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TO FREEZE THE THAMES

Natural Geo-Engineering and Biodiversity

THE IDEA OF a ‘steady-state economy’, a signal theme in the environmentalist politics of the 1970s with understandable appeal, has been refloated by ‘no growth’ thinkers in France and, most recently, by Herman Daly, in discussion with Benjamin Kunkel in *NLR* 109. If, as I shall argue here, steady-state economics is an ambiguous construction that actually offers little to egalitarian environmentalists, then on what foundations might an alternative green political economy be built? Neither population nor GDP will be its fundamental metric, but rather *land scarcity*. This is the concept that emerges—or rather re-emerges—as the most precious resource in any solution that brings the benign possibilities of geo-engineering to bear on the problem of faltering biodiversity and the entailments of an adequate deployment of renewable energy systems. A brisk panorama of the ‘Little Ice Age’ will help make these airy ideas solid.

‘Behold the liquid Thames now frozen o’er / That lately ships of mighty Burthen bore’, may seem to be the opening lines of a poet’s imagined world, but it recalls the actual freezing of London’s great waterway in 1740.¹ Although there are records of the river freezing since the fifteenth century, the frequency of such cold winters increased dramatically during the seventeenth century to about once a decade, often enough for ‘Frost Fairs’ to become a municipal institution. Between London Bridge and Blackfriars Bridge city-dwellers played skittles, baited bears and feasted atop a strangely solid Thames. Other regions too experienced bizarre shifts in climate during the Little Ice Age, an era of widespread cooling from the sixteenth to nineteenth centuries. Icelanders starved when the

frozen sea choked off their ports, Alpine Swiss dreaded glaciers expanding to swallow their villages and Manhattanites could walk to Staten Island. The poor harvests of the cool, wet seventeenth century have been held responsible for starving peasants and feeding instability: the Thirty Years' War, the Fronde, the English Civil War, the decline of the Ming dynasty, and war between Russia and Poland-Lithuania.² Hints of what caused the big chill were to be found in empty towns along the Mississippi.

In 1541 Hernando de Soto travelled along that mighty waterway and encountered a string of densely inhabited, warring settlements: Coosa, Mabila, Pacaha, Chicaza and Cofitachequi. Little is known today about Mississippian society aside from its penchant for moats and mounds; when the next European ventured there in 1682, the region was uninhabited. Most likely, epidemics of Old World origin had broken out between the two expeditions, which was hardly an unusual fate for the time. In 1492, the Americas had teemed with perhaps sixty million inhabitants, a population equaling Europe's; but the ensuing cataract of genocide, enslavement, war and epidemics reduced the indigenous population to fewer than 6 million by the mid-1600s. A slow demographic recovery began in South America a hundred years later, though mass deaths among First Nations have never truly ceased. But the de-peopling of the New World meant millions of hectares of maize, potato, squash and other crops lay fallow in the seventeenth century. Forest encroached on abandoned fields. Much of the verdant splendour of the New World that awed Europeans was the result of nature's reconquest of ancient agricultural land. Botanical regrowth on a bi-continental scale sequestered between 17 and 38 gigatonnes of carbon, lowering the store of atmospheric CO₂ by up to 10 parts per million (PPM). This was a significant share of the total CO₂—then, 276 PPM; today, 411 PPM—and enough to lower temperatures in the northern hemisphere by 0.6°C.³

¹ Unknown poet, 'Printed on the River Thames in the month of January, 1740', in Charles Dickens, William Harrison Ainsworth and Albert Smith, eds, *Bentley's Miscellany*, vol. 7, London 1841, p. 134.

² Geoffrey Parker, *Global Crisis: War, Climate Change, and Catastrophe in the Seventeenth Century*, New Haven, CT 2013. The parameters of the Little Ice Age remain hotly disputed. See, inter alia, Emmanuel Le Roy Ladurie, *Les Fluctuations du climat de l'an mil à aujourd'hui*, Paris 2011, and the discussion of Ladurie's work in Mike Davis, 'Taking the Temperature of History', NLR 110, March–April 2018.

³ Jed Kaplan et al., 'Holocene Carbon Emissions as a Result of Anthropogenic Land Cover Change', *Holocene*, vol. 21, no. 5, December 2010, pp. 775–91; R. J. Nevle et al., 'Neotropical Human–Landscape Interactions, Fire, and Atmospheric CO₂ during European Conquest', *Holocene*, vol. 21, no. 5, August 2010, p. 853.

The Little Ice Age not only provides insight into the far-reaching ecological repercussions of colonialism, it also hints at the possible democratization of Natural Geo-Engineering—accelerating carbon sequestration through natural processes, as a means of safely ameliorating climate change.⁴ A rival approach, Artificial Geo-Engineering, would put iron filings or limestone into the oceans and aerosols into the skies to reflect sunlight into space. Given the complexity of the global climate system, this tinkering is terribly risky even if increasingly likely. In a future closer than one expects, entrepreneurial scientists and their private corporations will aim to fire aerosols into the atmosphere by means of artillery, high-flying airplanes or balloons. Real-life experiments, despite their illegality, have already been carried out and patents sought.⁵ In contrast with this, giving up territory to nature through democratic choice is a safe way to counteract carbon pollution with unambiguously beneficial environmental multiplier effects.

However, Natural Geo-Engineering requires a lot of land. The mere thought of recreating a bloodless second Little Ice Age to avert a capitalist climatic Armageddon restores the central role of land scarcity to economics after an absence of two centuries. For as it happens, two other goals of the environmental movement—preserving biodiversity and switching to a zero-carbon energy system—also require expanses of continental scope. There are many reasons to forsake nuclear power and fossil fuels and embrace solar- and wind-based energy; but—outside very windy and sunny countries—the latter have extremely low ‘power densities’. Power density describes the relationship between energy produced or consumed relative to a system’s surface area, measurable in watts per square metre. While the richest deposits of fossil fuels can have power densities near 20,000 w/m², even shabby ones like Alberta’s tar sands have a power density of 1,000 w/m². This is why only half of one per cent of US territory is dedicated to the ‘business as usual’ energy system.⁶ In contrast, the highest power density for solar- and wind-powered

⁴ Oswald Schmitz, ‘How “Natural Geo-Engineering” Can Help Slow Global Warming’, *Yale e360*, 25 January 2016.

⁵ See Clive Hamilton, *Earthmasters: The Dawn of the Age of Climate Engineering*, New Haven, CT 2013, pp. 74–84; Philip Mirowski, *Never Let a Serious Crisis Go to Waste*, London and New York, pp. 325–58.

⁶ See Vaclav Smil, *Power Density*, Cambridge, MA 2015, p. 247. A notable exception to this is Appalachian mountain-top removal, which has a power density ‘well below’ 100 w/m²: p. 107.

infrastructure seems to be about 10 W/m^2 , and it is often less than half of that in sub-par locations. A fully renewable system will probably occupy one hundred times more land than a fossil-fuel-powered one. In the case of the US, between 25 and 50 per cent of its territory, and in a cloudy, densely populated country such as the UK, *all* of the national territory might have to be covered in wind turbines, solar panels and biofuel crops to maintain current levels of energy production. While ongoing tinkering will improve renewable energy systems, they will never have the power densities of fossil fuels.⁷ It is land scarcity, rather than rare natural resources, that is the ultimate limit to economic growth: energy consumption *must* be cut.

In addition to averting Artificial Geo-Engineering and fossil-fuel use, perhaps the third most pressing goal of the contemporary global environmentalist movement is to forestall the ‘Sixth Extinction’.⁸ The current haemorrhaging of flora and fauna species is occurring at a rate one thousand to ten thousand times faster than normal; a speed comparable only to the last great extinction 66 million years ago, when a huge asteroid careened into the earth and set off the volcanic eruptions of the Deccan Traps.⁹ Even if the explosion of present-day extinctions remains a quiet catastrophe, it will ultimately prove to be no less deadly to life on Earth. The principal cause of extinction is habitat loss, as underlined by the recent work of E. O. Wilson. Though notorious in the Reagan era as the genetic-determinist author of *Sociobiology*, Wilson is first and foremost a naturalist and conservationist. He estimates that, with a decrease of habitat, the sustainable number of species in it drops by roughly the fourth root of the habitable area. If half the habitat is lost, approximately a tenth of species will disappear, but if 85 per cent is destroyed, then half the species would be extinguished. Humanity is closely tracking this equation’s deadly curve: half of all species are expected to disappear by 2100. The only way to prevent this is to leave enough land for other

⁷ Even eco-optimists, such as Mark Jacobson, assume underwhelming rates of power density for renewables, with only 9 W/m^2 for wind: Mark Jacobson et al., ‘The United States Can Keep the Grid Stable at Low Cost with 100% Clean, Renewable Energy in all Sectors Despite Inaccurate Claims’, *PNAS*, vol. 114, no. 26, June 2017.

⁸ Elizabeth Kolbert, *The Sixth Extinction: An Unnatural History*, New York 2014.

⁹ J. M. de Vos et al., ‘Estimating the Normal Background Rate of Species Extinction’, *Conservation Biology*, vol. 29, no. 2, April 2015, pp. 452–62. Paul Renne et al., ‘State Shift in Deccan Volcanism at the Cretaceous-Paleogene Boundary, Possibly Induced by Impact’, *Science*, vol. 350, no. 6,256, October 2015, pp. 76–8.

living beings to flourish, which has led Wilson to call for a utopian programme of creating a ‘half Earth’, where 50 per cent of the world would be left as nature’s domain. Even though much has been lost, he argues that thirty especially rich biomes, ranging from the Brazilian *cerrado* to the Polish-Belarusian Białowieża Forest, could provide the core of a biodiverse, interconnected mosaic extending over half the globe.¹⁰ Yet, at present only 15 per cent of the world’s land-area has some measure of legal protection, while the fraction of protected areas in the oceans is even smaller—less than 4 per cent.

Arguably, it is a virtue that these three goals—Natural Geo-Engineering, renewable-energy systems and ‘half-earth’ habitat protection—are so land-hungry: constraint clarifies thought, and there are simply very few ways to find sufficient space. Furthermore, a focus on land scarcity also reveals new connections and opportunities; after all, cuts in consumption are needed to provide space for both wind farms and rewilded ecosystems, and the latter require a high degree of biodiversity to function effectively as carbon sinks, yet their ability to be effective carbon sinks depends on a rapid transition to renewable energy systems before climate change irreversibly undermines the integrity of ecosystems. Once land is reclaimed as an integral economic category, and goals of natural preservation and global economic equality are championed, then suddenly a new red–green political economy emerges. What follows, then, explores what such a programme would involve, initially by way of an extended thought-experiment. Extrapolated from the three fundamental aims of Natural Geo-Engineering, biodiversity and renewable-energy systems, the project might take on any number of mantles: ‘egalitarian eco-austerity’, ‘eco-socialism’ or, borrowing from Wilson, ‘half-earth economics’, to emphasize both the necessary scale of ambition and its crucial spatial aspect. First, though, a critical look at some of the most salient alternatives: the ‘steady state’ of Daly’s ecological economics and the possibilities for technological solutions.

Cap-and-trade equilibrium?

In contrast to a strong ‘half-earth’ programme, Herman Daly’s proposals for an ecologically sustainable ‘steady-state’ economy appear all too modestly reformist, risking capture by neo-liberal environmentalism.

¹⁰ E. O. Wilson, *Half-Earth: Our Planet’s Fight for Life*, New York 2016, pp. 136–51.

Repudiating the universal capitalist goal of economic growth—‘growthmania’, in his terms—Daly defines a steady-state economy as one that does not increase in size relative to the overall ecosphere, of which it is a sub-system: the material ‘throughput’ would remain constant in terms of resources consumed, although the output might improve in quality. The path towards it involves a three-part programme. First, ‘depletion quotas’, to limit resource use—these would be auctioned by the state, raising public revenues. Second, income redistribution, by way of a maximum-income cap and a minimum-income floor, to limit inequality. Third, a one-child-per-parent cap on human reproduction, regulated through tradable vouchers—the argument being that this would combine aggregate population control with a measure of individual choice. ‘Environmental impact is the product of the number of people times per capita resource use’, Daly argues, so a steady-state ecological-economic strategy would require both population and resource depletion to be held constant.¹¹

Daly’s critique of ‘growth fetishism’ and the macro-economic pursuit of rising GDP implies that capitalists could be persuaded not to pursue economic expansion. But growth is not the result of a misguided cultural notion. Daly has missed the crucial insight that capitalism is a novel system, emerging only in the early modern era and pitting rival capitals against each other, such that profit-making is a structural imperative, not merely an option. Capital must complete its circuit through the commodity form greater than when it started or there will be a crisis. Profitability, not abstract measurements like GDP, is what matters. The latter’s late arrival in the history of capitalism hints that it is mere foam, while the struggle to maintain profitability goes on in the churning depths.¹² Daly underestimates the difficulties of shackling capitalism so as to slow it down.

Despite the egalitarian gesture of restricted income inequality, his approach essentially relies on the market to regulate ‘growthmania’—a contradiction in terms. In his steady-state world, the rich would be licensed to breed, while the poor might have to trade their right to a child for the means of subsistence—echoes of Cold War eugenicism. Though

¹¹ Herman Daly and Benjamin Kunkel, ‘Ecologies of Scale’, NLR 109, pp. 88–93.

¹² Adam Tooze, *Statistics and the German State, 1900–1945: The Making of Modern Economic Knowledge*, Cambridge 2001. Robert Collins, *More: The Politics of Economic Growth in Postwar America*, Oxford 2002.

'depletion quotas' would be auctioned by the state, functioning as a sort of extraction tax, their actual operation under conditions of cartelized energy giants and captive state administrations would be no different from current programmes of 'cap and trade', as Daly acknowledges.¹³ The cap-and-trade concept was devised in 1968 by John Dales, an economist at the University of Toronto and a Chicago School fellow-traveller, to deal with the environmental degradation of the Great Lakes.¹⁴ He proposed that rather than simply dictate industrial standards, it would be more efficient to impose a limit, or 'cap', on emissions and then have industries buy and trade pollution-permits amongst themselves. Cleaner factories, for example, could sell permits to dirtier ones, if the latter wanted to avoid upgrades. Dales's idea has proven to be incredibly versatile, seemingly applicable to any environmental problem, including over-fishing, acid rain, climate change and biodiversity loss.

Daly is attracted to cap-and-trade for two reasons. First, it seems to offer a means to impose a 'steady state'—represented by the 'cap'—while still relying on the market to distribute goods efficiently.¹⁵ Second, it provides a way to theoretically reconcile the economy and nature—a problem which has absorbed Daly's attention since he famously doodled the sphere of the 'economy' enclosed by the world's 'ecosystem'. However, cap-and-trade doesn't overcome the binary of nature and the economy; it simply renders the former in market terms, deeming it 'natural capital'. This is why neo-liberals admire Daly's solution, just as they admired its neo-classical predecessor, Pigou's 'externalities'. Turning nature into 'natural capital' makes it *easier* to exploit; insisting on the non-fungibility of certain parts of nature by placing it beyond the economy's reach is its surest defence.¹⁶

Cap-and-trade is the point where the arc of Daly's optimism intersects with the neo-liberals' downward-sloping cynicism, for not only does cap-and-trade rarely work, sometimes it is not even intended to. The world's biggest cap-and-trade programme for CO₂ emissions, the European Emissions Trading System (ETS), has largely functioned to forestall meaningful action against climate change since its creation in 2005. At its nadir, in 2013, a tonne of carbon fetched less than €3, and even at the

¹³ Daly, 'Ecologies of Scale', p. 88.

¹⁴ John Dales, *Pollution, Property & Prices*, Toronto 1968.

¹⁵ Daly, 'Ecologies of Scale', p. 90.

¹⁶ Andreas Malm makes a similar point in *The Progress of this Storm*, London 2018.

moment of writing (early May 2018) the price is only €10 per tonne. This is a far cry from an effective price for carbon—ExxonMobil estimates that the price would need to be \$2,000 per tonne for global warming to be limited to 1.6 degrees centigrade.¹⁷ Even carbon capture and sequestration (CCS) projects need \$80–150 per tonne to break even, which is why CCS has proven to be such an unimpressive technology.¹⁸ The problem originated from the European Union’s decision to placate industry by setting the number of permits too high, so ensuring prices would remain low. Daly’s framework does not address the problem of the class capture of markets.

Furthermore, markets seek markets. With cap-and-trade, money that might have been used productively to alter the energy infrastructure instead gets pumped into ‘yet another set of speculative financial instruments, leading to bubbles, distortions of capital flows, and all the usual symptoms of financialization.’¹⁹ A similar tactic of delay and destroy can be detected in the burgeoning market for ‘biodiversity offsets’, a cap-and-trade policy engineered by mining companies in the early 2000s.²⁰ Potemkin technocracies of this sort are a dead end for the environmentalist movement.

Coal and other questions

As Daly stresses, classical political economy operated with a strong sense of the material limits of land and resources. In *The Coal Question* (1865), William Stanley Jevons—who used the language of Smith and Ricardo while simultaneously introducing marginalist techniques—carefully distinguished between coal’s exhaustion in a physical sense and in an economic one, where the cost of extraction would exceed the utility of the coal itself.²¹ For a brief period after 1945, petroleum appeared to buck both those limits. First, as Timothy Mitchell notes, oil declined continuously in price—‘although increasing quantities of energy were

¹⁷ Natasha Lamb and Bob Litterman, ‘Tell the truth, ExxonMobil: A low-carbon future is affordable—and necessary’, *Guardian*, 31 January 2016.

¹⁸ Sean Sweeney, *Hard Facts about Coal: Why Trade Unions Should Rethink Their Support for Carbon Capture and Storage*, New York 2015, p. 8.

¹⁹ Mirowski, *Never Let a Serious Crisis Go to Waste*, pp. 339–40.

²⁰ Sarah Benabou, ‘Making Up for Lost Nature: A Critical Review of the International Development of Voluntary Biodiversity Offsets’, *Environment and Society*, vol. 5, 2014, pp. 103–23.

²¹ William Stanley Jevons, *The Coal Question*, London 1865, Preface, p. 2.

consumed, the cost of energy did not appear to represent a limit to growth'. Second, 'thanks to its relative abundance and the ease of shipping it across oceans, oil could be treated as something inexhaustible.'²² While oil-price illusions were shattered by the 1973 OPEC embargo, there still remains a centuries-long total reserve of hydrocarbons, sufficient to fry the planet. Indeed, if there is any chance of capping warming at 2°C, on one authoritative estimate three-quarters of fossil-fuel reserves will have to stay in the ground.²³

Yet even if capitalism is not confronted with an absolute dearth of fossil fuels, it faces the problem predicted by Jevons 150 ago of rapidly increasing marginal costs. In the nineteenth century, the best reserves allowed the retrieval of a hundred barrels for every one used for extraction; an energy return on investment (EROI) of 100:1. The US, long the world's largest producer, still had an energy return of 100:1 in the 1930s, but four decades later this had dropped to 30:1.²⁴ Already by the 1960s, ultra-cheap Middle Eastern and US petroleum was being supplemented by more expensive production in Siberia, the North Sea, Alaska and the Gulf of Mexico. Since the 1990s, production at many of these second-tier deposits has begun to decline, leading to a new round of exploring ever more marginal reserves. Today's best prospects for future growth, US 'fracked' petroleum and Alberta's tar sands, have the measly energy-return rates of 7:1 and 3:1, respectively.²⁵ It can't get much lower than this. Nevertheless, 'Peak Oil' in terms of conventional petroleum occurred in 2005, suggesting that the future will resemble Alberta more than Al-Ghawār. Engineers in the Canadian tar sands have been busy sharing their expertise with US, Israeli, Venezuelan, Malagasy, Trinidadian and Chinese counterparts.²⁶ Relative to conventional petroleum, non-conventional fuel creates more pollution when it is extracted and

²² Timothy Mitchell, 'Carbon Democracy', *Economy and Society*, vol. 38, no. 3, August 2009, p. 418.

²³ Christophe McGlade and Paul Ekins, 'The Geographical Distribution of Fossil Fuels Unused when Limiting Global Warming to 2°C', *Nature*, vol. 517, pp. 187–90, January 2015.

²⁴ Ugo Bardi et al., 'Modelling EROI and Net Energy in the Exploitation of Non-Renewable Resources', *Ecological Modelling*, vol. 223, no. 1, December 2011, pp. 54–8.

²⁵ Rachel Nuwer, 'Oil Sands Mining Uses up Almost as Much Energy as It Produces', *Inside Climate News*, 19 February 2013.

²⁶ John L. Hallock, Jr et al., 'Forecasting the Limits to the Availability and Diversity of Global Conventional Oil Supply', *Energy*, vol. 64, January 2014, p. 130; MacDonald Stainsby, 'New Beginnings: Tar Sands Prospecting Abroad', in Toban Black et al., eds, *A Line in the Tar Sands*, Toronto 2014, pp. 101–8.

is much more dangerous to transport, as manifested by the fire-bombed Québécois town of Lac-Mégantic in 2013 or the desecration of the Kalamazoo River a few years earlier. The massive permanent toxic tailings lakes in Alberta and water-tables contaminated by secret proprietary fracking solvents will multiply globally as the industry transitions from conventional to non-conventional fossil fuels.²⁷

Nor will the seemingly greenest conventional substitutes suffice, for hydropower and methane (i.e. natural gas) are not nearly as 'clean' as advertised. When a forest is flooded to create a dam's reservoir, carbon dioxide is released from the decomposing trees. Algae growth is catalyzed by the silt trapped by the dam, creating massive emissions of methane. Some hydropower projects actually produce more greenhouse gas emissions than a fossil-fuel-fired plant would.²⁸ In addition, dams entail significant destruction of habitats and loss of species. It is worth noting that Mark Jacobson and his co-authors shy from adding new dams in their model because of these costs.²⁹ The power density of dams can be quite low—an order of magnitude lower than solar or wind-power—if placed on the middle or lower reaches of a river. Ghana's Akosombo Dam has a power density of only 0.1 W/m², leading its reservoir to gobble up 4 per cent of the country's landmass.³⁰ Methane too loses its lustre as a 'bridge fuel' upon closer examination. Fracking has been credited with reducing carbon pollution in the US, as cheaper methane-fired power plants have replaced coal-fired rivals. But this overlooks the fact that, while carbon emissions declined over the dozen years after 2002, any benefit was undone by increased methane pollution, which rose by a third. Although methane decomposes more quickly than carbon dioxide,

²⁷ The train that destroyed Lac-Mégantic was carrying fracked petroleum, laced with explosive chemicals. Jacquie McNish and Grant Robertson, 'The Deadly Secret behind the Lac-Mégantic Inferno', *Globe and Mail*, 3 December 2013. Elizabeth McGowan and Lisa Song, 'The Dilbit Disaster: Inside The Biggest Oil Spill You've Never Heard Of', *Inside Climate News*, 26 June 2012. Gillian Steward, 'Tailings Ponds a Toxic Legacy of Alberta's Oilsands', *Toronto Star*, 4 September 2015.

²⁸ Duncan Graham-Rowe, 'Hydroelectric Power's Dirty Secret Revealed', *New Scientist*, 24 February 2005. Bridget Deemer et al., 'Greenhouse Gas Emissions from Reservoir Water Surfaces', *BioScience*, vol. 66, no. 11, 1 November 2016, pp. 949–64.

²⁹ Mark Jacobson, '100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World', *Joule*, 6 September 2017, p. 93.

³⁰ Smil, *Power Density*, p. 73.

its 'greenhouse' effect is a hundred times greater in the short term, thirty times greater in the medium term. This is why only a tiny percentage needs to leak before any environmental advantage is nixed. The actual leakage rate is quite high, possibly even 9 per cent.³¹

If no rapid transition away from coal, methane and petroleum is on the cards, then Artificial Geo-Engineering, a dangerous and once-ostracized technology, becomes increasingly likely. It already has the blessing of the Intergovernmental Panel on Climate Change. The probable consequences are dystopian sci-fi. 'Solar radiation management' will bleach the sky white, cause tens of thousands of deaths from aerosol pollution, gash the ozone layer and interrupt vital climatic systems like the monsoon and the Gulf Stream. Some of these risks are even acknowledged by its advocates; the world's leading geo-engineer, David Keith, admits that the closest analogue to Artificial Geo-Engineering is nuclear weapons. It is appropriate that the natural habitat of this technology is in Alberta. In the 2000s, Keith was teaching at the University of Calgary, where both the institution and city have become inextricably linked to the tar-sands industry. To commodify his dangerous expertise he founded a firm, Carbon Engineering, which counts Bill Gates and tar-sands tycoon Murray Edwards as its billionaire patrons. Keith and his fellow thinkers were ostracized as dangerous quacks only a decade ago, but have become respectable through their embrace by the likes of Harvard (where Keith now teaches) and Oxford. Like nuclear waste, or the gargantuan tailings lakes of the tar-sands industry, Artificial Geo-Engineering will require millennia-long management. Should the 'climate shield' ever fail, if a war or some other disaster interrupts the aerosol cannons, then the world would rapidly overheat. Such an amplified geo-engineered summer could be as devastating to Earth life as a nuclear winter.

Atomic environmentalism

Nor is there much solace to be found in nuclear power, which is nowhere near as environmentally benign as its proponents claim. Studies of the life-cycle of CO₂ emissions of nuclear plants vary widely, since no one knows the total cost of decommissioning a nuclear reactor or

³¹ Bill McKibben, 'Global Warming's Terrifying New Chemistry', *Nation*, 23 March 2016. Nathan Phillips et al., 'Mapping Urban Pipeline Leaks', *Environmental Pollution*, vol. 173, February 2013, pp. 1–4.

permanently storing toxic waste.³² One can, however, estimate the greenhouse-gas emissions required to process uranium fuel. The use of low-grade ore (<0.01 per cent) may create the same greenhouse-gas footprint as a methane-fired power plant, belying claims that nuclear is a carbon-neutral source of power. More startlingly, perhaps, the use of low-grade ore would give a nuclear-power plant an energy return on investment of 1:1—literally not worth the effort. This is not an abstract problem: 37 per cent of global uranium reserves are found in deposits that are only half as rich (<0.005 per cent). Furthermore, the power density of nuclear plants varies tremendously, depending on the size of accompanying radioactive glacies and dedicated cooling lakes. While some projects have fairly high power density, as Fukushima Daiichi did (1,300 W/m²), others are puny, like the Wolf Creek facility in Kansas (30 W/m²).³³ Economically, of course, nuclear plants are always white elephants: every kilowatt-hour produced by Hinkley Point C will cost double the wholesale rate—and this at a time when prices for wind and solar power continue to plunge.

There have been enough accidents over the past half-century to discredit nuclear power. Without detailing all of these, in their various shades of hubris and incompetence, examination of the most recent will suffice. The clean-up crews at the Fukushima Daiichi plant do not even know where the fuel rods of the three destroyed reactors actually *are*. Six hundred tonnes of still-fissioning uranium melted through their containment vessels and continue even now to sink deep into the earth beneath the plant. Five robots sent to look for the lost fuel rods ‘died’ during their mission, when radiation destroyed their wiring. Cleaning up may take forty years or longer and cost \$20 billion, while the total cost of the disaster is estimated at \$188 billion.³⁴ Part of the reason why the destroyed plant is so difficult to clean is that it needs to be inundated daily with 150,000 litres of ocean water. In its early days, the

³² Benjamin Sovacool, ‘Valuing the Greenhouse Gas Emissions from Nuclear Power: A Critical Survey’, *Energy Policy*, vol. 36, August 2008, pp. 2,940–53. OECD, *Costs of Decommissioning Nuclear Power Plants*, Paris 2016.

³³ Keith Barnham, ‘False Solution: Nuclear Power is not “Low Carbon”’, *Ecologist*, 5 February 2015; Smil, *Power Density*, pp. 146–7.

³⁴ Aaron Sheldrick and Minami Funakoshi, ‘Fukushima’s Ground Zero’, *Reuters*, 11 March 2016; Yuka Obayashi and Kentaro Hamada, ‘Japan Nearly Doubles Fukushima Disaster-Related Cost to \$188 Billion’, *Reuters*, 8 December 2016.

deluge cooled and stabilized the damaged reactors, arresting the core's meltdown; without it, the radiation would have spread much farther, forcing the evacuation of up to 50 million people from Tokyo and its environs, a dislocation the Japanese prime minister compared to 'losing a huge war'.³⁵ The official stance of the government and the UN is that no one has died because of the disaster at Fukushima Daiichi, but this already defies belief. Some scientists have predicted that there will be 1,000 to 3,000 excess cancer deaths, a figure commensurate with the much smaller release of radioactivity compared to that of Chernobyl in 1986. It was not until twenty years later that the UN admitted there were any deaths at all as a result of the Chernobyl explosion, beyond the 50 in its early aftermath. Today, the most conservative estimates put the figure at 9,000.³⁶

According to the 'largest statistical analysis of nuclear accidents ever undertaken', another disaster on the scale of Fukushima in 2011 or Chernobyl in 1986 has a 50 per cent chance of occurring before 2050.³⁷ Yet prominent greens, including George Monbiot, James Hansen and James Lovelock have lined up to declare their support for nuclear power. Monbiot became pro-nuclear *after* the meltdown at Fukushima Daiichi, reasoning that the result wasn't so bad despite the worst possible luck.³⁸ Writing with the geo-engineer Ken Caldeira, a collaborator of Keith's, Hansen has called for the world to build a nuclear reactor every five days between now and 2050. These 2,135 new reactors would dwarf the current total of 440 and almost certainly inflate the peril of another

³⁵ Andrew Gilligan, 'Fukushima: Tokyo Was on the Brink of Nuclear Catastrophe, Admits Former Prime Minister', *Daily Telegraph*, 4 March 2016.

³⁶ See respectively Jan Beyea et al., 'Accounting for Long-Term Doses in Worldwide Health Effects of the Fukushima Daiichi Nuclear Accident', *Energy & Environmental Science*, vol. 6, no. 3, 2013, pp. 1,042–5; Frank von Hippel, 'The Radiological and Psychological Consequences of the Fukushima Daiichi Accident', *Bulletin of the Atomic Scientists*, vol. 67, no. 5, September 2011, pp. 27–36; WHO, 'Chernobyl: The True Scale of the Accident', 5 September 2005. Estimates of the number of deaths at Chernobyl vary between 9,000 and 93,000, the Greenpeace figure. Jim Green, 'The Chernobyl Death Toll', *Nuclear Monitor*, no. 785, 24 April 2014.

³⁷ Spencer Wheatley et al., 'Of Disasters and Dragon Kings: A Statistical Analysis of Nuclear Power Incidents and Accidents', *Risk Analysis*, 22 March 2016.

³⁸ George Monbiot, 'Why Fukushima Made Me Stop Worrying and Love Nuclear Power', *Guardian*, 21 March 2011. See also James Lovelock, 'We Have No Time to Experiment with Visionary Energy Sources', *Independent*, 24 May 2004.

meltdown.³⁹ Yet seemingly not content with the riskiness of common nuclear power, many atomic-environmentalists, including Monbiot, Hansen and Stewart Brand, advocate the even more untested and unstable variant of fast-breeder reactors, the name referring to their ability to produce more fissile material than they consume, usually turning uranium or thorium into plutonium, a bomb material *par excellence*.⁴⁰ Liquid sodium is used as a coolant, but this has a snag: it combusts upon exposure to air. Most breeders spend nine-tenths of the time offline for repairs, since even the smallest leak causes a fire, making renewable-energy systems seem quite reliable. The only fast-breeder facility with a better track record was Russia's BN-600 reactor in Zarechny which, uniquely and terrifyingly, continued operating during *fourteen* liquid-sodium conflagrations over seventeen years. Although many trumpet the advantage of breeders in producing little toxic waste from spent fuel, they ignore the fact that the sodium coolant becomes radioactive after use.⁴¹ After wasting \$100 billion on decades of experimentation, governments in the US and Western Europe have mothballed their fast breeders. India is one of the few countries that currently has plans to build them, but less as unreliable power plants than as plutonium factories to arm thousands of nukes.⁴²

Regreening the land

How would half-earthing work? First, it would be a political economy without the crutches of nuclear power or Artificial Geo-Engineering, which could not rely on economic growth to deal with its problems. Instead, it would have the advantages of a functioning ecosystem, stable

³⁹ James Hansen, Ken Caldeira et al., 'Nuclear Power Paves the Only Viable Path Forward on Climate Change', *Guardian*, 3 December 2015. At the 2017 UN Climate Change Conference in Bonn, Hansen shared the podium with Michael Shellenberger, president of the Breakthrough Institute, an outfit that supports 'market solutions', nuclear power and geo-engineering as means to overcome the climatic crisis.

⁴⁰ Todd Woody, 'Stewart Brand's Strange Trip', *Yale360*, 22 December 2009. Fred Pearce, 'Are Fast-Breeder Reactors a Nuclear Power Panacea?', *Yale360*, 30 July 2012. Jim Green, 'Nuclear Fallacies', *CounterPunch*, 5 October 2017.

⁴¹ Thomas Cochran et al., 'It's Time to Give up on Breeder Reactors', *Bulletin of the Atomic Scientists*, May 2010, pp. 50–6.

⁴² M. V. Ramana, 'A Fast Reactor at any Cost', *Bulletin of the Atomic Scientists*, 3 November 2016.

climate and egalitarian social order. A sketch of what's envisaged must address three issues: cutting greenhouse-gas emissions as low as possible; finding sufficient land for both a half-earth rewilding programme and a massive expansion of renewable energy systems; and offering the 'good life' to all.

Natural Geo-Engineering can influence the global climate system quite quickly. Reforestation has had a significant effect in the last decade or two, enough to forestall the worst of climate change's ill effects. The collapse of communist forestry and agriculture in the 1990s allowed the forests in Russia's European half to absorb more carbon, increasing by a third.⁴³ China, often regarded as bearing the brunt of globalization's environmental costs, actually has an extremely effective state-directed reforestation programme. In the last quarter of the twentieth century, the carbon sequestered by its forests increased fivefold. This was partly due to more tree plantations, but it was the expansion of protected wild forests that was particularly effective. Wild ecosystems generally sequester more carbon per hectare than their managed equivalents.⁴⁴ Elsewhere, forests have endured a less happy fate. Rainforests, both the temperate sort found in British Columbia and the tropical kinds strung along the Equator, are capable of sequestering 200–600 tonnes of carbon per hectare—Californian redwood forests can contain an amazing 3,500 tonnes per hectare—and their preservation should be the centre-piece of any climate policy. Species diversity matters amongst plants, too, as more diverse ecosystems have been found to retain more carbon.⁴⁵ Tropical deforestation rates are increasing again, however, after a brief deceleration in the 1990s, with land grabs to establish palm plantations in Indonesia, and soybean and cattle farms in Brazil, the main drivers. Luckily, tropical forest is capable of a fairly quick recovery if given the

⁴³ Yude Pan et al., 'A Large and Persistent Carbon Sink in the World's Forests', *Science*, 19 August 2011, p. 989.

⁴⁴ Chunhua Zhang et al., 'Disturbance-Induced Reduction of Biomass Carbon Sinks of China's Forests in Recent Years', *Environmental Research Letters*, vol. 10, 2015, p. 3. Jingyun Fang et al., 'Changes in Forest Biomass Carbon Storage in China between 1949 and 1998', *Science*, vol. 292, 2001, p. 2320; Vaclav Smil, *Harvesting the Biosphere: What We Have Taken from Nature*, Cambridge, MA 2012, p. 19.

⁴⁵ Smil, *Harvesting the Biosphere*, pp. 18–19; Shiping Chen et al., 'Plant diversity enhances productivity and soil carbon storage', *PNAS*, 17 April 2018, vol. 115, no. 16, pp. 4027–4032.

chance.⁴⁶ Less studied but no less important are marine biomes. Sea grasses and other marine flora are especially promising means to mitigate climate change, because their weight adds up to less than a twentieth of one per cent of all terrestrial plant biomass, but potentially captures an equal amount of carbon. Marine meadows, however, urgently need protection as they are *the* most endangered eco-system, facing an annual rate of depletion of 7 per cent.⁴⁷

There isn't much time left to implement Natural Geo-Engineering, for many ecosystems are already on the brink of systemic failure. Wildfires in western North America have doubled their area in the past forty years, as the region has become drier and warmer. The glaciers in the Rocky Mountains that feed the region's many deltas, streams, lakes and bogs have shrunk, often by half in terms of volume. Canada's boreal forest is already close to transitioning from a carbon sink into a source of emissions.⁴⁸ The Amazon rainforest is so damp because the trees themselves create their own regional climate; trapping water through transpiration contributes half of all rainfall in the forest. This works less well with fewer trees. As the Amazon rainforest shrinks it has endured unprecedented droughts in 2005, 2010 and 2015. If this trend worsens, the rainforest may transition into a savannah, becoming a huge source of carbon emissions.⁴⁹

Effective Natural Geo-Engineering is inseparable from biodiversity, which itself is dependent on territoriality, and needs to be upheld in its own right. Kelp, for example, needs to be protected from herbivores by higher predators. The rebound of otter populations in the North Pacific reduced the number of sea urchins, allowing kelp forests to recover to the point where they now absorb a tenth of British Columbia's carbon

⁴⁶ Do-Hyung Kim et al., 'Accelerated Deforestation in the Humid Tropics from the 1990s to the 2000s', *Geophysical Research Letters*, 7 May 2015, pp. 3495–501.

⁴⁷ Nicola Jones, 'How Growing Sea Plants Can Help Slow Ocean Acidification', *Yale e360*, 12 July 2016. See also the report: Grid-Arendal, *Blue Carbon: The Role of Healthy Oceans in Binding Carbon*, Arendal 2009.

⁴⁸ Its annual intake of carbon is down by half compared to the 1990s: Pan et al., 'A Large and Persistent Carbon Sink', p. 989. Only 5 per cent of the boreal wetland needs to be drained to counteract any benefit of carbon sequestration by the forest as a whole. See Peter Lee and Ryan Cheng, 'Bitumen and Biocarbon', Global Forest Watch Canada, Edmonton 2009, p. 8.

⁴⁹ Center for International Forestry Research, 'Amazon Forest Could Become an "Impoverished Savannah" under Climate Change', *Reuters*, 18 September 2014.

emissions. Similarly, wolves protect the boreal forest from marauding caribou that would otherwise feed on bark, weakening trees. The great wildebeest herds of the Serengeti regulate the carbon cycle of that vast prairie, as their grazing prevents dead grass from accumulating as kindling for wildfires. Wildebeest herds have quadrupled since the mid-twentieth century, and the Serengeti has returned to its status as a huge carbon sink. Whales can also act as a geological force, accelerating the carbon cycle, delivering plankton from the ocean's surface to its depths through everyday acts of eating, diving and excreting. This mechanism would have a stronger effect if much-depleted whale populations returned to their natural levels.⁵⁰ It makes little sense to attempt to preserve biodiversity or to further Natural Geo-Engineering without linking the two.

Natural Geo-Engineering would still be necessary even if a completely renewable energy system were to emerge tomorrow, for certain processes still require fossil fuels and thus need to be offset by carbon sequestration. Even an eco-austere society will need steel and cement, if only for hundreds of thousands of wind turbines. For both of these, fossil fuels are indispensable ingredients. Cement production requires kilns at extremely high temperatures to create 'clinker', for which there is as yet no green alternative to coal; it is responsible for some 5 per cent of all greenhouse-gas emissions, about as much as national emissions from Japan and Brazil combined.⁵¹ Steel furnaces may eventually be electrified, but coke is still necessary to smelt limestone and iron ore. Charcoal, a potential biomass alternative, can produce enough heat but cannot bear the weight of metal and rock in the way that coke can.⁵² About a third of steel currently produced every year comes from recycled scrap, a proportion that could be raised as overall production is reduced. Intercontinental trade and concourse will still depend to some extent on jet engines for planes and diesel for container ships, even

⁵⁰ Schmitz, 'How "Natural Geo-Engineering" Can Help Slow Global Warming'; Joe Roman and James McCarthy, 'The Whale Pump: Marine Mammals Enhance Primary Productivity in a Coastal Basin', *PLOS ONE*, vol. 5, no. 10, 2010, p. e13255.

⁵¹ Amazingly, concrete is the most consumed material in the world after water, usage equivalent to about three tons per person every year. See Madeline Rubenstein, 'Emissions from the Cement Industry', *State of the Planet*, 9 May 2012. There is no low-carbon alternative to making clinker according to the Pembina Institute, 'Alternative Fuel Use in Cement Manufacturing: Implications, Opportunities and Barriers in Ontario', Toronto 2014.

⁵² Smil, *Power Density*, p. 233.

though, with the onset of egalitarian eco-austerity, globalization would be a much reduced force.

Dimming the lights

Half-earthing will involve intensive eco-austerity in land and energy use. The ‘Two Thousand Watt Society’ proposed by Zürich’s Federal Institute of Technology provides a useful starting point. The plan marries environmental and global-economic justice, for it would allow the poorest to double or triple their consumption, while requiring a commensurate reduction by the rich. An average US citizen uses 12,000 watts, or 288 kwh, per day, which is twice as much as a typical western European, and a dozen times more than an Indian.⁵³ Once convergence at 2,000 watts has been established, it becomes much easier to fulfil other half-earthing goals, such as conversion to renewable energy. At the present rate of consumption, 6,000 watts per head, the entire land surface of Japan or Germany would have to be covered in solar panels or wind turbines; if this was reduced to 2,000 watts, then less than a third of the land would need to be taken up by renewable-energy systems. Environmentalist programmes have long been criticized for aiming to ossify the inequality between the global North and South. 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.’ This charge of hypocrisy has prevented greens from building coalitions across international borders and between social movements, but the half-earthing adoption of the 2,000-watt framework would overcome this history of division.

Although a binding referendum in 2008 committed Zürich to becoming a 2,000-watt city by 2050, even the proponents of the goal balk at the revolutionary implications of such a low global-energy quota, preferring to believe it will be achievable through greater energy efficiency,

⁵³ Eberhard Jochem, ed., *Steps toward a Sustainable Development*, Zürich 2006. In the 1980s the Brazilian environmentalist José Goldemberg argued for a quota of 1,000 watts; he was Brazil’s Secretary of the Environment during the 1992 Earth Summit. See José Goldemberg et al., ‘Basic Needs and Much More with One Kilowatt per Capita’, *Ambio*, vol. 14, no. 4–5, 1985, pp. 190–200; José Goldemberg et al., *Energy for a Sustainable World*, New York 1988.

electrification and continued reliance on hydropower. Yet gains from energy efficiency are unlikely to be so spectacular, and the effort will then almost certainly fail.⁵⁴ A further difficulty is that of Jevons's Paradox: greater efficiency *increases* total consumption, because energy becomes relatively cheaper. Effective conservation can be achieved only through state regulation capping total use. Getting down to 2,000 watts cannot happen without sacrifice by consumers and planning by governments, implications that the Swiss have skirted so far.

A more realistic 2,000-watt Society would be eco-austere. One would live in a 'passive' house that required little or no energy for heating or cooling, would eat vegan and rarely fly or drive a car, depending instead on free public transport, walking and cycling.⁵⁵ Many of these elements of an eco-austere life have matured in the womb of the old society itself, but they require a new political economy to realign them into a coherent whole. Alyssa Battistoni's work on recasting the care economy of teachers and health workers as the nucleus of a future zero-carbon society is exemplary in this regard. 'To put it plainly', she writes, 'pink-collar jobs are green.' What would that society look like?

In general, it will mean less work all around. But the kind of work that we'll need more of in a climate-stable future is work that's oriented toward sustaining and improving human life, as well as the lives of other species who share our world. That means teaching, gardening, cooking and nursing: work that makes people's lives better without consuming vast amounts of resources, generating significant carbon emissions, or producing huge amounts of stuff.⁵⁶

Battistoni's vision would be supplemented by renewable energy, clean public transport and state action on housing—so far, only the

⁵⁴ See François Maréchal et al., 'Energy in the Perspective of Sustainable Development: The 2,000 W Society Challenge', *Resources, Conservation and Recycling*, vol. 44, no. 3, June 2005, pp. 245–62; Thorsten Frank Schulz, 'Intermediate Steps Towards the 2,000-Watt Society in Switzerland: An Energy-Economic Scenario Analysis', PhD dissertation, ETH Zürich, 2007; Dominic Notter et al. 'The Western Lifestyle and Its Long Way to Sustainability', *Environmental Science & Technology*, vol. 47, no. 9, 2013, pp. 4,014–21.

⁵⁵ This echoes many of the recommendations in an influential synthetic review of the climate mitigation literature. Seth Synes and Kimberly Nicholas, 'The Climate Mitigation Gap: Education and Government Recommendations Miss the Most Effective Individual Actions', *Environmental Research Letters*, vol. 12, no. 7, July 2017.

⁵⁶ Alyssa Battistoni, 'Living, Not Just Surviving', *Jacobin*, 15 August 2017.

municipality of Brussels requires all new construction to meet passive standards, as opposed to offering modest subsidies or supporting one-off experimental houses or neighbourhoods.⁵⁷

Roads and urban sprawl are leading causes of ecosystem fragmentation; a serious reduction in car use would free up huge amounts of space. In many US cities, for example, approximately 60 per cent of municipal land area is dedicated to car use in the form of roads, car parks and easements.⁵⁸ Even if energy efficiency means that carbon pollution from off-demonized cars is not as great as one might have expected, reducing their use is important for reasons of land scarcity. Air travel will need to be rationed, too. Although planes have doubled their fuel efficiency since 1978, flying is the fastest growing sector of transportation and, in the short term, the greenhouse-gas pollution emitted by planes has an effect 20 times greater than all the world's cars, because of the sensitivity of the atmosphere's upper reaches.⁵⁹ Substitutes, such as solar-powered planes, will not be able to compete with kerosene-driven rivals for many decades. Here, there is no technological fix in sight.

Euthanize the carnivore

Agriculture is by far the most profligate sector of the economy in its greenhouse-gas emissions and land-use; its expansion, especially over the past half-century, has had terrible effects. Most deforestation occurs when new land is opened up for ranching and plantations, a process responsible for one-eighth of greenhouse-gas production. Industrial agriculture is heavily dependent on fossil fuels for pesticides, mechanical equipment, fertilizers and irrigation. Much of its prodigious waste stems from raising and slaughtering billions of animals every year. The energy losses entailed in transmuting grain into animal flesh generally result in an efficiency of only 10 per cent, as is generally the case when trophic levels are crossed. If the US alone redirected the grains currently

⁵⁷ Lenny Antonelli, 'How Brussels Went Passive', *Passive House+*, 26 October 2016. For a summary of international subsidy regimes, see Tom-Pierre Frappé-Sénéclauze et al., *Accelerating Market Transformation for High-Performance Building Enclosures*, Pembina Institute, Calgary 2016, pp. 119–26.

⁵⁸ Charlie Gardner, 'We Are the 25%: Looking at Street Area Percentages and Surface Parking', *Old Urbanist*, 12 December 2011.

⁵⁹ Duncan Clark, 'The Surprisingly Complex Truth about Planes and Climate Change', *Guardian*, 9 September 2010.

fed to livestock to human consumption, it could feed 800 million more people. Since extreme carnivorousness is closely linked to income, it is the bourgeois slivers of humanity that devour the lion's share of global meat production. The leading cause of the Sixth Extinction is manifest in the statistics of the world's terrestrial vertebrate biomass: one third is human, two-thirds is livestock, and only a few percentiles remain for all the world's wild animals.⁶⁰

Food production would have to be completely transformed to realize the goals of half-earth economics, but this should be predicated on *less* technology, not more. Organic vegan agriculture can achieve yields comparable to industrial agriculture, though it requires more labour and a different diet.⁶¹ If agriculture were to be deindustrialized and redirected towards making food for people rather than livestock, then emissions could be reduced and new swathes of land used for parks or energy facilities. Solar panels and wind turbines can largely overlap with cities and the remaining farms. Considering that about half of all territory in Europe and the US is currently dedicated to agriculture—a ratio that would drastically shrink in a meatless society—this would free up enough room to achieve all the goals of half-earthing. The average omnivore requires 1.08 hectares to grow enough food for herself, but a vegan needs only 0.13 hectares.⁶² Vegetarianism is a half-measure, as egg and cheese-eaters still need about 0.4 hectares per head.

It is from pasture, necessarily, that an eco-austere world will derive the land needed for Natural Geo-Engineering. Nearly half the world's non-mountainous land is already dedicated to agriculture. Of these 5 billion hectares, 3.5 billion are pasture, which vegans would not require at all, while of the remaining 1.5 billion dedicated to crops, 400 million are used to grow animal feed and 300 million for industrial purposes

⁶⁰ Nadia El-Hage Scialabba and Maria Müller-Lindenlauf, 'Organic Agriculture and Climate Change', *Renewable Agriculture and Food Systems*, vol. 25, no. 2, March 2010, pp. 158–69; 'US Could Feed 800 Million People with Grain that Livestock Eat, Cornell Ecologist Advises Animal Scientists', *Cornell Chronicle*, 7 August 1997; Smil, *Harvesting the Biosphere*, p. 299.

⁶¹ David Pimentel et al., 'Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems', *BioScience*, vol. 55, no. 7, 2005, pp. 573–82.

⁶² Christian Peters et al., 'Carrying Capacity of US Agricultural Land: Ten Diet Scenarios', *Elementa*, 22 July 2016.

such as biofuels and bioplastics. Only 800 million hectares of land are devoted to growing food directly for people. One study estimates that if 800 million hectares of land were reforested, the billions of new trees would sequester 215 GtC over the next century. Natural Geo-Engineering at this scale would decrease atmospheric carbon pollution at the scale of 85 PPM, bringing it to a much safer range in the low 300s PPM.⁶³ This feat would be relatively easy to accomplish in a mostly vegan world, even though a reforestation of this scale would be five times greater than the last massive rewilding during the Little Ice Age.

A global Cuba

There is room for some optimism, however, for a great experiment in creating a nearly fossil-fuel-free society has already taken place. Cubans had to make do with much less in the 1990s during the *Período Especial*, when Soviet petroleum exports evaporated along with the superpower itself. During the 1980s, known locally as the ‘years of the fat cow’, Cuba depended on a massive, industrialized, export-oriented sugar sector, grew few crops for sustenance and catered to extremely carnivorous tastes; its agriculture at the time was even more reliant on fossil-fuel inputs than its US counterpart. Due to the severity of US sanctions, far harsher than Saddam Hussein’s Iraq ever faced, and the distortions introduced by two decades of Soviet ‘support’, Cuba’s transition away from fossil fuels was a painful one, accomplished during a severe recession. But if this relatively poor and isolated island could refashion itself in this way, then no society has an excuse for inaction. Indeed, despite economic contraction and the tightening of the US embargo, universal healthcare and education were maintained in Cuba.⁶⁴

Getting by without petroleum or petroleum-based products (fertilisers and pesticides, for example) forced the largest and most compressed

⁶³ Sebastian Sonntag et al. ‘Reforestation in a High-CO₂ World—Higher Mitigation Potential than Expected, Lower Adaptation Potential than Hoped For’, *Geophysical Research Letters*, vol. 43, 2016, p. 6,548.

⁶⁴ Julia Wright, ‘The Little-Studied Success Story of Post-Crisis Food Security in Cuba’, *International Journal of Cuban Studies*, vol. 4, no. 2, Summer 2012, p. 132; Emily Morris, ‘Unexpected Cuba’, NLR 88, July–August 2014. The major crisis of the period was the effect on eyesight caused by nutritional deficiencies, alleviated by mass distribution of vitamin supplements once diagnosed. Christina Mills, ‘In the Eye of the Cuban Epidemic Neuropathy Storm’, *MEDICC Review*, vo. 13, no. 1, January 2011, pp. 10–15.

experiment in organic and urban gardening in history. The early 1990s saw the creation of 26,000 public gardens in Havana alone, turning the city into a big urban farm that supplied enough produce for about half of its nutritional needs. Although the notion will surely horrify work-shy futurists, the substitution of labour intensity for power intensity is in itself not a bad thing. If half-earthing were ever implemented, agriculture could usefully soak up unemployed workers from defunct industries that were dependent on high fossil-fuel consumption. During the *Período Especial*, Cuba bought over a million bicycles from China to replace the idle buses and cars. Eating less meat and more vegetables, combined with cycling or walking to work generally led to improved health in the general population. Plantation monocultures could not be managed without massive fossil-fuel inputs, so Cubans cultivated less land more intensively, returning about a third of farmland to wilderness. This has helped Cuba maintain its incredible biodiversity (indeed, it is listed amongst Wilson's global hotspots) and led the World Wildlife Fund to recognize it as the world's *only* 'sustainable' country.⁶⁵ With its effective and low-cost social policy and post-fossil fuel economy, the experience of Cuba in the 1990s offers the outline of a feasible, eco-egalitarian half-earth society.

The argument for half-earthing is predicated upon the clear and present danger of nuclear power, Artificial Geo-Engineering and fossil fuels. Capitalism *can* continue 'business as usual', but only at an ever greater cost to nature and the world's poor. An effective and desirable half-Earth political economy must offer a better life for most people. If egalitarian eco-austerity is to work, resources must be rationed for the sake of fairness and efficacy; asceticism cannot be a mere 'lifestyle choice'. An eco-austere life may mean fewer consumerist trifles and less work, but it would guarantee rights to shelter, health care, leisure and education. There is a vast literature on the uselessness of private consumption, beyond a certain point.⁶⁶ A solution to global environmental

⁶⁵ Gustav Cederlof, 'A Farewell to Oil: Low-Carbon Ecology and Social Power in Cuban Urban Agriculture', Master's thesis, Lund University, 2013, p. 67; Sarah Boseley, 'Hard Times behind Fall in Heart Disease and Diabetes in 1990s Cuba', *Guardian*, 9 April 2013; Elisa Botella-Rodríguez, 'Cuba's Inward-Looking Development Policies: Towards Sustainable Agriculture', *Historia Agraria*, no. 55, December 2011, p. 160; World Wildlife Fund, *Living Planet Report 2006*, Gland 2006, p. 19.

⁶⁶ See Kim Humphery, *Excess: Anti-Consumerism in the West*, Hoboken 2013.

crises requires the humbling of the global bourgeoisie, the richest several hundred million. The bourgeoisie cannot pretend that the society they have created can solve its own problems; a green veneer would signify little in a biologically impoverished world with a corporate-controlled climate. While this minority must adjust to relatively modest living standards, the very same ceiling to their consumption would imply a greatly raised floor for humanity's majority. Most importantly, this egalitarian limit would allow the amelioration of the global climate system that everyone depends upon and the preservation of millions of other species.

To avert a neo-liberal future that would entail the desecration of irreplaceable biomes and the climatic system, the environmentalist left needs new concepts, goals and tactics, along with a realistic reckoning of sacrifices. This is a costly programme in terms of the land required—giving up half the world to nature—but it is a price worth paying to prevent capitalism from continuing to enrich a few million rentiers while impoverishing billions, and irrevocably turning the planet into a factory farm or garbage dump. It is only within an eco-austere society that Londoners may perhaps one day enjoy another Frost Fair: 'This transient scene, a Universe of Glass / Whose various forms are pictur'd as they pass / Here future Ages may with wonder view / And what they scarce could think, acknowledge true.'⁶⁷

⁶⁷ *Bentley's Miscellany*, p. 134.