack the welfare state when opportunities presented themselves. They took advantage of the economic instability of the 1970s to orchestrate a bloody coup in Chile (1973), followed by electoral victories in Britain (1979) and the US (1980). The neoliberals won because they paired sudden ruthlessness with a willingness to wage a decades-long war of ideas. They can be beaten, but only if socialists and environmentalists create a diverse coalition guided by shared political aims. Until that happens, the only real competition the neoliberals face will be ‘racist-libertarians’ – the architects of Brexit, the alt-right, and Alternative für Deutschland – in what is basically an intra-Hayekian feud rather than a real clash of ideologies.⁴⁴ If the Left and the environmentalist movement had undergone a theoretical and organizational revision of Mont Pèlerin proportions following their defeats in the 1980s, then things might not be so bleak now.

In the decades since the collapse of the Eastern bloc, the Left has lost not only time to reinvent itself politically but also crucial ecological buffers that guard against collapse. From the vantage point of 2022, the natural world of the late 1980s and early 1990s appears almost Edenic. In 1988, atmospheric carbon pollution was only a modest 350 ppm, the pie-in-the-sky target that inspires Bill McKibben’s 350.org movement.⁴⁵ As we write this, 2021 is on course to be the first year in which atmospheric carbon levels have averaged 50 per cent higher (419 ppm) than the pre-industrial norm (278 ppm).⁴⁶ Well over half of all carbon emissions and most of the deforestation of the Amazon rainforest have occurred since 1990.⁴⁷ During that time, 420 million hectares of the world’s forests have been razed, an area equal to India and Pakistan put together.⁴⁸ At the end of the Cold War, China had only just begun to build up what was to become its gigantic livestock industry, thus bringing its millennia-old tradition of sustainable

agriculture to an end.⁴⁹ As a consequence of this agricultural industrialization, avian flu (H5N1) jumped for the first time from poultry to humans in 1997, with numerous outbreaks in China and elsewhere since then. The environmental crisis has *accelerated* since 1989 in large part because of the China boom – by far the largest and fastest industrial revolution ever.⁵⁰ With Deng Xiaoping's efforts to liberalize the Chinese economy in the 1980s, the fall of socialist governments, and the decimation of the global peasantry, the world market has now spread to the ends of the earth, accelerating resource extraction and leaving ecological devastation in its wake.

While time has been lost, hope need not be – if only because the neoliberals are few in number compared to those who suffer at their hands. This is not to say that unifying these multifarious millions will be easy. Making such a coalition requires that movements learn from each other and make concessions when necessary. Environmentalists must curb their Malthusianism, an ideology that blames ecological and economic problems on 'overpopulation'. A commitment to environmental justice, not the bigoted environmentalism of times past, must be central to the movement, so that people of colour – who bear the brunt of the environmental crisis – can take the lead in shaping the future. Conservationists need to work carefully with Indigenous nations to ensure that nature preserves do not continue to act as institutions of colonial exclusion.⁵¹ Socialists need to realize that the gravity of the current crisis demands taking environmental limits seriously, even if it means giving up fantasies of a post-capitalist Cockaigne. Although intellectuals on the Left faddishly invoke 'ecology' or the 'Anthropocene', too often this is mere analytical garnish rather than rigorous engagement with contemporary science. Scientists should ally with social movements – otherwise they are doomed to model ever more unlikely climate scenarios or back foolhardy measures like SRM. The gap between socialism and science was not always so wide as it is now. In 1941, Hayek fretted that the Left 'has been strongly supported and even led by men of science and engineers'; the renewal of that alliance would strike fear in the neoliberals' coal-black hearts.⁵²

The central role of the livestock industry in the climate and extinction crises means that the animal-rights movement should be a contingent within a Half-Earth socialist coalition even though they have often been the

‘orphans of the Left’.⁵³ Vegans have often fitted awkwardly within the broader Left because of their widespread adherence to utilitarianism – a creed that uncritically accepts capitalism. Nor have vegans helped their cause with their tone-deaf comparisons of the plight of animals with marginalized groups like the disabled, Black people, and victims of the Judeocide during World War II.⁵⁴ These problems, however, aren’t insurmountable and are sometimes magnified by misperceptions and clichés. In the US, for example, vegans are disproportionately working-class people of colour.⁵⁵ More than a century ago, Upton Sinclair imagined in his proletarian novel *The Jungle* that socialism would be largely vegetarian because no one should be forced to engage in the ‘debasement and repulsive’ work of the slaughterhouse.⁵⁶ Animal-rights groups could cooperate with workers to achieve Sinclair’s aim of squeezing profit margins through line slowdowns and higher wages until the industry is abolished.

Feminists, too, would be crucial allies in this struggle. Whether we achieve Half-Earth socialism or not, changes in the labour market are already beginning to centre women workers, and will continue to do so. Jobs that are often done by women, so-called ‘pink-collar’ jobs in health and education, not only represent some of the strongest segments of the labour movement today but also foreshadow the shift to a zero-carbon economy that prioritizes care work over extractive labour. ‘Labour movements in the nineteenth and twentieth centuries insisted that workers had built the world in the most literal sense’, observes political philosopher Alyssa Battistoni. ‘The labour movement of the twenty-first century needs to foreground the workers who will make it possible for us to live in it.’⁵⁷ The eco-socialist future is female. To reach such a bright horizon, however, we need to deal with the widespread misogyny in contemporary socialist, environmentalist, and animal-rights organizations.⁵⁸

Without a shared world-view to bind this heterogeneous movement of movements, each faction risks political impotence through isolation, or worse, co-optation by the ruling neoliberal bloc. If the expansion of green infrastructure through a Green New Deal is forever postponed, it will be hard to reproach trade unions for accepting the few jobs on offer in pipeline construction. While it is necessary to end the exploitation of animals, animal-rights activists should temper their attacks on Indigenous hunting, both out of respect for a different way of life and as a matter of tactics,

because native peoples have spearheaded many successful environmental campaigns.⁵⁹ Indigenous hunting, after all, is not what got us into this mess. In fact, biodiversity tends to be higher in Indigenous-managed territory than in nature preserves.⁶⁰ The pursuit of global equality, too, must be part of Half-Earth socialism if it is going to stand any chance of being realized. By refusing to countenance restrictions on energy use in the rich world, Northern environmentalists have fostered little solidarity with potential allies in the Global South.⁶¹ And so on. Neoliberals have not needed to divide and conquer their enemies because liberatory movements have obliged with their own interminable feuds.

How such a Half-Earth socialist coalition might come to power we cannot say. In some countries it might follow a path similar to the rise of Nelson Mandela and the African National Congress in South Africa: a mixture of strikes, divestment, sabotage, elections, boycotts, and violence. In other countries a purely electoral strategy might work, but such a victory would only mark a new phase of struggle. Karl Marx approved of competing in elections but predicted that if a dedicated socialist party were to ever win, the ruling class would unleash a ‘pro-slavery rebellion’ against a ‘peaceful and legal revolution’.⁶² Nearly a century later, this prediction was borne out by the massacre in Chile in 1973. As historian Eric Hobsbawm observed in its bloody aftermath, ‘the Left has generally underestimated the fear and hatred of the Right, the ease with which well-dressed men and women acquire a taste for blood’.⁶³ One should not expect the neoliberals to meekly accept defeat.

The Narrative Ark

In 1888, Edward Bellamy wrote *Looking Backward*, his vision of a harmonious futuristic socialism in the year 2000.⁶⁴ However, it is harder to share Bellamy’s optimism when we look backward from 2047. Although the future may appear bleak now, it is all the more pressing to imagine utopian alternatives to motivate and mobilize the dispirited masses. ‘To many thousands of isolated thinkers’, radical economist J. A. Hobson observed, ‘[*Looking Backward*] offered the first distinctively moral support and stimulus to large projects of structural reform in industry and

politics'.⁶⁵ For us, agreeing on the details of what that utopia might look like matters less than agreeing that speculation is a vital political act. This means reviving the utopian socialist tradition that has for far too long been marginalized by the 'scientific socialism' of Marxism. What was a nuanced critique of utopian socialism in Marx's hands became a bludgeon wielded by his epigones who scorned post-revolutionary proposals as frivolous 'recipes for the cookshops of the future'.⁶⁶ Condescension towards utopianism is not only poetically impoverished but also a tactical mistake, because it limits the Left's ability to implement a socialist programme upon taking power. There is in fact a literal need to write recipes for society after the revolution, because the environmental crisis makes clear that those cook-shops must be vegan. Think then of *Half-Earth Socialism* as a cookbook divided into four courses: the philosophical, the material, the technical, and the imaginative.

The first chapter can be thought of as a delicate hors d'oeuvre. It attempts to set the philosophical foundations for a new eco-socialism much in the way that the neoliberals of the 1940s worked from first principles to revive liberalism. To do so we go back to 1798, when three competing philosophies of nature emerged simultaneously – those of G. W. F. Hegel, Thomas Malthus, and Edward Jenner. Hegel believed that humanity would eventually fully 'humanize' and control nature, an attitude towards nature that would later be called 'Prometheanism' and adopted by Marx and his followers. While Malthus' influence on the environmental movement peaked in the 1960s and 1970s, his dread of 'overpopulation' remains widespread among green activists and thinkers today. Jenner, who studied and popularized the smallpox vaccine, presciently warned against humanity's unnatural dominion over the animal kingdom. This survey of the late eighteenth century leads us to the central problem confronted by neoliberals during the mid-twentieth: what can we know? While neoliberals stress the unknowability of the market – which is why central planning could never replace it – we counter that nature is much more complex. The environmental crisis forces us to decide between controlling the market and controlling nature, a dilemma that is especially clear in the case of SRM. A new eco-socialism, then, must be based on the unknowability of nature and, consequently, the need to control the economy within safe limits.

The second chapter is a hearty appetizer, where we begin to use the principles developed in the first chapter to decide upon an array of solutions

based on their material characteristics. We are interested in such things as yields per hectare and watts per square metre of various agricultural and energy systems. First we focus on the solutions offered by mainstream environmentalists: bioenergy carbon capture and sequestration (BECCS), nuclear power, and Wilson's Half-Earth. We show how these policies – yes, even Half-Earth – do not suffice to reverse the biosphere's deterioration. This is because energy, biodiversity, and carbon sequestration are not the three separate spheres they appear to be in environmental discourse but rather a single problem mediated through the scarcity of land. This insight, which we glean from examining the shortcomings of these three 'solutions', helps us develop the material aspects of Half-Earth socialism: veganism, renewables with energy quotas, and planetary rewilding.

The main course, the third chapter, delves into the devilishly difficult problem of planning. If it is necessary to prevent the market commodifying and controlling all of nature, and we also have a sense of what material goals we want to achieve, how then is it possible to organize production and consumption without a market? We draw on a range of influences, including Soviet cybernetics and mathematics, Chile's 'Cybersyn' programme, meteorology, and cutting-edge integrated assessment models (IAMs) used by climate scientists today. We have even constructed a Half-Earth socialist planning game to illustrate the difficult trade-offs such a society would have to navigate. We invite you to use the model online at <http://half.earth>, so that you, too, can be a Half-Earth socialist planner. With this preliminary model in hand, we try to envision what a complete global simulation might look like, and thus bring us closer to planning the world.

For dessert we indulge in utopian socialist fiction. Our story is a modest contribution to a literature that includes Thomas More's *Utopia* (1516) – which Karl Kautsky regarded as 'the foregleam of Modern Socialism' – Bellamy's *Looking Backward* (1888), William Morris' *News from Nowhere* (1890), Ursula K. Le Guin's *The Dispossessed* (1974), and many others. Instead of thinking abstractly about epistemology or on a global scale in terms of climate models, we focus our perspective on a neighbourhood and try to imagine quotidian life under Half-Earth socialism. What would it be like to work without the threat of unemployment? How would economic co-ordination function without money or a market? What might it be like to live in a world where nature can recover because half the planet has been

rewilded? What does it mean to live in a society where the economy is consciously and democratically controlled?

Half-Earth Socialism's four-course structure offers food for thought in two ways. The first is as a prospectus outlining what would be necessary to transcend the environmental crisis. Some of our readers might be sceptical of our programme of rewilding and central planning, and therefore we invite them to use the book a second way, as a guide to utopian thought experiments. Proceeding along the same three levels of analysis, another budding futurist could make judgements that differ from ours. Perhaps the key philosophical principle of eco-socialism is not the unknowability of nature but something else, say, the hybridity of nature and culture. At the next step, our utopian reader could opt for nuclear power or even SRM, rather than a fully renewable system. Another choice could be creating a Two-Thirds Earth to reduce extinction to even lower levels ($0.67^{0.25} = 0.90$). Lastly, one might come up with a mode of economic distribution different from our cybernetic central planning and instead espouse an 'ecosystem of markets'.⁶⁷ Such a reader would devise a utopia different from Half-Earth socialism, and that is fine, for we do not pretend to have all the answers to the world's most difficult questions.

For too long the Left has been better at critique than creating its own positive proposals. In the rare chance that they take power, socialists will falter and fall without a programme to guide the transition beyond capitalism. Half-Earth socialism, we hope, is a vision of the future that can develop into a total alternative to capitalism, including everything from a plan for resource allocation to an outline of what life will *feel* like. We invite everyone from all liberatory traditions to join us in the revolutionary kitchen to think up many new recipes and work together to realize them. Indeed, we need many speculative contributions on the political horizon before it is suffused with a sulphurous mist and the future becomes as dim as the fixed grey skies of neoliberal hegemony.

Appendix

Assumptions for the linear programming model outlined in [chapter three](#) are as follows.

We assume a population of 10 billion people, all to be supplied a nutritionally sufficient diet and allotted an equal energy quota. Total habitable land area is 104,000,000 km² (see Hannah Ritchie and Max Roser, ‘Land Use’, *Our World in Data*, September 2019, ourworldindata.org).

We assume two biophysical boundaries: at least 50 per cent of land (52,000,000 km²) must be left to nature, and carbon emissions must be mitigated such that, assuming moderate climate sensitivity, temperatures will not exceed a small amount of warming (1.5 or 2°C, depending on the plan).

For a 67 per cent chance of keeping warming below 1.5°C, we assume a remaining carbon budget of 570 gigatonnes of CO₂, generous given that four years have passed since the IPCC estimate was made. Assuming equal emissions across the population for the remainder of the century, that gives 0.73 tonnes CO₂/year/person. Limiting warming to 2°C is much easier, with a budget of 1,320 gigatonnes CO₂, corresponding to 1.69 tonnes CO₂/year/person. Although rewilding and even some deployment of carbon-removal technologies would reduce CO₂ and give some wiggle room, we do not factor this into our calculations. (For these carbon budgets, see Kelly Levin, ‘According to New IPCC Report, the World Is on Track to Exceed Its “Carbon Budget” in 12 Years’, World Resources Institute, 7 October 2018, wri.org.)

Land use and emissions for various diets were mentioned earlier in [chapter three](#), but to reiterate, there are three options the linear

programming algorithm can choose from: omnivory, with 1.08 hectares and 2.05 tonnes carbon/year/person; vegetarianism, with 0.14 hectares and 1.39 tonnes; and veganism, with 0.13 hectares and 1.05 tonnes. The sum of vegetarians, vegans, and omnivores equals the global population.

We assume some portion of the world's agriculture is 'regenerative', meaning that reforms are taken to protect soil carbon and reduce emissions. While some regenerative-agriculture advocates think emissions could be negative, we take the more modest figure of 70 per cent reduction cited earlier. We assume regenerative agriculture has lower yields and therefore needs more land to produce as much food as conventional agriculture; following an estimate for organic crops, we estimate a 34 per cent reduction in regenerative yields. (See Verena Seufert et al., 'Comparing the Yields of Organic and Conventional Agriculture', *Nature* 485, no. 7397 [2012]: 229–32.) We pick an ambitious 80 per cent of agriculture to be 'regenerative' in this sense, though as long as agricultural emissions are reduced below the per capita allowance (most relevant in the 1.5°C case), model output isn't overly sensitive to this quantity.

Emissions and land-use figures for different power generation methods are assumed as follows: coal and petroleum have emissions of 8.5 and 8.8 kg CO₂/year/W respectively, calculated using the same source as the methane (natural gas) emissions in the text, while their land-use costs are 1,000 W/m² for coal (high variance as with methane; Smil, *Power Density*, 140) and 650 W/m² for petroleum (2012 global mean for extraction; Smil, *Power Density*, 115); methane, to reiterate the text, costs 3.6 kg CO₂/year/W with a power density of 4,500 W/m²; biofuels, concentrated solar power (CSP), photovoltaics, and wind are all assumed to have zero emissions; CSP, photovoltaics, and wind have power densities of 20, 10, and 50 W/m² respectively, while liquid biofuels from a mix of ethanol and biodiesel have power densities of 0.3 W/m², and solid biofuels from wood and gaseous biofuels from phytomass have a density of 0.9 W/m² (Box 8.1 in Smil, *Power Density*, 246).

Following Smil's estimates, we assume wind and solar power compose equal parts of electricity generation. In the US in 2012, 15 per cent of fossil-fuel use went to electricity, 52 per cent to liquid fuels, and 33 per cent to solid and gaseous fuels. Hence we consider four scenarios: one where just electricity generation is made renewable but the overall mix remains

the same; one where electricity generation is renewable and fuel use falls by 50 per cent due to reforms such as the strict rationing of transportation, an uptick in recycling materials like steel, and curtailment of other resource use (new energy mix is 26 per cent electricity, 45 per cent liquid fuels, 29 per cent solid/gaseous fuels); one where all but 10 per cent of liquid fuels are entirely electrified and solid/gaseous fuel use halved (new mix 74 per cent electricity, 6 per cent liquid fuels, and 20 per cent solid/gaseous fuels); and one of total electrification of all sectors. For electricity generation, the linear programming model is free to choose any fuel source. For liquid fuels, it must meet the quota using one of liquid biofuels or petroleum. For solid/gaseous fuels, it must use solid/gaseous biofuels, methane, or coal.

The model is run using the PuLP package in Python.

Notes

Introduction

- 1 Thomas Knutson et al., ‘Tropical Cyclones and Climate Change Assessment: Part II: Projected Response to Anthropogenic Warming’, *Bulletin of the American Meteorological Society* 101, no. 3 (2020): E303–22.
- 2 David Keith, *A Case for Climate Geoengineering* (MIT Press, 2013), 71; David Keith, ‘The Perils and Promise of Solar Geoengineering’, lecture at Harvard Museum of Natural History, Cambridge, MA, 30 October 2019, YouTube video, 1:05:28, youtube.com.
- 3 David W. Keith et al., ‘Stratospheric Solar Geoengineering Without Ozone Loss’, *Proceedings of the National Academy of Sciences* 113, no. 52 (2016): 14910–14.
- 4 Daniel J. Cziczo et al., ‘Unanticipated Side Effects of Stratospheric Albedo Modification Proposals Due to Aerosol Composition and Phase’, *Scientific Reports* 9, no. 18825 (2019).
- 5 ‘MOP 30 Highlights’, *Earth Negotiations Bulletin* 19, no. 144 (2018), enb.iisd.org; Sara Stefanini, ‘US and Saudi Arabia Block Geoengineering Governance Push’, *Climate Home News*, 14 March 2019, climatechangenews.com.
- 6 Joshua Horton and David Keith, ‘Solar Geoengineering and Obligations to the Global Poor’, in *Climate Justice and Geoengineering: Ethics and Policy in the Atmospheric Anthropocene*, ed. Christopher J. Preston (Rowman & Littlefield, 2016).
- 7 John Lauerman and Tasos Vossos, ‘Pandemic Bonds Paying 11% Face Their Limits in Ebola-Hit Congo’, *Bloomberg Quint*, 14 August 2019, bloombergquint.com.
- 8 Jeremy Blackman, Micah Maidenberg, and Sylvia Varnham O’Regan, ‘Mexico’s Disaster Bonds Were Meant to Provide Quick Cash after Hurricanes and Earthquakes. But It Often Hasn’t Worked Out That Way’, *Los Angeles Times*, 8 April 2018, latimes.com.
- 9 Christopher J. Smith et al., ‘Impacts of Stratospheric Sulfate Geoengineering on Global Solar Photovoltaic and Concentrating Solar Power Resource’, *Journal of Applied Meteorology and Climatology* 56, no. 5 (2017): 1483–97; ExxonMobil, *Outlook for Energy: A Perspective to 2040* (2019), 30, corporate.exxonmobil.com/Energy-and-environment/Looking-forward/Outlook-for-Energy.
- 10 ‘The World Urgently Needs to Expand Its Use of Carbon Prices’, *Economist*, 23 May 2020, economist.com.
- 11 To keep warming below 1.5°C, the IPCC estimates that carbon taxes will have to fall into the range of \$135 to \$6,050 by 2030. Marc Hafstead and Paul Picciano, ‘Calculating Various Fuel Prices under a Carbon Tax’, *Resources*, 28 November 2017, resourcesmag.org; IPCC, *Global Warming of 1.5°C: An IPCC Special Report* (2018), 152.
- 12 ExxonMobil, *Outlook for Energy*, 9.
- 13 *Ibid.*, 14.

- 14 Ibid., 28.
- 15 ‘A World Turned Upside Down’, *Economist*, 25 February 2017; Jacques Leslie, ‘Utilities Grapple with Rooftop Solar and the New Energy Landscape’, *Yale Environment* 360, 31 August 2017, e360.yale.edu.
- 16 There are no good options for storage in a renewable energy system. Dams are quite destructive, while batteries have a very low energy density. Richard Heinberg and David Fridley, *Our Renewable Future: Laying the Path for One Hundred Percent Clean Energy* (Island Press, 2016), 56–7.
- 17 David McDermott Hughes, ‘To Save the Climate, Give Up the Demand for Constant Electricity’, *Boston Review*, 1 October 2020, bostonreview.net.
- 18 Linnea I. Laestadius et al., ‘No Meat, Less Meat, or Better Meat: Understanding NGO Messaging Choices Intended to Alter Meat Consumption in Light of Climate Change’, *Environmental Communication* 10, no. 1 (2016): 84–103; Brian Machovina, Kenneth J. Feeley, and William J. Ripple, ‘Biodiversity Conservation: The Key Is Reducing Meat Consumption’, *Science of the Total Environment* 536 (2015): 419–31.
- 19 ‘Meat and Meat Products’, Food and Agriculture Organization of the United Nations, fao.org/ag.
- 20 Mary J. Gilchrist et al., ‘The Potential Role of Concentrated Animal Feeding Operations in Infectious Disease Epidemics and Antibiotic Resistance’, *Environmental Health Perspectives* 115, no. 2 (2007): 313–16; Kate Kelland, ‘French-German *E. coli* Link Seen in Sprouted Seeds’, Reuters, 27 June 2011, reuters.com; Wim van der Hoek et al., ‘Epidemic Q Fever in Humans in the Netherlands’, *Advances in Experimental Medicine and Biology* 984 (2012): 329–64.
- 21 ‘Influenza: H5N1’, *World Health Organization*, who.int/news-room/q-a-detail/influenza-h5n1; James Sturcke, ‘Burning Issue’, *Guardian*, 22 August 2005.
- 22 For a criticism of culling, see Susanne H. Sokolow et al., ‘Ecological Interventions to Prevent and Manage Zoonotic Pathogen Spillover’, *Philosophical Transactions of the Royal Society B: Biological Sciences* 374, no. 1782 (2019): 20180342; Daniel G. Streicker et al., ‘Ecological and Anthropogenic Drivers of Rabies Exposure in Vampire Bats: Implications for Transmission and Control’, *Proceedings of the Royal Society B: Biological Sciences* 279, no. 1742 (2012): 3384–92.
- 23 Jonathan A. Patz et al., ‘Unhealthy Landscapes: Policy Recommendations on Land Use Change and Infectious Disease Emergence’, *Environmental Health Perspectives* 112, no. 10 (2004): 1092–8.
- 24 World Health Organization, *A Billion Voices: Listening and Responding to the Health Needs of Slum Dwellers and Informal Settlers in New Urban Settings* (WHO Kobe Centre, 2005), 4, who.int/social_determinants. For a countervailing analysis on this question, see Aaron Benanav, ‘Demography and Dispossession: Explaining the Growth of the Global Informal Workforce, 1950–2000’, *Social Science History* 43, no. 4 (2019): 679–703.
- 25 Cornelia Daheim and Ole Wintermann, *2050: The Future of Work* (Bertelsmann Stiftung, 2016), 11, bertelsmann-stiftung.de.
- 26 World Inequality Lab, *World Inequality Report 2018: Executive Summary*, Fig. E9, wir2018.wid.world/files.
- 27 Fiona Harvey, ‘World’s Richest 1% Cause Double CO₂ Emissions of Poorest 50%, Says Oxfam’, *Guardian*, 21 September 2020.
- 28 Among others, David Keith, a leading geoengineer, has received death threats from chemtrails conspiracy theorists. Virginia Gewin, ‘Real-Life Stories of Online Harassment – and How Scientists Got Through It’, *Nature*, 16 October 2018, nature.com.
- 29 Raymond Pierrehumbert, ‘The Trouble with Geoengineers “Hacking the Planet”’, *Bulletin of the Atomic Scientists*, 23 June 2017, thebulletin.org.

- 30 Simon Factor, 'The Experimental Economy of Geoengineering', *Journal of Cultural Economy* 8, no. 3 (2015): 309–24.
- 31 Steven D. Levitt and Stephen J. Dubner, *SuperFreakonomics: Global Cooling, Patriotic Prostitutes, and Why Suicide Bombers Should Buy Life Insurance* (William Morrow, 2011); Philip Mirowski, *Never Let a Serious Crisis Go to Waste: How Neoliberalism Survived the Financial Meltdown* (Verso, 2014), 340. Geengineer David Keith's start-up Carbon Engineering is supported by Chevron and Murray Edwards, a Canadian tar sands magnate. See carbonengineering.com/our-team.
- 32 Quite a few well-known intellectuals attended this luxury-hotel liberal jamboree, including Karl Popper, Raymond Aron, Milton Friedman, Ludwig von Mises, Michael Polanyi, and Bertrand de Jouvenel. Only one woman, historian Veronica Wedgwood, was invited. See Bruce Caldwell, 'Mont Pèlerin 1947', in *From the Past to the Future: Ideas and Actions for a Free Society*, ed. John B. Taylor (Mont Pèlerin Society, 2020), 44, hoover.org.
- 33 Friedrich Hayek, 'The Use of Knowledge in Society', *American Economic Review* 35, no. 4 (1945): 526. Philip Mirowski summarizes Hayek's innovation as recasting the market as a sort of all-knowing 'information-processor'. Mirowski, *Never Let a Serious Crisis Go to Waste*, 54.
- 34 Mirowski, *Never Let a Serious Crisis Go to Waste*, 77.
- 35 Ibid., 332. Mirowski observes that neoliberals 'have been able to promote and coordinate interlocking full-spectrum braces of alternative policies that expand until they entirely fill the public space of perceived alternatives.' There are also many ways to make a market: see Philip Mirowski and Edward Nik-Khah, *The Knowledge We Have Lost in Information: The History of Information in Modern Economics* (Oxford University Press, 2017).
- 36 Stuart Hall, 'Thatcher's Lessons', *Marxism Today* (March 1988): 20.
- 37 Jeremy Hance, 'Could We Set Aside Half the Earth for Nature?', *Guardian*, 15 June 2016.
- 38 In 1967, Wilson and MacArthur offered the formula of $S = CA^z$, 'where S is the number of species, A is the area, C is a constant that varies widely among taxa and according to the unit of area measurement, and z is a constant which falls in most cases between 0.20 and 0.35.' Edward O. Wilson and Robert H. MacArthur, *The Theory of Island Biogeography* (Princeton University Press, 1967), 17. In his recent book *Half-Earth*, Wilson uses the formula of the fourth root, equivalent to setting $z = 0.25$. Edward O. Wilson, *Half-Earth: Our Planet's Fight for Life* (Liveright, 2016), 186.
- 39 Sarah Gibbens, 'Less Than 3 Percent of the Ocean Is "Highly Protected"', *National Geographic*, 25 September 2019, nationalgeographic.com; Kendall R. Jones et al., 'One-Third of Global Protected Land Is under Intense Human Pressure', *Science* 360, no. 6390 (2018): 788.
- 40 Wilson, *Half-Earth*, 186.
- 41 Kate E. Jones et al., 'Global Trends in Emerging Infectious Diseases', *Nature* 451, no. 7181 (2008): 992.
- 42 To cite one of many grim statistics, at least 212 environmental activists were killed in 2019, with casualties disproportionately borne by Indigenous activists in Latin America. Mélissa Godin, 'Record Number of Environmental Activists Killed in 2019', *Time*, 29 July 2020, time.com.
- 43 Alan Beattie and James Politi, "'I Made a Mistake,'" Admits Greenspan', *Financial Times*, 23 October 2008, ft.com.
- 44 Quinn Slobodian, 'Anti-'68ers and the Racist-Libertarian Alliance: How a Schism among Austrian School Neoliberals Helped Spawn the Alt Right', *Public Culture* 15, no. 3 (2019): 372–86; Melinda Cooper, 'The Alt-Right: Neoliberalism, Libertarianism and the Fascist Temptation', *Theory, Culture & Society* (April 2021): 1–21; Quinn Slobodian and Dieter Plehwe, 'Neoliberals Against Europe', in *Mutant Neoliberalism: Market Rule and Political Ruptures*, ed. William Callison and Zachary Manfredi (Fordham University Press, 2018), 89–111.

- 45 'Monthly CO₂', *CO2.earth*, co2.earth/monthly-co2.
- 46 Richard Betts, 'Met Office: Atmospheric CO₂ Now Hitting 50% Higher Than Pre-Industrial Levels', Carbon Brief, 16 March 2021, carbonbrief.org.
- 47 'More Than Half of All CO₂ Emissions Since 1751 Emitted in the Last 30 Years', *Institute for European Environmental Policy*, 29 April 2020, ieep.eu; 'World of Change: Amazon Deforestation', NASA Earth Observatory, earthobservatory.nasa.gov.
- 48 'Deforestation Has Slowed Down but Still Remains a Concern, New UN Report Reveals', *UN News*, 21 July 2020, news.un.org.
- 49 Michael Perelman, *Farming for Profit in a Hungry World: Capital and the Crisis in Agriculture* (Allanheld, Osmun, 1978). The country's butchers slaughtered 2 billion chickens in 1989, a grisly number that has increased more than fivefold three decades later. FAOSTAT, fao.org.
- 50 Andreas Malm, 'China as Chimney of the World: The Fossil Capital Hypothesis', *Organization & Environment* 25, no. 2 (2012): 146–77.
- 51 We will see some examples of this dark history in [chapter two](#), particularly in the African context. For North America, see for example Karl Jacoby, *Crimes Against Nature: Squatters, Poachers, and the Hidden History of American Conservation* (University of California Press, 2014).
- 52 Friedrich Hayek, 'Planning, Science and Freedom', *Nature* 148 (1941): 580. Science and technology studies, which today is dominated by the explicitly anti-Marxist philosopher Bruno Latour and his epigones, emerged as an academic field after Soviet and British Marxist philosophers (such as J. D. Bernal, Nikolai Bukharin, and Mikhail Bakhtin) met at the 1931 International Congress of the History of Science in London. See Gary Werskey, *The Visible College: The Collective Biography of British Scientific Socialists of the 1930s* (Holt, Rinehart and Winston, 1978), chapter 5.
- 53 Will Kymlicka, 'Human Supremacism: Why Are Animal Rights Activists Still the "Orphans of the Left"?', *New Statesman*, 30 April 2019, [newstatesman.com](https://www.newstatesman.com); Ryan Gunderson, 'Marx's Comments on Animal Welfare', *Rethinking Marxism* 23, no. 4 (2011): 543–8.
- 54 Amie 'Breeze' Harper, 'Dear Post-Racial White Vegans: "All Lives Matter" Is a Racial Microaggression Contributing to Our Daily Struggle with Racial Battle Fatigue', *Sistah Vegan*, 13 January 2015, sistahvegan.com; Summer Anne Burton, 'Stop Comparing Black Lives Matter to Animal Rights', *Tenderly*, 4 June 2020, medium.com/tenderlymag; for a critique of the animal-rights movement from a disability studies perspective, see Sunaura Taylor, *Beasts of Burden: Animal and Disability Liberation* (New Press, 2017); David Szybel, 'Can the Treatment of Animals Be Compared to the Holocaust?', *Ethics and the Environment* 11, no. 1 (2006): 97–132.
- 55 'Why Black Americans Are More Likely to Be Vegan', BBC, 11 September 2020, [bbc.com](https://www.bbc.com).
- 56 Upton Sinclair, *The Jungle* (Penguin, 1985 [1905]), 408.
- 57 Alyssa Battistoni, 'Living, Not Just Surviving', *Jacobin*, 15 August 2017, jacobinmag.com.
- 58 'It's Not Intersectional, It's DxE: An Exposé Written by DxE's Victims', *Dismantle DxE*, 16 September 2015, dismantledxe.wordpress.com; Owen Hatherley, 'A Tale of Rape Claims, Abuses of Power and the Socialist Workers Party', *Guardian*, 8 February 2013.
- 59 Things have become better lately; see Joanna Kerr, 'Greenpeace Apology to Inuit for Impacts of Seal Campaign', Greenpeace, 24 June 2014, [greenpeace.org](https://www.greenpeace.org). For a historical perspective, see Ryan Tucker Jones, 'When Environmentalists Crossed the Strait: Subsistence Whalers, Hippies, and the Soviets', *RCC Perspectives*, no. 5 (2019): 81–8.
- 60 Richard Schuster et al., 'Vertebrate Biodiversity on Indigenous-Managed Lands in Australia, Brazil, and Canada Equals That in Protected Areas', *Environmental Science & Policy* 101 (2019): 1–6.

- 61 Mahathir bin Mohamad rightly scolded delegates during the 1992 Rio Earth Summit: ‘When the rich chopped down their own forests, built their poison-belching factories, and scoured the world for cheap resources, the poor said nothing. Indeed they paid for the development of the rich. Now the rich claim a right to regulate the development of poor countries.’ Mahathir bin Mohamad (address to the United Nations Conference on Environment and Development, Rio de Janeiro, Brazil, 13 June 1992), mahathir.com.
- 62 Friedrich Engels, ‘Preface to the English Edition’, in *Capital: A Critique of Political Economy*, vol. 1, by Karl Marx (Penguin, 1976 [1887]), 113.
- 63 Eric Hobsbawm, ‘The Murder of Chile’, *New Society*, 20 September 1973, quoted in Ralph Miliband, ‘The Coup in Chile’, *Jacobin*, 11 September 2016.
- 64 *Looking Backward* was one of the real blockbusters of the nineteenth century, alongside *Uncle Tom’s Cabin* and *Ben-Hur*.
- 65 John Atkinson Hobson, ‘Edward Bellamy and the Utopian Romance’, *Humanitarian* 13 (1898): 180, quoted in Matthew Beaumont, introduction to *Looking Backward: 2000–1887*, by Edward Bellamy (Oxford University Press, 2007 [1888]), xvii.
- 66 Karl Marx, ‘Postface to the Second Edition’, in *Capital: A Critique of Political Economy*, vol. 1 (Penguin, 1976 [1867]), 99. See also, e.g., Karl Marx and Friedrich Engels, *The Communist Manifesto* (Penguin, 2015 [1848]), 46–9.
- 67 Philip Mirowski, ‘Markets Come to Bits: Evolution, Computation and Markomata in Economic Science’, *Journal of Economic Behavior & Organization* 63, no. 2 (2007): 209–42.

1. Binding Prometheus

- 1 Peder Anker, ‘The Ecological Colonization of Space’, *Environmental History* 10, no. 2 (2005): 239.
- 2 Cyrus K. Boynton and Arthur K. Colling, ‘Solid Amine CO₂ Removal System for Submarine Application’, *SAE Transactions* 92 (1983): 601; Eugene A. Ramskill, ‘Nuclear Submarine Habitability’, *SAE Transactions* 70 (1962): 355.
- 3 Buckminster Fuller, *Operating Manual for Spaceship Earth* (Simon & Schuster, 1969).
- 4 The geodesic dome only garnered its green veneer in 1954 at the Milan Triennale (the theme that year: ‘Life Between Artifact and Nature: Design and the Environmental Challenge’) when Fuller won the Gran Premio award for his 13-metre-high cardboard hemisphere that was assembled on site using directions on the cardboard itself. ‘Geodesic Domes’, Buckminster Fuller Institute, bfi.org.
- 5 For an elaboration of this term, see Anker, ‘Ecological Colonization’, 243.
- 6 After the Cold War, the US opted instead to collaborate with Russia in building a vessel that would become the International Space Station. Sabine Höhler, ‘The Environment as a Life Support System: The Case of Biosphere 2’, *History and Technology* 26, no. 1 (2010): 48.
- 7 Anker, ‘Ecological Colonization’, 256. Incidentally, Biosphere 2 and Disney’s Epcot Center in Florida both feature geodesic domes.
- 8 The bees were already having a hard time, because the windowpanes blocked ultraviolet light, which they needed to guide their sight and navigation. ‘Lee Pivnik at Biosphere 2’, *Art Viewer*, 9 September 2017, artviewer.org.
- 9 For example, in some parts of south-western China today, hand-pollinators have replaced local bees killed by pesticides. Dave Goulson, ‘Pollinating by Hand: Doing Bees’ Work’, interview by Natalie Muller, *Deutsche Welle*, 31 July 2014, dw.com.

- 10 Mark Nelson, 'Biosphere 2: What Really Happened?', *Dartmouth Alumni Magazine*, May–June 2018, dartmouthalumnimagazine.com; Jane Poynter, 'What Lessons Came Out of Biosphere 2?', interview by Guy Raz, NPR, 27 September 2013, npr.org.
- 11 Joel E. Cohen and David Tilman, 'Biosphere 2 and Biodiversity – The Lessons So Far', *Science* 274, no. 5290 (1996): 1150.
- 12 James K. Wetterer et al., 'Ecological Dominance by *Paratrechina longicornis* (Hymenoptera: Formicidae), an Invasive Tramp Ant, in Biosphere 2', *Florida Entomologist* 82, no. 3 (1999): 381–8.
- 13 Cohen and Tilman, 'Biosphere 2 and Biodiversity', 1151.
- 14 Kolbert's book popularized the concept more recently, but it was coined earlier. See Richard E. Leakey and Roger Lewin, *The Sixth Extinction: Patterns of Life and the Future of Humankind* (Anchor, 1996); Norman Myers, *The Sinking Ark: A New Look at the Problem of Disappearing Species* (Pergamon Press, 1979).
- 15 Gerardo Ceballos, Paul R. Ehrlich, and Peter H. Raven, 'Vertebrates on the Brink as Indicators of Biological Annihilation and the Sixth Mass Extinction', *Proceedings of the National Academy of Sciences* 117, no. 24 (2020): 13596 (emphasis added).
- 16 Robert Costanza et al., 'Changes in the Global Value of Ecosystem Services', *Global Environmental Change* 26 (2014): 152–8. Robert Costanza started this whole genre when he first put a price on nature in 1997, some \$33 trillion annually. See Robert Costanza et al., 'The Value of the World's Ecosystem Services and Natural Capital', *Nature* 387, no. 6630 (1997): 253–60.
- 17 Oscar Wilde, 'Lady Windermere's Fan', in *Five Plays by Oscar Wilde* (Bantam Books, 1961), 42.
- 18 Terry Pinkard, *Hegel: A Biography* (Cambridge University Press, 2000), 24.
- 19 Thomas Malthus, *An Essay on the Principle of Population, as It Affects the Future Improvement of Society: With Remarks on the Speculations of Mr. Godwin, M. Condorcet, and Other Writers* (J. Johnson, 1798), 2.
- 20 Andrea A. Rusnock, 'Historical Context and the Roots of Jenner's Discovery', *Human Vaccines & Immunotherapeutics* 12, no. 8 (2012): 2027. Still, Britain's uptake of the new treatment trailed behind that of revolutionary France, whose army carried out an early mass vaccination campaign as early as 1803.
- 21 Raymond Plant highlights the importance of this work for Hegel's subsequent philosophy; see his 'Hegel and Political Economy (Part I)', *New Left Review* 1, no. 103 (1977): 82–4.
- 22 Georg W. F. Hegel, *Philosophy of Nature, Being Part Two of the Encyclopaedia of the Philosophical Sciences (1830)* (Oxford University Press, 2004), 444.
- 23 Georg W. F. Hegel, 'The Spirit of Christianity and Its Fate', in *On Christianity: Early Theological Writings by Friedrich Hegel*, trans. T. M. Knox (Harper & Brothers, 1961), 182.
- 24 Hegel notes that the Greek myth of the Flood was quite different from the Jewish tradition. While neither Nimrod nor Noah managed to return to the state of nature, 'a more beautiful pair, Deucalion and Pyrrha', enjoyed a different fate, and 'after the flood in their time, invited men once again to friendship with the world, to nature, made them forget their need and their hostility in joy and pleasure, made a peace of *love*, were the progenitors of more beautiful peoples, and made their age the mother of a newborn natural life which maintained its bloom of youth.' Hegel, 'Spirit of Christianity', 184–5. Ironically, Deucalion was Prometheus' son.
- 25 *Ibid.*, 183. As Hegel explains, 'life was yet so far respected that men were prohibited from eating the blood of animals because in it lay the life, the soul, of the animals.'
- 26 *Ibid.*, 184.
- 27 *Ibid.*, 186.
- 28 Plant, 'Hegel and Political Economy (Part I)', 84.

- 29 Godwin was a strange opponent for Malthus, for they both were critics of the French Revolution. Godwin not only opposed 1789, but was a self-declared ‘enemy of revolutions’. William Petersen, ‘The Malthus–Godwin Debate, Then and Now’, *Demography* 8, no. 1 (1971): 16.
- 30 William Godwin, ‘Of Avarice and Profusion’, in *The Enquirer* (John Anderson Junior, 1823 [1793]), 156–7; Malthus, *An Essay on the Principle of Population*, i.
- 31 Malthus, *An Essay on the Principle of Population*, 14.
- 32 Jenner did not know of Jesty’s method because Jesty never published his results. James F. Hammarsten, William Tattersall, and J. E. Hammarsten, ‘Who Discovered Smallpox Vaccination? Edward Jenner or Benjamin Jesty?’, *Transactions of the American Clinical and Climatological Association* 90 (1979): 44–55.
- 33 Jenner’s understanding was incomplete because he did not realize at first that his vaccination method did not provide lifelong immunity. Murray Dworetzky, Sheldon Cohen, and David Mullin, ‘Prometheus in Gloucestershire: Edward Jenner, 1749– 1823’, *Journal of Allergy and Clinical Immunology* 112, no. 4 (2003): 810.
- 34 Arthur Boylston, ‘The Origins of Vaccination: No Inoculation, No Vaccination’, *Journal of the Royal Society of Medicine* 106, no. 10 (2013): 396.
- 35 Edward Jenner, *An Inquiry into the Causes and Effects of the Variolæ vaccinae, a Disease Discovered in Some of the Western Counties of England, Particularly Gloucestershire, and Known by the Name of the Cow Pox* (Sampson Low, 1798), 1.
- 36 *Ibid.*, 2.
- 37 Carlton Gyles, ‘One Medicine, One Health, One World’, *Canadian Veterinary Journal* 57, no. 4 (2016): 345–6; Michael Francis, ‘Vaccination for One Health’, *International Journal of Vaccines & Vaccination* 4, no. 5 (2017), 00090.
- 38 In a rare case where it is mentioned, it is mocked as a ‘rambling hypothesis that many human diseases were derived from animals’. Boylston, ‘The Origins of Vaccination’, 395.
- 39 Lisa Herzog, *Inventing the Market: Smith, Hegel, and Political Theory* (Oxford University Press, 2013), 59–60.
- 40 Malthus, *An Essay on the Principle of Population*, 16.
- 41 James P. Huzel, ‘The Demographic Impact of the Old Poor Laws: More Reflections on Malthus’, in *Malthus and His Time*, ed. Michael Turner (Palgrave Macmillan, 1986), 40–59.
- 42 One of the few socialist thinkers who have explored this concept is John O’Neill. See ‘Science, Wonder and the Lust of the Eyes’, *Journal of Applied Philosophy* 10, no. 2 (1993): 139–46.
- 43 Karl Marx, *Economic and Philosophic Manuscripts of 1844* (Prometheus Books, 1988 [1932]), 77.
- 44 *Ibid.*, 107–8.
- 45 Hesiod, ‘Theogony’, in *Hesiod*, trans. Richmond Lattimore (University of Michigan Press, 1959), p. 153, line 510; p. 157, line 567.
- 46 Karl Marx and Friedrich Engels, review of *Die Religion des Neuen Weltalters: Versuch einer Combinatorisch-Aphoristischen Grundlegung*, by Georg Friedrich Daumer (Hamburg, 1850), in *Collected Works*, vol. 10 (Lawrence & Wishart, 1978), 245, quoted in Reiner Grundmann, ‘The Ecological Challenge to Marxism’, *New Left Review* 1, no. 187 (1991): 110. Jenner was the first to argue that the cuckoo was a parasitic species, a debate that would last until 1921 when photographic evidence of the behaviour settled the matter.
- 47 Rick Kuhn, ‘Marxism and Birds’, 30 March 1998, sa.org.au/marxism_page/marxbird/marxbird.htm. For Stalin, see John Lewis Gaddis, *The Landscape of History: How Historians Map the Past* (Oxford University Press, 2002), 117.
- 48 Karl Marx, *Capital: A Critique of Political Economy*, vol. 1 (Penguin, 1976 [1867]), 639n49; Karl Marx, ‘Economic Manuscript of 1861–63’, in *Collected Works*, vol. 31 (Lawrence &

- Wishart, 1989), 345.
- 49 Jonathan Sperber, *Karl Marx: A Nineteenth-Century Life* (Liveright, 2013), 354.
 - 50 Bertell Ollman, 'Marx's Vision of Communism: A Reconstruction', *Critique* 8, no. 1 (1977): 27–8.
 - 51 Friedrich Engels, 'Outlines of a Critique of Political Economy', in *Collected Works*, vol. 3 (Lawrence & Wishart, 1975), 440.
 - 52 Kohei Saito, *Karl Marx's Ecosocialism: Capital, Nature, and the Unfinished Critique of Political Economy* (Monthly Review Press, 2017), 229.
 - 53 Leon Trotsky, *Literature and Revolution* (Haymarket, 2005 [1924]), 204.
 - 54 Stephen Brain, 'Stalin's Environmentalism', *Russian Review* 69, no. 1 (2010): 93–118; John Bellamy Foster, 'Late Soviet Ecology and the Planetary Crisis', *Monthly Review*, 1 June 2015, monthlyreview.org.
 - 55 Boris Lyubimov, *Bering Strait Dam* (US Joint Publications Research Service, 1960), 1, apps.dtic.mil.
 - 56 Ken Caldeira and Govindasamy Bala, 'Reflecting on 50 Years of Geoengineering Research', *Earth's Future* 5, no. 1 (2017): 10.
 - 57 Philip Micklin, 'The Aral Sea Disaster', *Annual Review of Earth and Planetary Sciences* 35 (2007): 47–72.
 - 58 Beatrice Grabish, 'Dry Tears of the Aral', *UN Chronicle* 1 (1999): 38–44.
 - 59 See John Bellamy Foster and Paul Burkett, *Marx and the Earth: An Anti-Critique* (Brill, 2016). For a review that criticizes the eco-socialist literature on this point, see Andreas Malm, 'For a Fallible and Lovable Marx: Some Thoughts on the Latest Book by Foster and Burkett', *Critical Historical Studies* 4, no. 2 (2017): 267–75.
 - 60 Alex Williams and Nick Srnicek, '#ACCELERATE MANIFESTO for an Accelerationist Politics', *Critical Legal Thinking*, 14 May 2013, criticallegalthinking.com.
 - 61 Leigh Phillips and Michal Rozworski, 'Planning the Good Anthropocene', *Jacobin*, 15 August 2017, jacobinmag.com; Peter Frase, 'By Any Means Necessary', *Jacobin*, 15 August 2017.
 - 62 Holly Jean Buck, *After Geoengineering: Climate Tragedy, Repair, and Restoration* (Verso, 2019), 168, 181.
 - 63 *Ibid.*, 173, 178.
 - 64 See Thomas Robertson, *The Malthusian Moment: Global Population Growth and the Birth of American Environmentalism* (Rutgers University Press, 2012); Alison Bashford and Joyce E. Chaplin, *The New Worlds of Thomas Robert Malthus: Rereading the Principle of Population* (Princeton University Press, 2016).
 - 65 Paul R. Ehrlich, *The Population Bomb* (Ballantine Books, 1968), 15.
 - 66 *Ibid.*, xi.
 - 67 Garrett Hardin, 'The Tragedy of the Commons', *Science* 162, no. 3859 (1968): 1246.
 - 68 Garrett Hardin, 'Commentary: Living on a Lifeboat', *BioScience* 24, no. 10 (1974): 561.
 - 69 Thomas Malthus, *An Essay on the Principle of Population, or, A View of Its Past and Present Effects on Human Happiness: With an Inquiry into Our Prospects Respecting the Future Removal or Mitigation of the Evils Which It Occasions*, 2nd ed. (J. Johnson, 1803), 6.
 - 70 Garret Hardin, 'Conspicuous Benevolence and the Population Bomb: Why Good Fences Make Good Neighbors', *Chronicles* 15, no. 10 (1991): 18–22; 'Garrett Hardin', [Southern Poverty Law Center, splcenter.org](http://splcenter.org).
 - 71 For instance, the textbook *Environment and Society: A Reader*, ed. Schlottmann et al. (New York University Press, 2017), conspicuously excerpted 'The Tragedy of the Commons' – a short essay – to leave out the most odious sections, including the one cited above.

- 72 Mark Tran, 'David Attenborough: Trying to Tackle Famine with Bags of Flour Is "Barmy"', *Guardian*, 18 September 2013, theguardian.com; George Monbiot, 'Population Panic Lets Rich People Off the Hook for the Climate Crisis They Are Fuelling', *Guardian*, 26 August 2020, theguardian.com.
- 73 The permit idea was broached by the environmental economist Kenneth Boulding as a joke (though this is disputed), but it is still taken seriously by some, such as Herman Daly. See 'Ecologies of Scale', *New Left Review* 1, no. 108 (2018): 92. In 1973, the involuntary sterilization of two Black girls, Minnie and Mary Alice Relf, in Alabama brought to national attention that the federal government annually underwrote the sterilization of 100,000 to 150,000 people who otherwise would have had their welfare benefits cut. ZPG's ambivalent stance during this tragedy led to a rift between environmentalists and African American organizations. 'Relf v. Weinberger', Southern Poverty Law Center, splcenter.org.
- 74 Natasha Lennard, 'The El Paso Shooter Embraced Eco-Fascism. We Can't Let the Far Right Co-opt the Environmental Struggle', *Intercept*, 5 August 2019, theintercept.com.
- 75 Michael Greger, 'The Human/Animal Interface: Emergence and Resurgence of Zoonotic Infectious Diseases', *Critical Reviews in Microbiology* 33, no. 4 (2007): 243.
- 76 Robin Weiss and Anthony J. McMichael, 'Social and Environmental Risk Factors in the Emergence of Infectious Diseases', *Nature Medicine* 10, no. 12 (2004): S72; Kennedy Shortridge, 'Severe Acute Respiratory Syndrome and Influenza: Virus Incursions from Southern China', *American Journal of Respiratory and Critical Care Medicine* 168, no. 12 (2003): 1417; Tony McMichael, *Human Frontiers, Environments and Disease: Past Patterns, Uncertain Futures* (Cambridge University Press, 2001), 101.
- 77 Igor Babkin and Irina N. Babkina, 'The Origin of the Variola Virus', *Viruses* 7, no. 3 (2015): 1106–7.
- 78 Nathan Wolfe, Claire Panosian Dunavan, and Jared Diamond, 'Origins of Major Human Infectious Diseases', *Nature* 447, no. 7142 (2007): 282.
- 79 Mark S. Smolinski, Margaret A. Hamburg, and Joshua Lederberg, eds, *Microbial Threats to Health: Emergence, Detection, and Response* (National Academies Press, 2003), 17.
- 80 C. E. Gordon Smith, 'Introductory Remarks', in *Ebola Virus Hemorrhagic Fever*, ed. S. R. Pattyn (Elsevier, 1978), 13.
- 81 The author continued: 'Such a change, if sufficiently adopted or imposed, could still reduce the chances of the much-feared [avian] influenza epidemic.' David Benatar, 'The Chickens Come Home to Roost', *American Journal of Public Health* 97, no. 9 (2007): 1545–6.
- 82 Aysha Z. Akhtar et al., 'Health Professionals' Roles in Animal Agriculture, Climate Change, and Human Health', *American Journal of Preventive Medicine* 36, no. 2 (2009): 182–7.
- 83 Kate E. Jones et al., 'Global Trends in Emerging Infectious Diseases', *Nature* 451 (2008): 992.
- 84 Sonia Shah, *Pandemic: Tracking Contagions, from Cholera to Ebola and Beyond* (Sarah Crichton Books, 2016), 19.
- 85 'Paris's elite attended elaborate masquerade parties where, in denial and defiance of cholera's toll, they danced to "cholera waltzes", costumed as the ghoulish corpses many would soon become ... Every now and then, one of the revelers would rip off his mask, face purpled, and collapse. Cholera killed them so fast they went to their graves still clothed in their costumes.' *Ibid.*, 43.
- 86 Although most biographical accounts agree that Hegel died of cholera, this interpretation is not unanimous. Terry Pinkard blames an 'upper gastrointestinal' disease for his death. Pinkard, *Hegel*, 616.
- 87 Hesiod, 'The Works and Days', in *Hesiod*, trans. Richmond Lattimore (University of Michigan Press, 1959), p. 29, lines 90–2.

- 88 See Marshall Sahlins ‘The Original Affluent Society’, in *Stone Age Economics* (Aldine-Atherton, 1972).
- 89 Hesiod, ‘The Works and Days’, p. 29, line 95.
- 90 Ibid., pp. 29–31, lines 101–3.
- 91 ‘The Bourgeois does not work for another. But he does not work for himself, taken as a biological entity, either. He works for himself taken as a “legal person”, as a private *Property-owner*: he works for Property taken as such – i.e., Property that has now become *money*; he works for Capital.’ Alexandre Kojève, *Introduction to the Reading of Hegel: Lectures on the Phenomenology of Spirit*, ed. Alan Bloom (Cornell University Press, 1980 [1947]), 65.
- 92 Marx, *Capital*, 1:255.
- 93 Karl Marx, ‘Results of the Immediate Process of Production’, in *Capital*, 1:1062.
- 94 Ibid., 1:988.
- 95 Quoted in Herzog, *Inventing the Market*, 55.
- 96 Marx, *Capital*, 1:254.
- 97 Max Horkheimer and Theodor W. Adorno, *Dialectic of Enlightenment: Philosophical Fragments* (Stanford University Press, 2002 [1944]), 26.
- 98 Ibid., 27.
- 99 Moishe Postone argued that capitalism could not stay still because ‘increasing productivity increases the amount of use-values produced per unit of time, but results only in short-term increases in the magnitude of value created per unit of time. Once that productive increase becomes general, the magnitude of value falls to its base level. The result is a sort of treadmill dynamic.’ See his ‘Critique and Historical Transformation’, *Historical Materialism* 12, no. 3 (2004): 59.
- 100 IPCC, *Global Warming of 1.5°C: An IPCC Special Report* (2018), 148, 353, 354, 364.
- 101 John O’Neill, ‘Who Won the Socialist Calculation Debate?’, *History of Political Thought* 17, no. 3 (1996): 434.
- 102 Otto Neurath, ‘Pseudorationalismus der Falsifikation’, *Erkenntnis* 5 (1935): 353–65; Otto Neurath, ‘The Problem of the Pleasure Maximum’, in *Empiricism and Sociology*, ed. Marie Neurath and Robert S. Cohen (D. Reidel, 1973 [1912]), 113–22; Otto Neurath, ‘Through War Economy to Economy in Kind’, in *Empiricism and Sociology*, 146.
- 103 Neurath, ‘Economy in Kind’, 145.
- 104 Otto Neurath, ‘Total Socialisation’, in *Economic Writings, Selections 1904–1945*, ed. Thomas E. Uebel and Robert S. Cohen (Springer, 2005 [1920]), 399.
- 105 Otto Neurath, ‘What Is Meant by a Rational Economic Theory?’, in *Unified Science*, ed. Brian McGuinness (D. Reidel, 1987 [1935]), 108.
- 106 Jordi Cat, ‘Political Economy: Theory, Practice, and Philosophical Consequences’, in *Stanford Encyclopedia of Philosophy* (Fall 2019 edition), ed. Edward N. Zalta, plato.stanford.edu.
- 107 Neurath, ‘Economy in Kind’, 131.
- 108 Ibid., 136, 141, 146–7.
- 109 Ibid., 142.
- 110 In the closely interconnected world of the Viennese intelligentsia, Mises knew Neurath personally as the two had attended the economist Eugen Ritter von Böhm-Bawerk’s seminar before the war. Even then, Mises despised Neurath for spouting ‘nonsense’ with ‘fanatical fervor’. Bruce Caldwell, *Hayek’s Challenge: An Intellectual Biography of F. A. Hayek* (University of Chicago Press, 2004), 114. For an overview of this debate, see Jessica Whyte, ‘Calculation and Conflict’, *South Atlantic Quarterly* 119, no. 1 (2020), 31–51.
- 111 Friedrich Hayek, ‘The Nature and the History of the Problem’, in *Collectivist Economic Planning*, ed. Friedrich Hayek (Routledge & Kegan Paul, 1935), 30.

- 112 Ludwig von Mises, *Economic Calculation in the Socialist Commonwealth* (Mises Institute, 1990 [1920]), 21n. In the original version of this text, Neurath was not even mentioned. Hayek later on explained that, indeed, it was Neurath's text that had 'provoked' Mises to write his 1920 essay. See Caldwell, *Hayek's Challenge*, 116.
- 113 Mises, *Economic Calculation*, 14.
- 114 'Both as an expression of recognition for the great service rendered by him and as a memento of the prime importance of sound economic accounting, a statue of Professor Mises ought to occupy an honourable place in the great hall of the Ministry of Socialisation or of the Central Planning Board of the socialist state.' Oskar Lange, 'On the Economic Theory of Socialism: Part One', *Review of Economic Studies* 4, no. 1 (1936): 53.
- 115 Thomas E. Uebel, 'Otto Neurath as an Austrian Economist: Behind the Scenes of the Early Socialist Calculation Debate', in *Otto Neurath's Economics in Context*, ed. Elisabeth Nemeth et al. (Springer, 2007), 41.
- 116 'A planning agency is likely to make widespread use of arithmetic, and indeed, if one wants to make localized decisions on the optimal use of resources by arithmetic means, then Mises' argument about the need to convert different products into some common denominator for purposes of calculation is quite correct. If, however, one wishes to perform global optimizations on the whole economy, other computational techniques, having much in common with the way nervous systems are thought to work, may be more appropriate, and these can in principle be performed without resort to arithmetic. Of course it would be anachronistic to fault Mises for failing to take into account developments in computer science which took place long after he wrote.' Allin Cottrell and W. Paul Cockshott, 'Calculation, Complexity and Planning: The Socialist Calculation Debate Once Again', *Review of Political Economy* 5, no. 1 (1993): 79.
- 117 Friedrich Hayek, 'The Use of Knowledge in Society', *American Economic Review* 35, no. 4 (1945): 519.
- 118 *Ibid.*, 526.
- 119 This term comes from Robert N. Proctor and Londa Schiebinger, eds, *Agnology: The Making and Unmaking of Ignorance* (Stanford University Press, 2008).
- 120 Frank Knight, 'Some Fallacies in the Interpretation of Social Cost', *Quarterly Journal of Economics* 38, no. 4 (1924): 606.
- 121 Bruce Caldwell, 'F. A. Hayek and the Economic Calculus', *History of Political Economy* 48, no. 1 (2016): 161n.
- 122 Early on, Hayek complained: 'It seems that that skeleton in our cupboard, the "economic man", whom we have exorcised with prayer and fasting, has returned through the back door in the form of a quasi-omniscient individual.' See his 'Economics and Knowledge', *Economica* 4, no. 13 (1937): 45.
- 123 Philip Mirowski, *Never Let a Serious Crisis Go to Waste: How Neoliberalism Survived the Financial Meltdown* (Verso, 2014), 332.
- 124 Friedrich Hayek, 'The Trend of Economic Thinking', *Economica* 40 (1933): 123, 130. In later years, Hayek would add cybernetic and evolutionary insights to his economic analysis. Naomi Beck, *Hayek and the Evolution of Capitalism* (University of Chicago Press, 2018).
- 125 Hayek, 'The Trend of Economic Thinking', 123; Friedrich Hayek, 'The Pretence of Knowledge', lecture to the memory of Alfred Nobel, Stockholm, 11 December 1974, nobelprize.org.
- 126 H. Scott Gordon, 'The Economic Theory of a Common-Property Resource: The Fishery', *Journal of Political Economy* 62, no. 2 (1954): 124–42; Edward Nik-Khah, 'Neoliberal Pharmaceutical Science and the Chicago School of Economics', *Social Studies of Science* 44, no. 4 (2014): 489–517.
- 127 Mirowski, *Never Let a Serious Crisis Go to Waste*, 340.

- 128 John H. Dales, *Pollution, Property and Prices: An Essay in Policy-Making and Economics* (Edward Elgar, 2002 [1968]), 102–4. Similarly, Ronald Coase understands environmental problems as ‘nuisances’. See Ronald Coase, ‘The Problem of Social Cost’, *Journal of Law & Economics* 3 (October 1960): 1–44.
- 129 Mises, *Economic Calculation*, 11.
- 130 Paul J. Crutzen, ‘The Influence of Nitrogen Oxides on the Atmospheric Ozone Content’, *Quarterly Journal of the Royal Meteorological Society* 96, no. 408 (1970): 320–5; Paul J. Crutzen, ‘SST’s: A Threat to the Earth’s Ozone Shield’, *Ambio* 1, no. 2 (1972): 41–51.
- 131 Mario J. Molina and F. Sherwood Rowland, ‘Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom-Catalysed Destruction of Ozone’, *Nature* 249, no. 5460 (1974): 810–12.
- 132 This problem inspired Albert Einstein to join up with his friend Leo Szilard to make a much safer fridge – one that didn’t use CFCs. Sam Kean, ‘Einstein’s Little-Known Passion Project? A Refrigerator’, *Wired*, 23 July 2017, wired.com.
- 133 Susan Solomon, ‘The Mystery of the Antarctic Ozone “Hole”’, *Reviews of Geophysics* 26, no. 1 (1988): 131.
- 134 ‘An Undeniable Problem in Antarctica’, *Understanding Science*, undsci.berkeley.edu.
- 135 Richard A. Kerr, ‘Deep Chill Triggers Record Ozone Hole’, *Science* 282, no. 5388 (1998): 391.
- 136 ‘An Undeniable Problem in Antarctica’.
- 137 Alan Robock, ‘20 Reasons Why Geoengineering May Be a Bad Idea’, *Bulletin of the Atomic Scientists* 64, no. 2 (2008): 15–16.
- 138 David W. Keith et al., ‘Solar Geoengineering Without Ozone Loss’, *Proceedings of the National Academy of Sciences* 113, no. 52 (2016): 14910.
- 139 Daniel J. Cziczo et al., ‘Unanticipated Side Effects of Stratospheric Albedo Modification Proposals Due to Aerosol Composition and Phase’, *Scientific Reports* 9, no. 18825 (2019).
- 140 Kat Eschner, ‘One Man Invented Two of the Deadliest Substances of the 20th Century’, *Smithsonian Magazine*, 18 May 2017, smithsonianmag.com. Midgley’s misadventures in invention eventually killed him: ‘Later in life, he was struck by polio, writes *Encyclopedia Britannica*, and lost the use of his legs. Being of an inquiring mind, he invented a hoist mechanism to help him get in and out of bed. He died when he became tangled in the ropes and the device strangled him.’
- 141 Thomas J. Algeo and Stephen E. Scheckler, ‘Terrestrial-Marine Teleconnections in the Devonian: Links Between the Evolution of Land Plants, Weathering Processes, and Marine Anoxic Events’, *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 353, no. 1365 (1998): 113–30.
- 142 The first time Boulding used the idea was in Kenneth E. Boulding, ‘The University, Society, and Arms Control’, *Journal of Conflict Resolution* 7, no. 3 (1963): 458–63.
- 143 Kenneth E. Boulding, ‘The Economics of the Coming Spaceship Earth’, in *Environmental Quality Issues in a Growing Economy*, ed. Henry Jarrett (RFF Press, 1966), 9.
- 144 See for example Fred Scharmen, ‘Jeff Bezos Dreams of a 1970s Future’, *Bloomberg CityLab*, 13 May 2019, bloomberg.com.
- 145 Bruce Caldwell, ‘Mont Pèlerin 1947’, in *From the Past to the Future: Ideas and Actions for a Free Society*, 42, hoover.org.
- 146 David Keith, ‘The Earth Is Not Yet an Artifact’, *IEEE Technology and Society Magazine* 19, no. 4 (2000): 27.
- 147 Horkheimer and Adorno, *Dialectic of Enlightenment*, 1.
- 148 Neurath, ‘Total Socialisation’, 395.
- 149 ‘A huge whale hangs in the middle of the hall; but we do not learn how the “beard” is transformed into old-fashioned corsets, how the skin is transformed into shoes, or the fat into

- soap that finds its way to the dressing room of a beautiful woman. Nor do we learn how many whales are caught per annum, or how much whale bone, fat, and leather are produced by this means ... Human fortunes are connected with this exhibit – starving seamen, hungry families of fishermen in the north of Norway. And so, everything leads to men and society.’ Otto Neurath, ‘Museums of the Future’, in *Empiricism and Sociology*, 219–20.
- 150 Otto Neurath, ‘The Lost Wanderers of Descartes and the Auxiliary Motive (On the Psychology of Decision)’, in *Philosophical Papers 1913–1946*, ed. Robert S. Cohen and Marie Neurath (D. Reidel, 1983 [1913]), 8.
- 151 Cameron Hu coined the term ‘unbuilding’ during our conversations about the book.
- 152 To finish the quotation: ‘Let us recall that this Hegelian theme, among many others, was taken up by Marx. History properly so-called in which men (“classes”) fight among themselves for recognition and fight against Nature by work, is called in Marx the “Realm of necessity” (*Reich der Notwendigkeit*); *beyond (jenseits)* is situated the “Realm of freedom” (*Reich der Freiheit*), in which men (usually recognizing one another without reservation) no longer fight, and work as little as possible (Nature having been definitely mastered – that is, harmonized with Man).’ Kojève, *Introduction to the Reading of Hegel*, 158–9n6.
- 153 Otto Neurath, ‘A System of Socialisation’, in *Economic Writings*, 345.
- 154 Otto Neurath, ‘Anti-Spengler’, in *Empiricism and Sociology*, 199.

2. A New Republic

- 1 Angela Davis, ‘Social Justice in the Public University of California: Reflections and Strategies’ (teach-in at the University of California Davis, 23 February 2012), video.ucdavis.edu. Lightly edited for clarity.
- 2 Plato, *The Republic*, trans. Paul Shorey, Loeb Classical Library (Harvard University Press, 1937 [1930]), 372b.
- 3 *Ibid.*, 372c–d.
- 4 *Ibid.*, 373b–d.
- 5 *Ibid.*, 373e.
- 6 Plato, *Euthyphro. Apology. Crito. Phaedo. Phaedrus.*, trans. Harold N. Fowler, Loeb Classical Library 36 (Harvard University Press, 1914), 230d.
- 7 Thomas More, ‘Utopia’, in *Three Early Modern Utopias*, ed. Susan Bruce (Oxford University Press, 1999), 81.
- 8 *Ibid.*, 22.
- 9 *Ibid.*, 44.
- 10 *Ibid.*, 23.
- 11 Ellen Meiksins Wood, *The Origin of Capitalism: A Longer View* (Verso, 2002), 109.
- 12 William Shakespeare, *The Life and Death of Richard II*, act 2, sc. 1.
- 13 Wood, *The Origin of Capitalism*, 152–6. The number of sheep jumped from 3 million to 4 million between 1500 and 1600. William Lazonick, ‘Karl Marx and Enclosures in England’, *Review of Radical Political Economics* 6, no. 2 (1974): 19. Over the longer arc of history, 1300 to 1850, livestock yields grew 400 per cent, a rate that surpassed increases in labour productivity (56 per cent) and grain harvests (120 per cent). Robert C. Allen, ‘English and Welsh Agriculture, 1300–1850: Outputs, Inputs, and Income’ (working paper, Nuffield College, University of Oxford, 2006), 2, ora.ox.ac.uk.
- 14 Wood, *The Origin of Capitalism*, 153.

- 15 For reasons why the Tudors were wary of enclosures, see Lazonick, 'Karl Marx and Enclosures in England', 17.
- 16 The colonization of Ireland had already progressed by the Tudor period but deepened profoundly during Cromwell's reign. Donald Woodward, 'The Anglo-Irish Livestock Trade of the Seventeenth Century', *Irish Historical Studies* 18, no. 72 (1973): 489–523; Tiarnán Somhairle, 'Capital's First Colony? A Political Marxist Approach to Irish "Underdevelopment"', *Historical Materialism*, 5 February 2018, historicalmaterialism.org.
- 17 John Locke, *Second Treatise of Civil Government* (Prometheus Books, 1986 [1690]), 20.
- 18 Wood, *The Origin of Capitalism*, 162; More, 'Utopia', 63. More's Utopians 'count this the most just cause of war, when any people holdeth a piece of ground void and vacant to no good nor profitable use, keeping others from the use and possession of it.'
- 19 They would need \$60–\$150/tC. Sean Sweeney, 'Hard Facts about Coal: Why Trade Unions Should Rethink Their Support for Carbon Capture and Storage' (working paper, Trade Unions for Energy Democracy, New York, October 2015), 8, unionsforenergydemocracy.org. There is a list of all the cancelled CCS plants: MIT, 'Cancelled and Inactive Projects', Carbon & Sequestration Technologies, 30 September 2016, sequestration.mit.edu. The Institute for the Study of CCS at MIT, which devised the list, itself closed down in 2016.
- 20 See for example Carl-Friedrich Schleussner et al., 'Differential Climate Impacts for Policy-Relevant Limits to Global Warming: The Case of 1.5 C and 2 C', *Earth System Dynamics* 7, no. 2 (2016): 327–51; Richard J. Millar et al., 'Emission Budgets and Pathways Consistent with Limiting Warming to 1.5 C', *Nature Geoscience* 10, no. 10 (2017): 741–7.
- 21 For an overview of the concept, see Richard A. Houghton, 'Balancing the Global Carbon Budget', *Annual Review of Earth and Planetary Sciences* 35 (2007): 313–47.
- 22 UN Environment Programme, 'Cut Global Emissions by 7.6 Percent Every Year for Next Decade to Meet 1.5°C Paris Target – UN Report', press release, 26 November 2019, unenvironment.org; Simon Evans, 'Analysis: Coronavirus Set to Cause Largest Ever Annual Fall in CO₂ Emissions', Carbon Brief, 9 April 2020, carbonbrief.org.
- 23 Zeke Hausfather, 'Analysis: Why the IPCC 1.5C Report Expanded the Carbon Budget', Carbon Brief, 8 October 2018, carbonbrief.org.
- 24 At the time, he called the technology 'biomass energy with CO₂ removal and permanent sequestration (BECS)'. Kenneth Möllersten, 'Opportunities for CO₂ Reductions and CO₂-Lean Energy Systems in Pulp and Paper Mills' (doctoral thesis, Royal Institute of Technology, Stockholm, 2002), kth.diva-portal.org.
- 25 Michael R. Obersteiner et al., *Managing Climate Risk* (IIASA interim report, 2001), 6, 16, pure.iiasa.ac.at. A much shorter version of the report was published in *Science* soon thereafter, where it has become a highly cited article: Michael R. Obersteiner et al., 'Managing Climate Risk', *Science* 294, no. 5543 (2001): 786–7.
- 26 David Keith, 'Sinks, Energy Crops and Land Use: Coherent Climate Policy Demands an Integrated Analysis of Biomass', *Climatic Change* 49 (2001): 7.
- 27 *Ibid.*, 9.
- 28 One problem was the 'instability of carbon in biological reservoirs' compared with artificial sequestration like CCS. He also noted that 'the effectiveness of [natural] sinks is controversial, and depends critically on the timescale and management regime considered.' *Ibid.*, 3.
- 29 Vera Heck et al., 'Biomass-Based Negative Emissions Difficult to Reconcile with Planetary Boundaries', *Nature Climate Change* 8, no. 2 (2018): 151–5. For the landmark planetary boundary study, see Will Steffen et al., 'Planetary Boundaries: Guiding Human Development on a Changing Planet', *Science* 347, no. 6623 (2015): 1259855.

- 30 Alister Doyle, 'Extracting Carbon from Nature Can Aid Climate but Will Be Costly: U.N.', Reuters, 26 March 2014, reuters.com.
- 31 Heck et al., 'Biomass-Based Negative Emissions', 153.
- 32 Anna Harper, 'Why BECCS Might Not Produce "Negative" Emissions After All', Carbon Brief, 14 August 2018, carbonbrief.org.
- 33 Keith, 'Sinks, Energy Crops and Land Use', 5.
- 34 Matteo Muratori et al., 'Global Economic Consequences of Deploying Bioenergy with Carbon Capture and Storage (BECCS)', *Environmental Research Letters* 11, no. 9 (2016): 4.
- 35 Philip Mirowski, *Never Let a Serious Crisis Go to Waste: How Neoliberalism Survived the Financial Meltdown* (Verso, 2014), 332.
- 36 'Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C Approved by Governments', IPCC Newsroom, 8 October 2018, ipcc.ch.
- 37 Hansen has been arrested three times on the White House lawn (2010, 2011, 2013), and twice at protests elsewhere.
- 38 See James Hansen and Michael Shellenberger, 'The Climate Needs Nuclear Power', *Wall Street Journal*, 4 April 2019, wsj.com; James Hansen et al., 'Nuclear Power Paves the Only Viable Path Forward on Climate Change', *Guardian*, 3 December 2015, theguardian.com.
- 39 Hansen et al., 'Nuclear Power Paves the Only Viable Path'.
- 40 In the US in 2012, 15 per cent of fossil fuel use went to electricity, 52 per cent to liquid fuels, and 33 per cent to solid and gaseous fuels. Vaclav Smil, *Power Density: A Key to Understanding Energy Sources and Uses* (MIT Press, 2015), 246.
- 41 Spencer Wheatley, Benjamin Sovacool, and Didier Sornette, 'Of Disasters and Dragon Kings: A Statistical Analysis of Nuclear Power Incidents and Accidents', *Risk Analysis* 37, no. 1 (2017): 112.
- 42 Philip Ball, 'James Lovelock Reflects on Gaia's Legacy', *Nature*, 9 April 2014, nature.com; George Monbiot, 'Why Fukushima Made Me Stop Worrying and Love Nuclear Power', *Guardian*, 21 March 2011; George Monbiot, 'The Unpalatable Truth Is That the Anti-Nuclear Lobby Has Mised Us All', *Guardian*, 5 April 2011, theguardian.com. Hansen goes so far as to claim that nuclear power has in fact *saved* 1.8 million lives that would have been lost had that energy been provided by fossil fuels (a statistic soon cited by Shellenberger). Pushker A. Kharecha and James E. Hansen, 'Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power', *Environmental Science & Technology* 47, no. 9 (2013): 4889–95.
- 43 World Health Organization, 'World Health Organization Report Explains the Health Impacts of the World's Worst-Ever Civil Nuclear Accident', press release, 26 April 2006, who.int.
- 44 Ian Fairlie and David Sumner, *The Other Report on Chernobyl (TORCH)* (study for the European Parliament, Brussels, 2006); Kate Brown, *Manual for Survival: A Chernobyl Guide to the Future* (W. W. Norton, 2019), 311.
- 45 Debora Mackenzie, 'Caesium Fallout from Fukushima Rivals Chernobyl', *New Scientist*, 29 March 2011, newscientist.com; Tetsuji Imanaka, 'Comparison of Radioactivity Release and Contamination from the Fukushima and Chernobyl Nuclear Power Plant Accidents', in *Low-Dose Radiation Effects on Animals and Ecosystems: Long-Term Study on the Fukushima Nuclear Accident*, ed. Manabu Fukumoto (Springer, 2020), 257.
- 46 Jan Beyea et al., 'Accounting for Long-Term Doses in Worldwide Health Effects of the Fukushima Daiichi Nuclear Accident', *Energy & Environmental Science* 6, no. 3 (2013): 1042–5; Frank von Hippel, 'The Radiological and Psychological Consequences of the Fukushima Daiichi Accident', *Bulletin of the Atomic Scientists* 67, no. 5 (2011): 27–36.
- 47 'Accident Cleanup Costs Rising to 35–80 Trillion Yen in 40 Years', Japan Center for Economic Research, 3 July 2019, jcer.or.jp.

- 48 'Cleaning up Nuclear Waste Is an Obvious Task for Robots', *Economist*, 20 June 2019, economist.com.
- 49 Ben Dooley, Eimi Yamamitsu, and Makiko Inoue, 'Fukushima Nuclear Disaster Trial Ends with Acquittals of 3 Executives', *New York Times*, 19 September 2019, nytimes.com.
- 50 Associated Press, 'Japanese Power Company TEPCO Admits It Lied about Meltdown after Fukushima', CBC News, 21 June 2016, cbc.ca.
- 51 Indeed, assessments often omit these 'external' phases of the life cycle and focus only on generation. Keith Barnham, 'False Solution: Nuclear Power Is Not "Low Carbon"', *Ecologist*, 5 February 2015, theecologist.org.
- 52 Benjamin K. Sovacool, 'Valuing the Greenhouse Gas Emissions from Nuclear Power: A Critical Survey', *Energy Policy* 36, no. 8 (2008): 2941. Note that these measurements are CO₂ equivalents rather than CO₂ per se.
- 53 By contrast, the average coal-fired power plant emits around 1,050 gCO₂/kWh. Daniel Nugent and Benjamin K. Sovacool, 'Assessing the Lifecycle Greenhouse Gas Emissions from Solar PV and Wind Energy: A Critical Meta-Survey', *Energy Policy* 65 (2014): 229–44.
- 54 Simon Evans, 'Solar, Wind and Nuclear Have "Amazingly Low" Carbon Footprints, Study Finds', Carbon Brief, 8 December 2017, carbonbrief.org.
- 55 Terry Norgate, Nawshad Haque, and Paul Koltun, 'The Impact of Uranium Ore Grade on the Greenhouse Gas Footprint of Nuclear Power', *Journal of Cleaner Production* 84 (2014): 365.
- 56 Ibid., Figs. 8–9. If one looks further ahead to only 0.001 per cent ore quality, then nuclear power's emissions would jump to 594 gCO₂/kWh – more than some fossil fuels. Ibid., 263.
- 57 See for example James Hansen, *Storms of My Grandchildren: The Truth about the Coming Climate Catastrophe and Our Last Chance to Save Humanity* (Bloomsbury, 2009), 201.
- 58 Frank von Hippel, 'Plutonium Programs in East Asia and Idaho Will Challenge the Biden Administration', *Bulletin of the Atomic Scientists*, 12 April 2021, thebulletin.org.
- 59 Frank von Hippel, 'Bill Gates' Bad Bet on Plutonium-Fueled Reactors', *Bulletin of the Atomic Scientists*, 22 March 2021.
- 60 Galina Raguzina, 'Holy Grail or Epic Fail? Russia Readies to Commission First Plutonium Breeder Against Uninspiring Global Track Record', Bellona, 4 August 2014, bellona.org; Thomas B. Cochran et al., 'It's Time to Give Up on Breeder Reactors', *Bulletin of the Atomic Scientists* 66, no. 3 (2010): 52.
- 61 Masa Takubo, 'Closing Japan's Monju Fast Breeder Reactor: The Possible Implications', *Bulletin of the Atomic Scientists* 73, no. 3 (2017): 182–7.
- 62 R. D. Kale, 'India's Fast Reactor Programme – A Review and Critical Assessment', *Progress in Nuclear Energy* 122 (2020): 103265; M. V. Ramana, 'A Fast Reactor at Any Cost: The Perverse Pursuit of Breeder Reactors in India', *Bulletin of the Atomic Scientists*, 3 November 2016.
- 63 S. Rajendran Pillai and M. V. Ramana, 'Breeder Reactors: A Possible Connection Between Metal Corrosion and Sodium Leaks', *Bulletin of the Atomic Scientists* 70, no. 3 (2014): 51–2.
- 64 The project's name referred not to the goal of transparency but to the idea that radiation was as omnipresent as sunshine. Here we also see the emergence of the modern notion of the 'environment'.
- 65 Joseph Masco, 'Bad Weather: On Planetary Crisis', *Social Studies of Science* 40, no. 1 (2010): 13–14. For the stolen baby bones, see Jacob Darwin Hamblin, *Arming Mother Nature: The Birth of Catastrophic Environmentalism* (Oxford University Press, 2013), 103.
- 66 Hamblin, *Arming Mother Nature*, 103; Sue Rabbitt Roff, 'Project Sunshine and the Slippery Slope: The Ethics of Tissue Sampling for Strontium-90', *Medicine, Conflict and Survival* 18, no. 3 (2002): 300, 304; Murray Campbell, 'Project Sunshine's Dark Secret', *Globe and Mail*, 6 June 2001, theglobeandmail.com.

- 67 Louise Zibold Reiss, 'Strontium-90 Absorption by Deciduous Teeth: Analysis of Teeth Provides a Practicable Method of Monitoring Strontium-90 Uptake by Human Populations', *Science* 134, no. 3491 (1961): 1669–73.
- 68 Rachel Carson, *Silent Spring* (Penguin, 2000 [1962]), 22.
- 69 The idea for such a study was sketched by Herman Kalckar, a biochemist at Johns Hopkins University. See his 'An International Milk Teeth Radiation Census', *Nature* 182, no. 4631 (1958): 283–4.
- 70 Reiss, 'Strontium-90 Absorption', 1669.
- 71 Harold L. Rosenthal, 'Accumulation of Environmental 90-Sr in Teeth of Children', in *Radiation Biology of the Fetal and Juvenile Mammal*, ed. Melvin R. Sikov and D. Dennis Mahlum (US Atomic Energy Commission, 1969), 163–71.
- 72 Barry Commoner and Ursula Franklin belonged to the Greater St. Louis Citizens' Committee on Nuclear Information.
- 73 Joseph J. Mangano et al., 'An Unexpected Rise in Strontium-90 in US Deciduous Teeth in the 1990s', *Science of the Total Environment* 317, nos. 1–3 (2003): 43. For a corroborative study see Jay M. Gould et al., 'Strontium-90 in Deciduous Teeth as a Factor in Early Childhood Cancer', *International Journal of Health Services* 30, no. 3 (2000): 515–39.
- 74 Karl Jacoby, *Crimes Against Nature: Squatters, Poachers, Thieves, and the Hidden History of American Conservation* (University of California Press, 2014); Jane Carruthers, *The Kruger National Park: A Social and Political History* (University of Natal Press, 1995).
- 75 For a history of the group, see Keith Makoto Woodhouse, *The Ecocentrists: A History of Radical Environmentalism* (Columbia University Press, 2018), 258–61.
- 76 Reed Noss, 'The Wildlands Project: Land Conservation Strategy', *Wild Earth*, special issue 'The Wildlands Project' (1992): 15. The difference between CPAWS' 50 per cent goal in 2005 and Noss' work in 1992 was that the Wildlands Network never adopted Noss' aim as official policy.
- 77 See Michael Soulé and Reed Noss, 'Rewilding and Biodiversity: Complementary Goals for Continental Conservation', *Wild Earth* 8 (1998): 18–28.
- 78 Edward O. Wilson, *The Diversity of Life* (Harvard University Press, 1992), 337. See also Harvey Locke, 'The International Movement to Protect Half the World: Origins, Scientific Foundations, and Policy Implications', in *Reference Module in Earth Systems and Environmental Sciences* (Elsevier, 2018).
- 79 See Edward O. Wilson, 'A Personal Brief for the Wildlands Project', *Wild Earth* 10, no. 1 (2000): 1–2. Wilson certainly knew his audience and wrote an alarmist essay on overpopulation. See also Harvey Locke, 'A Balanced Approach to Sharing North America', in the same issue.
- 80 Jenny Levison et al., *Apply the Brakes: Anti-immigrant Co-optation of the Environmental Movement* (Center for New Community, 2010), 3.
- 81 Ian Angus, 'Dave Foreman's Man Swarm: Defending Wildlife by Attacking Immigrants', review of *Man Swarm and the Killing of Wildlife*, by Dave Foreman, *Climate & Capitalism*, 25 April 2012, climateandcapitalism.com.
- 82 Indeed, Locke worked closely with Indigenous nations to expand nature preserves in Canada's Northwest Territories. Harvey Locke, 'Civil Society and Protected Areas: Lessons from Canada's Experience', *George Wright Forum* 26, no. 2 (2009): 101–28.
- 83 Dinitia Smith, 'Master Storyteller or Master Deceiver?', *New York Times*, 3 August 2002.
- 84 J. D. F. Jones, 'Van der Posture', *London Review of Books* 5, no. 2 (1983).
- 85 Harry Wels, *Securing Wilderness Landscapes in South Africa: Nick Steele, Private Wildlife Conservancies and Saving Rhinos* (Brill, 2015), 58.
- 86 For the WILD Foundation's conference programmes, see wild.org.
- 87 Malcolm Draper, 'Zen and the Art of Garden Province Maintenance: The Soft Intimacy of Hard Men in the Wilderness of KwaZulu-Natal, South Africa, 1952–1997', *Journal of Southern*

- African Studies* 24, no. 4 (1998): 818.
- 88 Ibid., 817. Indeed, the new parks were under the jurisdiction of the IFP's conservation authority.
 - 89 Adrian Guelke, 'Interpretations of Political Violence During South Africa's Transition', *Politikon* 27, no. 2 (2000): 241.
 - 90 Zoo directors would visit Aspinall's estate in Kent to study his successful captive gorilla breeding programme. Aspinall impressed even zoologist and Nobel Prize winner Konrad Lorenz with his 'uncanny knack' with animals. Yet, he was a hardened Malthusian too. When told by Richard Nixon that a nuclear war might kill 200 million people, he thought that was too few. As a misogynist, he boasted of treating women 'with disdain' (especially if they were left-wing), and he likely abetted Lord Lucan's escape after the latter murdered his nanny. In 1997, Aspinall ran for Parliament under the banner of the Euro-sceptic Referendum Party. Malcolm Draper and Gerhard Maré, 'Going In: The Garden of England's Gaming Zookeeper and Zululand', *Journal of Southern African Studies* 29, no. 2 (2003): 551–69.
 - 91 Stephen J. Gould, 'Cardboard Darwinism', *New York Review of Books*, 25 September 1986, 47–54.
 - 92 Ed Douglas, 'Darwin's Natural Heir', *Guardian*, 16 February 2001; Edward O. Wilson, *Half-Earth: Our Planet's Fight for Life* (Liveright, 2016), 205.
 - 93 Bram Büscher et al., 'Half-Earth or Whole Earth? Radical Ideas for Conservation, and Their Implications', *Oryx* 51, no. 3 (2017): 407–10.
 - 94 Karl Marx, *Capital: A Critique of Political Economy*, vol. 1 (Penguin, 1976 [1867]), 494; Karl Marx, *Grundrisse: Foundations of the Critique of Political Economy* (Penguin, 1973), 612.
 - 95 The ability to work, what Marx calls 'labour power', is different from other natural forces in that it is not merely exchanged as other commodities as equivalents (e.g., \$100 of oil for \$100 pork); instead, it provides the capitalist with the opportunity to capture surplus value. Marx, *Capital*, vol. 1, chapter 6.
 - 96 Lazonick, 'Karl Marx and Enclosures in England', 16.
 - 97 David Wykes, 'Robert Bakewell (1725–1795) of Dishley: Farmer and Livestock Improver', *Agricultural History Review* 52, no. 1 (2004): 39.
 - 98 Karl Marx, *Capital: A Critique of Political Economy*, vol. 2 (Penguin, 1987 [1885]), 315.
 - 99 Ibid.
 - 100 Richard L. Hills, 'Sir Richard Arkwright and His Patent Granted in 1769', *Notes and Records of the Royal Society of London* 24, no. 2 (1970): 260.
 - 101 Andreas Malm, 'The Origins of Fossil Capital: From Water to Steam in the British Cotton Industry', *Historical Materialism* 21, no. 1 (2013): 53.
 - 102 Timothy Mitchell, *Carbon Democracy: Political Power in the Age of Oil* (Verso, 2011).
 - 103 Kenneth Fish, *Living Factories: Biotechnology and the Unique Nature of Capitalism* (McGill-Queen's University Press, 2013), 141.
 - 104 Ibid., 150.
 - 105 Marx, *Capital*, 1:508 (translation amended).
 - 106 Fish, *Living Factories*, 6.
 - 107 For an excellent study of such tendencies in aquaculture, see Stefano B. Longo, Rebecca Clausen, and Brett Clark, *The Tragedy of the Commodity: Oceans, Fisheries, and Aquaculture* (Rutgers University Press, 2015).
 - 108 M. J. Zuidhof et al., 'Growth, Efficiency, and Yield of Commercial Broilers from 1957, 1978, and 2005', *Poultry Science* 93, 12 (2014): 2980.
 - 109 Don P. Blayney, *The Changing Landscape of U.S. Milk Production* (US Department of Agriculture Statistical Bulletin 978, 2002), appendix table 1, ers.usda.gov; 'Milk: Production per Cow by Year, US', United States Department of Agriculture, nass.usda.gov.

- 110 Hannah Ritchie and Max Roser, 'Land Use', *Our World in Data*, September 2019, ourworldindata.org.
- 111 Brian Machovina et al., 'Biodiversity Conservation: The Key Is Reducing Meat Consumption', *Science of the Total Environment* 536 (2015): 420.
- 112 Yinon M. Bar-On et al., 'The Biomass Distribution on Earth', *Proceedings of the National Academy of Sciences* 115, no. 25 (2018): 6508.
- 113 Robert Goodland and Jeff Anhang, 'Livestock and Climate Change', *World Watch* (November/December 2009): 11–12, awellfedworld.org.
- 114 Smil, *Power Density*.
- 115 *Ibid.*, 113–14. A notable exception to this is Appalachian mountain-top removal, which has a power density 'well below 100 W/m²'.
- 116 *Ibid.*, 146–7.
- 117 Chunhua Zhang et al., 'Disturbance-Induced Reduction of Biomass Carbon Sinks of China's Forests in Recent Years', *Environmental Research Letters* 10, no. 11 (2015): Table 1; Jingyun Fang et al., 'Changes in Forest Biomass Carbon Storage in China Between 1949 and 1998', *Science* 292, no. 5525 (2001): 2320.
- 118 Joris P. G. M. Cromsigt et al., 'Trophic Rewilding as a Climate Change Mitigation Strategy?', *Philosophical Transactions of the Royal Society B: Biological Sciences* 373, no. 1761 (2018): 20170440.
- 119 *Ibid.*, 3.
- 120 *Ibid.*, 7.
- 121 Oswald J. Schmitz et al., 'Animating the Carbon Cycle', *Ecosystems* 17, no. 2 (2014): 348–9.
- 122 James W. Fourqurean et al., 'Seagrass Ecosystems as a Globally Significant Carbon Stock', *Nature Geoscience* 5, no. 7 (2012): 505.
- 123 Nicola Jones, 'How Growing Sea Plants Can Help Slow Ocean Acidification', *Yale Environment* 360, 12 July 2016, e360.yale.edu.
- 124 Joe Roman and James McCarthy, 'The Whale Pump: Marine Mammals Enhance Primary Productivity in a Coastal Basin', *PLoS ONE* 5, no. 10 (2010): e13255.
- 125 Andrew J. Pershing et al., 'The Impact of Whaling on the Ocean Carbon Cycle: Why Bigger Was Better', *PloS ONE* 5, no. 8 (2010): e12444.
- 126 World Wildlife Fund and Zoological Society of London, *Living Blue Planet Report: Species, Habitats and Human Well-Being* (WWF, 2015), 6; Rob Williams et al., 'Competing Conservation Objectives for Predators and Prey: Estimating Killer Whale Prey Requirements for Chinook Salmon', *PloS ONE* 6, no. 11 (2011): e26738; Elizabeth Pennisi, 'North Atlantic Right Whale Faces Extinction', *Science* 358, no. 6364 (2017): 703–4.
- 127 Wilson, *Half-Earth*, 136–51.
- 128 Vaclav Smil, *Harvesting the Biosphere: What We Have Taken from Nature* (MIT Press, 2013), 18–19.
- 129 Ulrich Kreidenweis et al., 'Afforestation to Mitigate Climate Change: Impacts on Food Prices under Consideration of Albedo Effects', *Environmental Research Letters* 11, no. 8 (2016): 085001.
- 130 Andy Skuce, "'We'd Have to Finish One New Facility Every Working Day for the Next 70 Years" – Why Carbon Capture Is No Panacea', *Bulletin of the Atomic Scientists*, 4 October 2016.
- 131 Karl-Heinz Erb et al., 'Exploring the Biophysical Option Space for Feeding the World Without Deforestation', *Nature Communications* 7 (2016): 11382.
- 132 Kreidenweis et al., 'Afforestation to Mitigate Climate Change', Table 1.

- 133 For a survey of the debate see Tomek de Ponti, Bert Rijk, and Martin K. van Ittersum, 'The Crop Yield Gap Between Organic and Conventional Agriculture', *Agricultural Systems* 108 (2012): 2.
- 134 David Pimentel et al., 'Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems', *BioScience* 55, no. 7 (2005): 573–82.
- 135 Catherine Badgley and Ivette Perfecto, 'Can Organic Agriculture Feed the World?', *Renewable Agriculture and Food Systems* 22, no. 2 (2007): 81.
- 136 Janne Bengtsson, Johan Ahnström, and Ann-Christin Weibull, 'The Effects of Organic Agriculture on Biodiversity and Abundance: A Meta-Analysis', *Journal of Applied Ecology* 42, no. 2 (2005): 261–9.
- 137 Smil, *Power Density*, 247.
- 138 *Ibid.*, 247–8.
- 139 *Ibid.*, 246. His figures are 50 per cent displaced by PV (10 W/m^2) = 16,000 km², 25 per cent displaced by CSP (20 W/m^2) = 4,000 km², 25 per cent displaced by wind (50 W/m^2) = 1,600 km². One can quibble that Smil does not count the land between wind turbines because this can be cultivated, boosting their power density from around 10 W/m^2 to 50 W/m^2 in his calculations. However, even if one reduces wind power's contribution to a more likely 10 W/m^2 , the system's land area would only increase to 28,000 km² (the system is a mix of wind and solar).
- 140 'After Many False Starts, Hydrogen Power Might Now Bear Fruit', *Economist*, 4 July 2020.
- 141 See Eberhard Jochem, ed., *Steps Toward a Sustainable Development: A White Book for R&D of Energy-Efficient Technologies* (CEPE/ETH Zurich, 2004). Two thousand watts as a rate of primary energy use per person equates to 17,500 kWh per year or 48 kWh per day.
- 142 Julia Wright, 'The Little-Studied Success Story of Post-crisis Food Security in Cuba', *International Journal of Cuban Studies* 4, no. 2 (2012): 131–2.
- 143 *Ibid.*, 138; Sinan Koont, 'The Urban Agriculture of Havana', *Monthly Review* 60, no. 8 (2009): 50.
- 144 Sarah Boseley, 'Hard Times Behind Fall in Heart Disease and Diabetes in 1990s Cuba', *Guardian*, 9 April 2013.
- 145 This is the main argument of Emily Morris, 'Unexpected Cuba', *New Left Review* 1, no. 88 (2014): 5–45. She compares Cuba favourably with post-communist 'transitional' economies in Eastern Europe. The major crisis of the period, however, was Cuban epidemic neuropathy. In 1992, 30,000 people lost their eyesight due to nutritional deficiencies, but once the state had diagnosed the cause of the epidemic, it was able to respond quickly by distributing vitamin supplements via its robust primary care system. Rosaralis Santiesteban, 'In the Eye of the Cuban Epidemic Neuropathy Storm', interview by Christina Mills, *MEDICC Review* 13, no. 1 (2011): 10–15.
- 146 Elisa Botella-Rodriguez, 'Cuba's Inward-Looking Development Policies: Towards Sustainable Agriculture (1990–2008)', *Historia Agraria* 55 (2011): 160.
- 147 World Wide Fund for Nature, *Living Planet Report 2006* (World Wide Fund for Nature, 2006), 19.
- 148 Meghan E. Brown et al., 'Plant Pirates of the Caribbean: Is Cuba Sheltered by Its Revolutionary Economy?', *Frontiers in Ecology and the Environment* (2021); 'Cuba's Thriving Honey Business', *Economist*, 22 September 2018.
- 149 Stephen Milder, 'Between Grassroots Activism and Transnational Aspirations: Anti-Nuclear Protest from the Rhine Valley to the Bundestag, 1974–1983', *Historical Social Research/Historische Sozialforschung* 39, no. 1 (147) (2014): 194.

- 150 Adrian Mehic, ‘The Electoral Consequences of Nuclear Fallout: Evidence from Chernobyl’ (working paper, Department of Economics, School of Economics and Management, Lund University, 2020), project.nek.lu.se.
- 151 Michael Shellenberger, ‘The Real Reason They Hate Nuclear Is Because It Means We Don’t Need Renewables’, *Forbes*, 14 February 2019; Michael Shellenberger, ‘Stop Letting Your Ridiculous Fears of Nuclear Waste Kill the Planet’, *Forbes*, 19 June 2018, forbes.com.
- 152 James Hansen, ‘Baby Lauren and the Kool-Aid’, 29 July 2011, Columbia University, columbia.edu.
- 153 Michael Shellenberger, ‘Democratic Presidential Candidates Target Meat, Plastic Straws to Combat Climate Change, Reject Nuclear Power’, interview by Dana Perino, *The Daily Briefing*, Fox News, 5 September 2019, video.foxnews.com.

3. Planning Half-Earth

- 1 Alan Bollard, *Economists at War: How a Handful of Economists Helped Win and Lose the World Wars* (Oxford University Press, 2020), 137–8.
- 2 Harrison E. Salisbury, *The 900 Days: The Siege of Leningrad* (Harper & Row, 1969), 412.
- 3 Bollard, *Economists at War*, 138.
- 4 Leonid V. Kantorovich, *The Best Use of Economic Resources* (Pergamon Press, 1965 [1959]), xviii.
- 5 *Ibid.*, xxii.
- 6 Kantorovich’s vision was popularized in the novel *Red Plenty*. See Francis Spufford, *Red Plenty* (Graywolf Press, 2012 [2010]).
- 7 *Ibid.*, 254.
- 8 Leonid V. Kantorovich, ‘Mathematical Methods of Organizing and Planning Production’, *Management Science* 6, no. 4 (1960 [1939]).
- 9 Like calculus’ twin births centuries earlier, linear programming was discovered a second time nearly a decade later in the United States. George Dantzig was a military planner who had been tasked with personnel and equipment procurement for the Air Force, which motivated his version of linear programming in 1947: the ‘simplex’ method. A year later, this tool rationalized efforts to relieve the Soviet siege of Berlin. Inspired by Dantzig’s success, managers of private firms began to use linear programming to streamline their own operations. A notable difference between Dantzig and Kantorovich was that the former focused more on price, while the latter used in natura units. Robert Dorfman, ‘The Discovery of Linear Programming’, *Annals of the History of Computing* 6, no. 3 (1984): 283–95; Richard Cottle, Ellis Johnson, and Roger Wets, ‘George B. Dantzig (1914–2005)’, *Notices of the AMS* 54, no. 3 (2007): 344–62.
- 10 Leonid V. Kantorovich, ‘My Journey in Science (Proposed Report to the Moscow Mathematical Society)’, *Russian Math. Surveys* 42, no. 2 (1987): 233.
- 11 In the mid-century Soviet context, such a metric might be GDP or economic growth, though Neurath would surely disagree with optimizing quantities rooted in the ‘pseudorational’ world of money. In practice, this overall metric mattered little so long as constraints were well posed: if biodiversity and climate are respected while supplying everyone with enough energy and food, then whether we minimize energy use or land use matters only at the margins.
- 12 ‘At first talk was about countably-analytic calculators that had been acquired for the 1939 population census and after this were hardly used. Apparently these machines were first applied to numerical calculations by Professor Yanzhul from the Astronomical Institute in Leningrad.

The possibilities for using these machines for other calculations were discussed at the seminar. They were very slow – the tabulator took half a second for an addition, and for multiplication between five and eight seconds. They were casually talking about initial developments in electronic computers and countably-analytic calculators constructed on the same principles (of type Mark I and Mark II in the USA). Kantorovich, ‘My Journey in Science’, 260.

- 13 Kantorovich, ‘Mathematical Methods’, 368.
- 14 Kantorovich, ‘My Journey in Science’, 259.
- 15 Bollard, *Economists at War*, 153.
- 16 See Eric Magnin and Nikolay Nenovsky, ‘Calculating Without Money: Theories of In-Kind Accounting of Alexander Chayanov, Otto Neurath and the Early Soviet Experiences’, *European Journal of the History of Economic Thought* 28, no. 3 (2020): 456–77.
- 17 Pareto condoned the new fascist regime but died a year after the March on Rome. Renato Cirillo, ‘Was Vilfredo Pareto Really a “Precursor” of Fascism?’, *American Journal of Economics and Sociology* 42, no. 2 (1983): 235–45. Neoclassical economics is a politically ambivalent tradition; despite its conservative reputation now, during the first half of the twentieth century many of its theorists were either liberal or socialist.
- 18 Kantorovich, ‘My Journey in Science’, 259.
- 19 Kantorovich contributed through his meticulous calculations of the atomic bomb’s critical mass. Stanislav M. Menshikov, ‘Topicality of Kantorovich’s Economic Model’, *Journal of Mathematical Sciences* 133 (2006): 1394.
- 20 Slava Gerovitch, *From Newspeak to Cyberspeak: A History of Soviet Cybernetics* (MIT Press, 2002), 269.
- 21 Adam E. Leeds, ‘Dreams in Cybernetic Fugue: Cold War Technoscience, the Intelligentsia, and the Birth of Soviet Mathematical Economics’, *Historical Studies in the Natural Sciences* 46, no. 5 (2016): 660. The vision of a half-human, half-machine building didn’t work out as planned, and the building ended up being used more conventionally.
- 22 Cybernetics was a diffuse set of ideas about using computers to control complex systems, rather than to merely perform computations. ‘Once cybernetics became en vogue, the general intellectual climate became yet more favourable for Kantorovich’s ideas. Generally, the democratic tendencies of the Thaw and the widespread optimism about scientific progress, reinforced by the Sputnik euphoria, became two decisive factors in fostering the popularity of his notion of optimal planning.’ Ivan Boldyrev and Till Düppe, ‘Programming the USSR: Leonid V. Kantorovich in Context’, *British Journal for the History of Science* 53, no. 2 (2020): 268.
- 23 Jenny Andersson and Egle Rindzevičiūtė, ‘The Political Life of Prediction: The Future as a Space of Scientific World Governance in the Cold War Era’, *Les Cahiers européens de Sciences Po* 4 (2012): 13; Richard E. Ericson, ‘The Growth and Marcescence of the “System for Optimal Functioning of the Economy” (SOFE)’, *History of Political Economy* 51, no. S1 (2019): 165.
- 24 Edwin Bacon, ‘Reconsidering Brezhnev’, in *Brezhnev Reconsidered*, ed. Edwin Bacon and Mark Sandle (Palgrave Macmillan, 2002), 11–12; Abraham Katz, *The Politics of Economic Reform in the Soviet Union* (Praeger, 1972), 180–1.
- 25 János Kornai argues that the bureaucrats are bound together by (1) their values and shared belief in a noble purpose, (2) their ‘resolve to retain power’, (3) their prestige and relative privilege, and (4) self-discipline. János Kornai, *The Socialist System: The Political Economy of Communism* (Princeton University Press, 1992), 41–3. According to historians Ivan Boldyrev and Olessia Kirtchik, Soviet planning had changed little since its inception in the 1930s, remaining until the end a set of ‘negotiations between different actors including Gosplan, ministries, and large industrial units competing for scarce resources’. Ivan Boldyrev and Olessia

- Kirtchik, 'The Cultures of Mathematical Economics in the Postwar Soviet Union: More Than a Method, Less Than a Discipline', *Studies in History and Philosophy of Science* 63 (2017): 5.
- 26 Egle' Rindzevičiūte', 'Toward a Joint Future Beyond the Iron Curtain: East–West Politics of Global Modelling', in *The Struggle for the Long-Term in Transnational Science and Politics: Forging the Future*, ed. Jenny Andersson and Egle' Rindzevičiūte' (Routledge, 2015), 130.
 - 27 Boldyrev and Düppe, 'Programming the USSR'.
 - 28 Leonid Kantorovich, 'Mathematics in Economics: Achievements, Difficulties, Perspectives', prize lecture given for the 1975 Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel, nobelprize.org.
 - 29 We are not the first to notice Kantorovich's and Neurath's frameworks as complementary. See Paul Cockshott, 'Calculation In-Natura, from Neurath to Kantorovich', University of Glasgow, 15 May 2008, dcs.gla.ac.uk.
 - 30 This literature began to take off in 2009, when the planetary boundaries concept was coined in Johan Rockström et al., 'Planetary Boundaries: Exploring the Safe Operating Space for Humanity', *Ecology and Society* 14, no. 2 (2009), though the idea was around long before. Julia Steinberger's research group at the University of Leeds has done important work to further this research. See, for example, Daniel O'Neill et al., 'A Good Life for All Within Planetary Boundaries', *Nature Sustainability* 1, no. 2 (2018): 88–95. Another notable example is Kate Raworth, *Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist* (Chelsea Green Publishing, 2017).
 - 31 For an overview of the variety of IAMs used at present, see Alexandros Nikas, Haris Doukas, and Andreas Papandreou, 'A Detailed Overview and Consistent Classification of Climate-Economy Models', in *Understanding Risks and Uncertainties in Energy and Climate Policy: Multidisciplinary Methods and Tools for a Low Carbon Society*, ed. Haris Doukas, Alexandros Flamos, and Jenny Lieu (Springer, 2019), 1–54. Of particular interest to this book's readers will be computable general equilibrium models that undergird the scenarios used in IPCC climate reports.
 - 32 For some discussions of IAMs, see for example Paul Parker et al., 'Progress in Integrated Assessment and Modelling', *Environmental Modelling & Software* 17, no. 3 (2002): 209–17; Frank Ackerman et al., 'Limitations of Integrated Assessment Models of Climate Change', *Climatic Change* 95, nos. 3–4 (2009): 297–315; Lisette van Beek et al., 'Anticipating Futures Through Models: The Rise of Integrated Assessment Modelling in the Climate Science-Policy Interface Since 1970', *Global Environmental Change* 65 (2020): 102191.
 - 33 One prominent *Nature* paper, which limits warming to 1.5°C without the need to use negative emissions technologies like BECCS, requires the dramatic curtailment of the meat industry, serious cuts to energy use, and rapid reforestation (policies parallel to what we advocate in this book). Detlef P. van Vuuren et al., 'Alternative Pathways to the 1.5°C Target Reduce the Need for Negative Emission Technologies', *Nature Climate Change* 8, no. 5 (2018): 391–7. See also Arnulf Grubler et al., 'A Low Energy Demand Scenario for Meeting the 1.5°C Target and Sustainable Development Goals Without Negative Emission Technologies', *Nature Energy* 3, no. 6 (2018): 515–27.
 - 34 Otto Neurath, 'Through War Economy to Economy in Kind', in *Empiricism and Sociology*, ed. Marie Neurath and Robert S. Cohen (D. Reidel, 1973 [1919]), 151.
 - 35 *Ibid.*, 151, 154.
 - 36 *Ibid.*, 154.
 - 37 See, for example, C. T. M. Clack et al., 'Linear Programming Techniques for Developing an Optimal Electrical System Including High-Voltage Direct-Current Transmission and Storage', *International Journal of Electrical Power & Energy Systems* 68 (2015): 103–14.

- 38 W. Paul Cockshott and Allin Cottrell, *Towards a New Socialism* (Spokesman, 1993). For a response to these ‘labour money’ schemes, see Jasper Bernes, ‘The Test of Communism’, March 2021, jasperbernesdotnet.files.wordpress.com.
- 39 Rockström et al., ‘Planetary Boundaries’.
- 40 ‘Ambient (Outdoor) Air Pollution’, World Health Organization, 2 May 2018, [who.int](https://www.who.int).
- 41 The following paper estimates a global energy use of 149 EJ in 2050 (15.3 GJ/cap/yr), which is approximately 485 W. Joel Millward-Hopkins et al., ‘Providing Decent Living with Minimum Energy: A Global Scenario’, *Global Environmental Change* 65 (2020): 102168.
- 42 Emissions are from Peter Scarborough et al., ‘Dietary Greenhouse Gas Emissions of Meat-Eaters, Fish-Eaters, Vegetarians and Vegans in the UK’, *Climatic Change* 125, no. 2 (2014): 179–92. Land use is from Christian J. Peters et al., ‘Carrying Capacity of U.S. Agricultural Land: Ten Diet Scenarios’, *Elementa: Science of the Anthropocene* 4, no. 000116 (2016): Fig. 2. The 2.05 tonne figure is for ‘medium meat-eaters’; high meat-eaters emit a whopping 2.62 tonnes.
- 43 For example, ‘regenerative’ agricultural practices – where farmers carefully manage their soil so that it absorbs more carbon from the atmosphere, using methods like no-till agriculture or the use of cover crops – could cut food emissions by as much as 70 per cent (though this field is notorious for its many implausible promises). Presumably other efficiency gains outside of food production could also help improve this figure, such as a transition to organic agriculture. ‘Regenerative Agriculture: Good for Soil Health, but Limited Potential to Mitigate Climate Change’, World Resources Institute, 12 May 2020, wri.org. When we run the model later in this chapter, we find that assuming these improvements on food emissions are necessary if we are to meet the objectives of our model, because if we assume food emissions for vegans are 1.05 tonnes per year, this alone exceeds the per capita emissions quota for the 1.5°C scenario for a 10-billion-person planet if we assume moderate climate sensitivity.
- 44 OECD/FAO, *OECD–FAO Agricultural Outlook 2018–2027* (OECD Publishing, 2018), Fig. 6.7, fao.org.
- 45 Summary report of the EAT-Lancet Commission, ‘Food, Planet, Health: Healthy Diets from Sustainable Food Systems’, 14.
- 46 See [chapter two](#) for our scepticism regarding nuclear. This power source could easily be added in a more sophisticated model.
- 47 Biofuel power densities are from Vaclav Smil, *Power Density: A Key to Understanding Energy Sources and Uses* (MIT Press, 2015), 226–9. Biofuels can have positive emissions due to the complexities of soil carbon. See Anna Harper, ‘Why BECCS Might Not Produce “Negative” Emissions After All’, Carbon Brief, 14 August 2018, carbonbrief.org.
- 48 Smil, *Power Density*, 227.
- 49 Emissions of natural gas are assumed to be 0.91 pounds of CO₂ per kWh, as reported at ‘How Much Carbon Dioxide Is Produced Per Kilowatt-Hour of U.S. Electricity Generation?’, US Energy Information Administration, 15 December 2020, eia.gov. This converts to 3.61 kg CO₂/W, a figure which may be overly optimistic due to fugitive emissions and other upstream methane leaks. There is a wide range of power densities for natural gas electricity generation given in Smil’s work, largely depending on the configuration of the plant. We chose 4,500 W/m², representing the upper range of power density for the Kawagoe plant in Japan’s Mie prefecture, which was in the middle of estimates that ranged between 1,200 W/m² for some American plants to 20,000 W/m² for the Ravenwood plant in Queens, New York. Smil, *Power Density*, 142–3.
- 50 Smil, *Power Density*, 238–43.

- 51 David McDermott Hughes, 'To Save the Climate, Give Up the Demand for Constant Electricity', *Boston Review*, 1 October 2020, bostonreview.net.
- 52 See for example 'Energy Perspectives: Industrial and Transportation Sectors Lead Energy Use by Sector', US Energy Information Administration, 18 December 2012, eia.gov.
- 53 These energy-consuming sectors are included in every individual's 2,000-watt quota, in addition to the basic energy requirements of social goods, such as health care and education. In many statistical aggregations, agriculture is considered a part of industry.
- 54 'After Many False Starts, Hydrogen Power Might Now Bear Fruit', *Economist*, 4 July 2020, economist.com. We briefly discuss hydrogen in the second chapter.
- 55 Mark Z. Jacobson and Mark A. Delucchi, 'Providing All Global Energy with Wind, Water, and Solar Power, Part I: Technologies, Energy Resources, Quantities and Areas of Infrastructure, and Materials', *Energy Policy* 39, no. 3 (2011): 1154–69, Table 4.
- 56 Smil, *Power Density*, 244.
- 57 Ibid.
- 58 A 2016 study estimates that the amount of land used for biofuel globally was 413,000 km². Maria Cristina Rulli et al., 'The Water-Land-Food Nexus of First-Generation Biofuels', *Scientific Reports* 6, no. 22521 (2016): Table 1.
- 59 Otto Neurath, 'The Orchestration of the Sciences by the Encyclopedism of Logical Empiricism', *Philosophy and Phenomenological Research* 6, no. 4 (1946): 505.
- 60 Jordi Cat writes: '(1) Basic symbols must be self-evident, clear in themselves, representatives of a general concept or type; (2) symbols must be independent of color; (3) the use of color is not regulated in general; (4) symbols must be drawn without perspective; (5) symbols must leave a vivid lasting impression on the mind; (6) symbols must be combinable; (7) a symbol can stand for a number of things, as a graphic unit, and a number of symbols then stand for a corresponding multiple number of things; (8) pictorial statistics are to be read from top left to bottom right like a book, except when comparing national statistics, on a geographical map; (9) combinations of symbols may form a unit of information like a story. Clearly, the pictorial language is semantically, syntactically and pragmatically limited and underdeveloped. In addition, its transmission relied on exemplars and training rather than an explicit theory.' Jordi Cat, 'Visual Education' (supplement to 'Otto Neurath'), in *Stanford Encyclopedia of Philosophy* (fall 2019 edition), ed. Edward N. Zalta (Stanford University, 1997), plato.stanford.edu.
- 61 Otto Neurath, *International Picture Language: The First Rules of ISOTYPE* (Kegan Paul, Trench, Trubner & Co., 1936), 22. See also Eve Blau, 'Isotype and Architecture in Red Vienna: The Modern Projects of Otto Neurath and Josef Frank', *Austrian Studies* 14 (2006): 227–59.
- 62 Wiener notes that 'we also wish to refer to the fact that the steering engines of a ship are indeed one of the earliest and best-developed forms of feedback mechanisms'. Norbert Wiener, *Cybernetics: Or Control and Communication in the Animal and the Machine*, 2nd ed. (MIT Press, 1961), 12.
- 63 Peter Galison, 'The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision', *Critical Inquiry* 21, no. 1 (1994): 228–66.
- 64 Ibid., 240.
- 65 Gerovitch, *From Newspeak to Cyberspeak*, 58–9.
- 66 Leeds, 'Dreams', 649.
- 67 Ibid., 650–2.
- 68 Benjamin Peters, 'Normalizing Soviet Cybernetics', *Information & Culture* 47, no. 2 (2012): 150, 160.
- 69 Leeds, 'Dreams', 665.

- 70 To simulate each variable in his model over time, say steel production, Kantorovich realized that he could treat it at every moment as a separate variable: ‘Products of a particular type are differentiated with respect to the time period during which they are produced.’ By applying a special set of rules to relate these duplicated variables to one another, Kantorovich hacked the single-shot linear programming algorithm so that it could simulate change over time – it just had that many more variables to optimize. Leonid Kantorovich, ‘A Dynamic Model of Optimum Planning’, *Problems in Economics* 19, nos. 4–6 (1976 [1964]): 24–50.
- 71 Adam Leeds distinguishes between mathematical economists, who favoured optimization, and cyberneticians of various stripes, who favoured control. Leeds, ‘Dreams’, 664–5.
- 72 ‘The relationship between Kantorovich’s institute and CEMI, however, has not been as close as one would expect. Kantorovich ... considered the expectations of CEMI to be exaggerated, specifically those relating to the so-called system of optimal functioning of the economy (SOFE) that had the ambition to indeed “programme the USSR”.’ Boldyrev and Düppe, ‘Programming the USSR’, 274.
- 73 Leonid V. Kantorovich et al., ‘Toward the Wider Use of Optimizing Methods in the National Economy’, *Problems in Economics* 29, no. 10 (1987 [1986]): 17.
- 74 Leeds, ‘Dreams’, 663.
- 75 Leeds summarizes this well, if perhaps making Kantorovich sound overly liberal: ‘In sum, whereas the cyberneticians imagined a single well-controlled goal-oriented system, the economists imagined *calculating* parameters to steer another system, one external to the controllers: an evolving economy of independent agents.’ *Ibid.*, 664.
- 76 For the reader familiar with computer science: recent developments in linear programming have improved its computational complexity to current matrix multiplication time (see Michael B. Cohen, Yin Tat Lee, and Zhao Song, ‘Solving Linear Programs in the Current Matrix Multiplication Time’, arXiv.org, 18 October 2018). Furthermore, linear programming can make use of hardware acceleration made available by new architectures, such as Graphic Processing Units (GPUs), and in some cases can be sped up with sparse matrix calculations, or decomposed and parallelized. However, even this would not be enough to solve the problem. For a discussion on why planning the USSR in one giant linear programming model would be impossible, see Cosma Shalizi, ‘In Soviet Union, Optimization Problem Solves You’, *Crooked Timber*, 30 May 2012, crookedtimber.org.
- 77 Friedrich Hayek, ‘The Use of Knowledge in Society’, *American Economic Review* 35, no. 4 (1945): 526.
- 78 Eden Medina, *Cybernetic Revolutionaries: Technology and Politics in Allende’s Chile* (MIT Press, 2014), 28.
- 79 Quoted in *ibid.*, 26.
- 80 W. Ross Ashby, ‘Requisite Variety and Its Implications for the Control of Complex Systems’, in *Facets of Systems Science*, ed. George J. Klir (Springer, 1991), 405–17.
- 81 This exposition follows Medina’s excellent explanation of Beer’s viable systems model, which synthesizes several of Beer’s writings. Medina, *Cybernetic Revolutionaries*, 34–9.
- 82 *Ibid.*, 37.
- 83 *Ibid.*
- 84 *Ibid.*, 38.
- 85 *Ibid.*, 86.
- 86 Otto Neurath, ‘A System of Socialisation’, in *Economic Writings: Selections 1904–1945*, eds. Thomas E. Uebel and Robert S. Cohen (Springer, 2005), Fig. 5.
- 87 Henry Mauricio Ortiz Osorio and José Díaz Nafría, ‘The Cybersyn Project as a Paradigm for Managing and Learning in Complexity’, *Systema* 4, no. 2 (2016): 13.
- 88 Medina, *Cybernetic Revolutionaries*, 146–50.

- 89 Ibid., 81.
- 90 Ibid., 106.
- 91 Ibid. While CHECO was never fully operational, it did provide many simulations used by Chilean engineers.
- 92 Quoted in *ibid.*, 107.
- 93 Ibid., 211.
- 95 Daniel Kuehn, “‘We Can Get a Coup’: Warren Nutter and the Overthrow of Salvador Allende”, in *Research in the History of Economic Thought and Methodology: Including a Selection of Papers Presented at the 2019 ALAHPE Conference*, ed. Luca Fiorito, Scott Scheall, and Carlos Eduardo Suprinyak (Emerald Publishing, 2021), 151–86.
- 95 Soon after the 1980 constitution was implemented, Hayek told the Chilean newspaper *El Mercurio* that ‘I prefer a liberal dictator to democratic government lacking liberalism’. For more on Hayek’s relationship to the Pinochet regime, see Andrew Farrant and Edward McPhail, ‘Can a Dictator Turn a Constitution into a Can-Opener? F. A. Hayek and the Alchemy of Transitional Dictatorship in Chile’, *Review of Political Economy* 26, no. 3 (2014): 331–48. On 26 October 2020, progressive forces won a referendum in Chile that abolished the 1980 constitution and set up a convention to draft a new one.
- 96 Diana Kurkovsky West, ‘Cybernetics for the Command Economy: Foregrounding Entropy in Late Soviet Planning’, *History of the Human Sciences* 33, no. 1 (2020): 44.
- 97 Olga Burmatova, *Optimizatsiia prostranstvennoi struktury TPK: ekologicheskii aspekt* [Optimization of the spatial structure of TPC: The ecological aspect] (Nauka, 1983), 32, quoted in West, ‘Command Economy’, 47.
- 98 West, ‘Command Economy’, 48.
- 99 Burmatova, *Optimizatsiia*, 218, quoted in West, ‘Command Economy’, 48.
- 100 This enormous field is called ‘data assimilation’ and will be discussed briefly later in this section. The main algorithms used are Bayesian methods such as the Kalman filter (and its ensemble variant), ‘variational’ methods such as 4DVAR (ubiquitous in weather forecasting), and various other filters. For further reference, consult Sebastian Reich and Colin Cotter, *Probabilistic Forecasting and Bayesian Data Assimilation* (Cambridge University Press, 2015); Mark Asch, Marc Bocquet, and Maëlle Nodet, *Data Assimilation: Methods, Algorithms, and Applications* (SIAM, 2016); and Kody Law, Andrew Stuart, and Konstantinos Zygalakis, *Data Assimilation: A Mathematical Introduction* (Springer, 2015).
- 101 Rindzevičiūte, ‘Toward a Joint Future’, 127–8.
- 102 Paul N. Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming* (MIT Press, 2010), 8.
- 103 Rasmus Benestad, ‘Downscaling Climate Information’, *Oxford Research Encyclopedia of Climate Science*, 7 July 2016, oxfordre.com.
- 104 See for example Reich and Cotter, *Probabilistic Forecasting*, 33–64.
- 105 Medina, *Cybernetic Revolutionaries*, 79.
- 106 Otto Neurath, ‘Character and Course of Socialization’, in *Empiricism and Sociology*, 140.
- 107 A highly active participant in debates over reform within Warsaw Pact nations, Kornai criticized both Kantorovich and Western neoclassical economists for their overly simplistic understanding of real economies in his book *Anti-Equilibrium: On Economic Systems Theory and the Tasks of Research* (North-Holland Publishing Company, 1971).
- 108 Kornai, *The Socialist System*, 233–4 (emphasis in original).
- 109 So-called ‘lemon socialism’ can also occur in capitalist countries, where poorly run but vital or well-connected firms can always count on government bailouts in a crisis.

- 110 Robert Brenner, *The Economics of Global Turbulence: The Advanced Capitalist Economies from Long Boom to Long Downturn, 1945–2005* (Verso, 2006).
- 111 Also called ‘Japanification’ in the popular press. For an example of Summers’ view, see Lawrence H. Summers, ‘Accepting the Reality of Secular Stagnation’, *Finance and Development* 57, no. 1 (2020): 17–19. For a Marxist perspective, see Aaron Benanav, *Automation and the Future of Work* (Verso, 2020).
- 112 *Ibid.*, 569–70.

4. News from 2047

- 1 Karl Marx and Friedrich Engels, *The German Ideology* (Prometheus Books, 1998), 53.
- 2 Leonid Kantorovich, ‘Mathematics in Economics: Achievements, Difficulties, Perspectives’, lecture given for the 1975 Sveriges Riksbank (Bank of Sweden) Prize in Economic Sciences in Memory of Alfred Nobel, nobelprize.org.
- 3 Ron Scollon and Suzie Wong Scollon, ‘The Axe Handle Academy: A Proposal for a Bioregional, Thematic Humanities Education’, in *Lessons Taught, Lessons Learned: Teachers’ Reflections on Schooling in Rural Alaska*, ed. Ray Barnhardt and J. Kelly Tonsmeire (Alaska State Department of Education, 1986), available at ankn.uaf.edu.

Epilogue

- 1 William Morris, *News from Nowhere* (Cambridge University Press, 1995 [1890]), 135.
- 2 Aaron Bastani, *Fully Automated Luxury Communism: A Manifesto* (Verso, 2019), 189. Bastani is an exception to the otherwise anti-environmentalist FALC collective in that he supports rewilding and abolishing the livestock industry.
- 3 For another melding of Hegel and Morris, see Rudolphus Teeuwen, ‘An Epoch of Rest: Roland Barthes’s “Neutral” and the Utopia of Weariness’, *Cultural Critique* 80 (2012): 1–26.
- 4 J. Bruce Glasier, *William Morris and the Early Days of the Socialist Movement* (Longmans, Green, and Co., 1921), 150.
- 5 William Morris, review of *Looking Backward: 2000–1887*, by Edward Bellamy, *Commonweal* 5, no. 180 (1889): 194–5, marxists.org.
- 6 William Morris, ‘The Aims of Art’, in *Signs of Change: Seven Lectures Delivered on Various Occasions* (Reeves and Turner, 1888), 136.
- 7 Friedrich Hayek, ‘The Trend in Economic Thinking’, *Economica* 40 (1933): 123.
- 8 Friedrich Hayek, *The Counter-Revolution in Science: Studies on the Abuse of Reason* (Free Press, 1952), 88.
- 9 John Oswald, ‘The Cry of Nature; Or, an Appeal to Mercy and to Justice, on Behalf of the Persecuted Animals’, International Vegetarian Union, ivu.org.
- 10 Carol J. Adams, *The Sexual Politics of Meat: A Feminist-Vegetarian Critical Theory* (Continuum, 2010 [1990]), 268n6.
- 11 Percy Bysshe Shelley, *A Vindication of Natural Diet* (Offices of the Vegetarian Society, 1884 [1813]), 9, 20.

- 12 Edward Aveling and Eleanor Marx-Aveling, 'Shelley and Socialism', *To-Day*, April 1888, 103–16, marxists.org.
- 13 Adams, *The Sexual Politics of Meat*, 155.
- 14 Julia V. Douthwaite and Daniel Richter, 'The Frankenstein of the French Revolution: Nogaret's Automaton Tale of 1790', *European Romantic Review* 20, no. 3 (2009): 381–411.
- 15 Mary Shelley, *Frankenstein: Or the Modern Prometheus* (Routledge, 1888 [1818]), 77.
- 16 Fiona MacCarthy, review of *Edward Carpenter: A Life of Liberty and Love*, by Sheila Rowbotham, *Guardian*, 1 November 2008, theguardian.com.
- 17 Leah Leneman, 'The Awakened Instinct: Vegetarianism and the Women's Suffrage Movement in Britain', *Women's History Review* 6, no. 2 (1997): 271–87.
- 18 Karl Marx, *Capital: A Critique of Political Economy*, vol. 1 (Penguin, 1976 [1867]), 343.
- 19 George Orwell, *The Road to Wigan Pier* (Harcourt Brace, 1958 [1937]), 216, 222.
- 20 Ursula K. Le Guin, *A Wizard of Earthsea* (Houghton Mifflin, 2012 [1968]), 54.
- 21 Colin Burrow, 'It's Not Jung's, It's Mine', *London Review of Books* 43, no. 2 (2021): 12.
- 22 Ursula K. Le Guin, 'A Left-Handed Commencement Address', Mills College, 22 May 1983, americanrhetoric.com.
- 23 Ursula K. Le Guin, 'The Carrier Bag Theory of Fiction', in *The Ecocriticism Reader: Landmarks in Literary Ecology*, ed. Cheryll Glotfelty and Harold Fromm (University of Georgia Press, 1996), 154.