CHAPTER 1

In the Heat of the Past: Towards a History of the Fossil Economy

In those spacious halls the benignant power of steam summons around him his myriads of willing menials, and assigns to each the regulated task, substituting for painful muscular effort on their part, the energies of his own gigantic arm, and demanding in turn only attention and dexterity to correct such little aberrations as casually occur in workmanship.

Andrew Ure, *The Philosophy of Manufactures* (1835)

The chemical changes which thus take place are constantly increasing the atmosphere by large quantities of carbonic acid [i.e. carbon dioxide] and other gases noxious to animal life. The means by which nature decomposes these elements, or reconverts them into a solid form, are not sufficiently known.

Charles Babbage, *On the Economy of Machinery and Manufactures* (1835)

Besides, what has your steam engine and your cast iron done for us? Not to mention the gas, whose frequent explosions threaten one day to blow up Babylon itself.

Anonymous worker in *The Metropolitan*, 'Imprisonment for debt' (May 1834)

Global warming is the unintended by-product par excellence. A cotton manufacturer of early nineteenth-century Lancashire who decided

to forgo his old waterwheel and invest in a steam engine, erect a chimney and order coal from a nearby pit did not, in all likelihood, entertain the possibility that this act could have any kind of relationship to the extent of Arctic sea ice, the salinity of Nile Delta soil, the altitude of the Maldives, the frequency of droughts on the Horn of Africa, the diversity of amphibian species in Central American rain forests, the availability of water in Asian rivers or, for that matter, the risk of flooding along the Thames and the English coastline. Nonetheless, sporadic forebodings appear in the literature of the time. One notable flash of apprehension about the atmospheric consequences of employing steam power in factories can be found in the first chapter of Charles Babbage's classic treatise *On the Economy of Machinery and Manufactures*. Babbage is credited with being the father of the modern computer; his book is considered the first to introduce 'the factory into the realm of economic analysis'.[1] He made his fleeting remark some three decades before John Tyndall explained the greenhouse effect and some six decades before Svante Arrhenius first calculated the rise in surface temperature on the earth following an increase in emissions of carbon dioxide (called 'carbonic acid' by Arrhenius as well).[2]

But the environmentally concerned enquiry of the pioneer economist was instantly truncated, due to sheer lack of knowledge. Babbage was verging on uncharted territory. Instead, his book continued as one long encomium to the wonders of machinery – first and foremost 'the check which it affords against the inattention, the idleness, or the dishonesty of human agents'.[3] In that turn of phrase, Babbage articulated a leitmotif of bourgeois thinking corresponding to the operating procedures of manufacturers, who fought the annoying idiosyncrasies of human workers precisely by installing ever more machinery impelled by ever more powerful steam engines, unsuspecting of any particular noxious effects. Those on the receiving end of that machinery had more reason to be afraid.

Now They Know What They Do

By now the science of the by-product is perfectly clear. It has been so, in its basic outlines, for roughly as long as capitalism has been free of really existing adversaries: in 1990, the Intergovernmental Panel on Climate Change (IPCC) submitted its first report on the likely fate of a warming world. The facts and projections served as the basis for the United Nations Framework Convention on Climate Change (UNFCCC), signed at the Earth Summit

in Rio de Janeiro in 1992 and ratified by all UN members, who pledged to 'prevent dangerous anthropogenic interference with the climate system' by *cutting* their emissions of greenhouse gases, chief among them carbon dioxide. Yet in 2012, global CO_2 emissions were 58 percent higher than in 1990.[4] By that time, the IPCC was preparing its fifth report – each edition more certain of the disastrous implications of 'business-as-usual' than the previous one – as a permanent hailstorm of scientific warnings rained down on humanity. A random pick from some leading journals in the years 2012–14: hurricanes in all ocean basins are becoming markedly stronger due to higher temperatures; North American butterfly populations have embarked on a perilous journey north to escape the rising heat; Arctic ecosystems are fast approaching a whole range of tipping points; the threshold beyond which the Greenland ice sheet will plunge into irreversible melting – raising sea levels by six meters – is a warming of 1.6°C rather than 3.1°C as previously thought; the retreat of glaciers in Tien Shan is accelerating, primarily in areas where they are most essential for irrigation in summertime, some rivers having already shrunk to tiny rivulets; since the mid-1980s, the vegetation of Congolese rain forests has browned, dried out and declined; climate change could wipe out the equivalent of the entire present yield of maize, soybeans, wheat and rice in key producing regions by the end of the century; the old target of keeping global warming below 2 degrees – widely regarded as obsolete, due to the already painful impacts of a mere 0.85 degrees – is rapidly slipping out of reach: and on it goes.[5] Everybody knows it. Whether one chooses to ignore, suppress, deny or agonise over the knowledge of what is happening, it is there, in the air, heavier by the year. And yet the descendants of the Lancashire manufacturers, whose dominion now span the globe, are taking decisions on a daily basis to invest in new oil wells, new coal-fired power plants, new airports, new highways, new liquefied natural gas facilities, new machines to replace human workers, so that emissions are not only continuing to grow but doing so at a higher speed. In the 1990s, the annual increase in global CO_2 emissions stood at an average 1 percent; since 2000, the figure has been 3.1 percent – a tripled growth rate, exceeding the worst-case scenarios developed by the IPCC and expressing a trend that still does not show any sign of reversal: the more knowledge there is of the consequences, the more fossil fuels are burnt.[6]

How did we get caught up in this mess?

History under a Heavy Sky

In the first pages of his acclaimed textbook *Political Ecology*, Paul Robbins travels to Yellowstone National Park to observe what lies behind its veneer of pristine wilderness. To an untrained eye, the iconic features of the landscape might appear perfectly natural. In fact they are intensely produced. The native hunters that once roamed the land have been removed by fiat; wolves were first extinguished and then reintroduced. Managing authorities have alternated between culling elk populations and allowing them to explode, suppressing fires and permitting them to rip through the valleys and leave their mark on the biota. At every step, walking through forests and along rivers, sighting some animals and not others, Robbins discerns the effects of power struggles that have raged over the park: between the state and the native population, between hunters and environmentalists, hoteliers and scientists. Out of the raw material at hand, political actors have created the ecology of Yellowstone, often with chains of unintended consequences.[7]

A traveller along the frontiers of climate change today – not to speak of tomorrow – might encounter a landscape even more thoroughly shaped by humans with power. Weather conditions, types of vegetation, entire biomes, even the sea itself might have fallen into place as a fallout of the combustion of fossil fuels. But where Robbins is able to trace a certain property of the Yellowstone landscape to a specific decision made in the past – the absence of natives to their historical removal – the climate change traveller can, by the nature of things, see no such straight lines. A submerged islet has born the full weight of a history lacking differentiation. No single decision, no emission of one tonne of greenhouse gases can be connected to this particular scene: the burning of this barrel of Texas oil cannot be pinned down as the cause of this Levantine drought. Every impact of anthropogenic climate change carries the imprint of every human act with a radiative forcing, such that they are infinitesimal representatives of two moving aggregates – the aftermath and the source – intimately coupled yet strangely disconnected from each other. Eyes gazing on abruptly transformed ecosystems are forced to turn back towards human society to understand what has happened – but where should they look? Only a totality can be the object of interest. We shall call it, provisionally, 'the fossil economy'.

Seen from another angle, global warming is a sun mercilessly projecting a new light onto history. Only now is it becoming apparent what it really

meant to burn coal and send forth smoke from a stack in Manchester in 1842. When natural scientists discovered global warming, they passed on a discovery to historians yet to be made on anything like a comprehensive scale: these things were there for two centuries, invisible up to the present. Now is the time to turn over a thousand stones, to unearth the climatic implications of innumerable actions – not merely because the smallest puff of smoke in Manchester in 1842 released a quantity of CO_2 which then lingered in the atmosphere, playing a microscopic part in the creation of the current climate, but also, and more importantly, because the fossil economy was established, entrenched and expanded in the process. It is as though a novel dimension has been suddenly revealed in modern history. Just think, in this light, of the building of the railway networks, the construction of the Suez Canal, the introduction of electricity, the discovery of oil in the Middle East, the rise of suburbia, the CIA coup against Mohammad Mossadeq, the opening of the Chinese economy by Deng Xiaoping, the American invasion of Iraq … As a series of moments in the historical totality of the fossil economy – deepening its channels, adding ever-greater volumes of fossil fuels to the fire – these events are retroactively suffused with a new significance, calling for a return to history, eyes wide open.

Would such a history be environmental? Most traditional concerns in the field – say, deforestation, air pollution, species extinction through hunting or overfishing, pathogen movement through trade or invasion – exhibit some kind of historical immediacy: the cutting down of a forest *is* deforestation. In his *The Chimney of the World: A History of Smoke Pollution in Victorian and Edwardian Manchester*, Stephen Mosley points out that 'smoke could be easily perceived by four of the five senses: one could see it, smell it, touch it, and it could be tasted.'[8] He is obviously engaging in an environmental history, writing of how the natural world in and around Manchester was transformed through the explosive spread of dense black clouds in the nineteenth century. But the burning of coal in that town also had another ramification, which did not, as it were, touch down in the environment until much later, after a whole series of biogeochemical and social mediations. The writing of that history should be a central task, and yet it is bound to have an odd quality of detachment from environmental repercussions. Insofar as we are interested in the fossil economy as the instigator of climate change, its ecological dimensions must be placed within the brackets of posterity in a way that hardly applies to any other problem of environmental history: even nuclear waste, whose fallout is comparable to global warming in duration, is immediately constituted and

handled as such. Anthropogenic climate change – this is part of its very definition – has its roots *outside* the realm of temperature and precipitation, turtles and polar bears, inside a sphere of human praxis that could be summed up in one word as *labour*.

At the intersection of climate and history, most scholarly traffic has so far moved in the other direction. The search for meteorological causes of past events is currently undergoing a spectacular renaissance: climatic fluctuations are said to have had a finger or two in everything from the collapse of the Mayan civilisation and the conquests of the Vikings to the witch hunts and the French Revolution. Promising analogues for the future, this endeavour uses data on temperature and precipitation to explain crisis, war, persecution, upheaval and other social affairs – explanations well worth pursuing for their own sake (albeit with certain well-known pitfalls) but not particularly appropriate in constructing the historiography of global warming. Here it is a matter of searching not for climate in history, but for *history in climate*. Data on factory legislation or free-trade policy should be brought to bear on rainfall and ice, rather than the other way around; in a warming world, causation runs, at least initially, from company to cloud. It is that leap across ontological divides that calls for reconstruction.

The Revenge of Time

Over the past decades, critical theory has moved towards space, away from time as the long-favoured dimension, the classical vessel of structure, causation, rupture, possibility. Within historical materialism, this 'spatial turn' has generated the meteoric rise of critical geography, now equalling or surpassing the time-honoured discipline of history in innovativeness and influence: the star of David Harvey shines brighter than that of any Marxist historian. Another adept in the field, Neil Smith, hymns the victory of space over time in *Uneven Development: Nature, Capital, and the Production of Space*, quoting approvingly such one-liners as 'we are in the epoch of simultaneity'; 'the present epoch will perhaps be above all the epoch of space'; 'prophecy now involves a geographical rather than historical projection' (whatever that could possibly mean) – even endorsing Francis Fukuyama's infamous thesis of the 'end of history' by asserting that 'indeed historical time would seem to be over'.[9] Global warming should put such fantasies to rest.

Floors below the desk where these words are written, people travel to work in cars, go on visits and vacations in cars, drive their shopping lists and shopping bags back and forth in cars: nowhere is simultaneity to be seen. Cars, to begin with, run on fossil energy, a legacy of photosynthesis originating hundreds of millions of years ago. The vehicles were not invented just now; they spread in the twentieth century. The choice to travel in them rather than in trams or buses or on bicycles is conditioned by a vast infrastructure of oil terminals, petroleum refineries, asphalt plants, road networks, gasoline stations – not to speak of the film industry, the lobbying groups, the billboards – which did not fall from the sky in this moment but was built up *over time*, eventually amassing such weight and inertia that other modes of transportation are now excluded, or at least prevented from rising to predominance. This is what some refer to as 'carbon lock-in': a cementation of fossil fuel–based technologies, deflecting alternatives and obstructing policies of climate change mitigation: a poisoned fruit of history.[10] Furthermore, there is reason to suspect that the heat wave and drought plaguing this part of the country, sending residents to seek relief by leaving the town in cars, has some connection to climate change – signs of a future to come, a state-of-weather-in-the-making – and if that suspicion is at least partly correct, not even the weather belongs fully to the moment. It is a product of past emissions. The emissions produced by the cars running to and fro, meanwhile, will have their greatest impact on generations not yet born: they are so many invisible missiles aimed at the future.

Wherever we look at our changing climate, we find ourselves in the grip of the flow of *time*. The transfer of carbon from geological reserves to fireplaces and thence to the atmosphere, into the running carbon cycle from which it was locked away for ages and eras, sets the process in motion. But the effects are always delayed. It takes time before a certain quantity of CO_2 emissions is realised as a corresponding amount of warming, and before that warming takes its full toll on the ecosystems. For every emission added to past output, the atmospheric concentration of the gas increases, its effect further augmented in accordance with 'the fundamental tenet of climate science: emissions are cumulative'.[11] The release of one tonne of CO_2 would not be so dangerous were it not for the billions of tonnes already out there; it is the total accumulation that pushes temperatures upwards, and the more that has been emitted, the smaller the prospect of limiting the ongoing rise. If humanity wishes to avoid a certain temperature threshold – say, 2 degrees Celsius – only a certain amount can be

emitted – roughly one trillion tons – and for every year emissions continue (not to speak of *increase*) that budget is progressively squandered.[12] If one tonne is emitted in this second, a fourth of it will stay in the atmosphere for hundreds of thousands of years.[13] If we wait some time longer and then demolish the fossil economy in one giant blow, it would still cast a shadow far into the future: emissions slashed to zero, the sea might continue to rise for many hundreds of years, the waters slowly expanding as the heat makes its way deeper and deeper into the oceans. A rising and warming sea could then unhinge ice sheets, thaw permafrost, destabilise methane hydrates or trigger other feedback mechanisms centuries after a complete cessation of emissions – once a certain historical level has been reached – in keeping with 'the long memory of the climate system'.[14] At its core, then, climate change is a messy mix-up of time scales. The fundamental variables of the process – the nature of fossil fuels, the economies based on them, the societies addicted to them, the consequences of their combustion – operate over seemingly unrelated temporal spans, all refracted in the moving, elusive present of a warming world; in an elevated sense of the term, every *conjuncture* now combines relics and arrows, loops and postponements that stretch from the deepest past to the most distant future, via a now that is non-contemporaneous with itself.[15] Ours is, if anything, an epoch of diachronicity.

'The temporal aspect is particularly striking,' writes philosopher Stephen Gardiner, who has done perhaps more than anyone to foreground it, in *A Perfect Moral Storm: The Ethical Tragedy of Climate Change*: it catches us in a bind. Given that global warming is 'seriously backloaded' (every moment experiencing a higher temperature posted from the past) and 'substantially deferred' (the cumulative effects of current emissions arriving in the future), a warped ethical structure arises. The person who harms others by burning fossil fuels cannot even potentially encounter his victims, because they do not yet exist. Living in the here and now, he reaps all the benefits from the combustion but few of the injuries, which will be suffered by people who are not around and cannot voice their opposition. Each generation, reasons Gardiner, thus faces a perverse incentive to 'pass the buck' to the next, which also profits from its own fossil fuel combustion while dodging the pain from it, and so on, in a vicious cycle of infliction of harm.[16]

Rob Nixon would call it 'slow violence'. In *Slow Violence and the Environmentalism of the Poor*, he grapples with a problem closely related to Gardiner's, though coming from the angle of literary theory. 'Violence

is customarily conceived as an event or action that is immediate in time, explosive and spectacular in space, and as erupting into instant sensational visibility', he writes, but there is also a different kind of violence: not rapid but slow motion, not instantaneous but incremental, not body-to-body but playing out over vast stretches of time *through the medium of ecosystems* and therefore far more difficult to capture between book covers or on-screen than the bullets of a sniper. When a company dumps a toxic chemical substance in a poor country, the violence is only being felt gradually, 'decoupled from its original causes by the workings of time', never contemporaneous with the act itself; Nixon places fossil fuel combustion in the same category.[17] He then asks: how can slow violence be represented in narratives that catch our attention? What are its equivalents in the crime novel, the war epic, the action movie? Symptomatically, he finds and reads stories and essays on the slow violence of the Bhopal disaster, oil exploitation in the Arabian Gulf and the Niger Delta, mega-dams in India, natural parks in South Africa, depleted uranium in Iraq *but none on climate change as such*. Here the capacity to imagine violence seems to have reached its limit.

There is more to these temporalities than dilemmas of ethics and representation, however. The longer business-as-usual persists, the harder it becomes to break out of it. Every round of new pipelines and tankers and deep-water drilling rigs encumbers the next decades with an even more ponderous mass of infrastructure into which carbon has been locked: the ruts of path dependency deepen. Every generation presiding over growing emissions adds more than the former to the accumulation of CO_2 in the atmosphere.[18] For every year global warming continues and temperatures soar higher, living conditions on earth will be determined more intensely by the emissions of yore, so that the grip of yesteryear on today intensifies – or, put differently, *the causal power of the past inexorably rises*, all the way up to the point when it is indeed 'too late'. The significance of that terrible destiny, so often warned of in climate change discourse, is the final *falling in of history on the present*.

History does not usually work in this way. The echo of Caesar's march across Rubicon, the fall of the Ming dynasty, the formation of the Sokoto caliphate or the storming of the Bastille can be expected to fade away as time goes by – or at least there is no inbuilt mechanism to amplify it. But in times of global warming, iron laws of economics and geophysics boost the past from behind, so to speak. 'The tradition of the dead generations weighs like a nightmare on the minds of the living,' Karl Marx famously

wrote in *The Eighteenth Brumaire of Louis Bonaparte*: in a warming world, it weighs down heavier and heavier, on the bodies of the living and their surroundings, in a relentless consolidation of the tyranny of the past.[19] This will certainly be more than a gradual progression. Extreme weather events convert the attrition of slow violence into photogenic spectacle: think of a flooding in Pakistan or a wildfire in Colorado. The snap disasters of abrupt climate change – the fatal crossings of tipping points in the earth system – would mark the sudden irruption of the mounting history of the fossil economy onto the stage of the present. Indeed, as unseasonable weather is becoming the new norm, this is already happening: when Julius, the protagonist in Teju Cole's novel *Open City*, roams the streets of New York in the middle of November without yet having had the occasion to wear his coat, he cannot help but suspect, with a sense of 'sudden discomfort', an effect of global warming.[20] Contrary to popular misconceptions in the media (and to Julius's own scepticism), it is now perfectly possible to attribute a particular heat wave or other anomaly to the underlying rise in average temperatures, in whose absence such events would have been utterly improbable.[21] The thermometer can be legitimately suspected as a barometer of the rolling invasion of the past into the present.

There follows, from all of this, a very peculiar temporality of climate change politics. Few if any other issues have such heightening urgency built into them by dint of sheer physical laws: the point of *too late* is coming closer by the day, and the closer it comes, the more swift and comprehensive the emissions cuts must be. The tradition of the dead is breathing down the necks of the living, leaving them with two choices: smash their way out of business-as-usual – and the heavier the breath, the more extreme the measures must be – or succumb to an accumulated, unbearable destiny. As of this writing, both scenarios remain possible. The famed 'window of opportunity' for abolishing the fossil economy and stabilising climate within tolerable bounds – even returning it to safer conditions – is still there; if emissions were reduced to zero, the rise in temperatures would soon taper off.[22] Such an enterprise would have to stage a full-scale onslaught on the structural nightmares bequeathed by the past. It would be a revolution against history, an exodus, an escape from it in the last moment, and it would have to know what it has to struggle against.

None of this is meant to deny that space is a crucial dimension or that geographers have enriched critical theory with an abundance of insights; we shall deal with the former and draw on the latter quite extensively in what follows. But now is a singularly bad time for declaring the demise of

time.[23] The spaces of climate change are relevant only insofar as they are folded within the process: the *change*, the warm*ing*. As the word indicates, this tempest is eminently temporal.

Searching for the Origins of the Fossil Economy

What do we mean by 'the fossil economy'? A simple definition would be: an economy of self-sustaining growth predicated on the growing consumption of fossil fuels, and therefore generating a sustained growth in emissions of carbon dioxide. Roughly synonymous with 'business-as-usual' in the lexicon of climate politics, this, we submit, is the main driver of global warming. It first appeared during the Industrial Revolution, whose great historical feat was to inaugurate an era of 'self-sustaining growth', meaning a process of growth that was not episodic, evanescent, broken off after a brief efflorescence, but persistent and unremitting, a secular progression propelled by its own inner forces.[24] In biophysical or thermodynamic terms, no growth can, of course, feed upon itself: one of the key lessons of ecological economics is that it always relies on the withdrawal and dissipation of natural resources. But through mechanisms to be specified later, the fire of modern growth reproduces an economic gas that necessarily ignites as more growth, the result of the process spurring it to advance further, the loop reinforced anew on a grander scale – and in this and only this sense is it self-sustaining. The fossil economy was born when that fire began to be fed by the material fuel of fossil energy.

Now we immediately see that the fossil economy, under this definition, cannot account for all human influence on the climate. Fossil fuel combustion is only one cause of global warming, just as the sun is only one of the bodies in the solar system and the American president only one in a larger team: the others, puny by comparison, revolve around it. 'Land-use change' – read: deforestation – accounts for a fourth of all CO_2 released since 1870, but its share is secularly diminishing, now standing at around 8 percent of current emissions, fossil fuels taking up virtually all the rest.[25] Then there are the other greenhouse gases – methane, nitrous dioxide, ozone, sulphur hexafluoride… – whose social histories would have to be recounted for a full picture to emerge. But it is safe to say that the burning of fossil fuels is the hard core of the problem, quantitatively dominant and qualitatively determinant. It deserves special focus.

If emissions of carbon dioxide ceased to increase and stayed constant, atmospheric concentrations would still continue to climb: absolute volumes of CO_2 are, in the end, what matters for climate. Then why include their *growth* in the definition of the fossil economy? Because it is the union of economic expansion and fossil energy consumption that has pushed emissions up to the present, utterly unsustainable – and still rising – levels: this is the really existing process, the alloy that has brought us to this warmer place. Three major deviations from the norm are possible. An economy that grows while its emissions flatten out, even if on a high level, can be classified as a *decoupled* fossil economy; it might still be overwhelmingly based on fossil fuels, but only one of the two components remains in motion. One with no trend in either respect may be termed a *steady-state* fossil economy, while one with continuously diminishing emissions – due to spontaneous breakdown, deliberately orchestrated policies or some other factor – is a fossil economy *in decline*. To the extent that these variants have existed at all, they have been exceptions proving the rule, or aberrations from business-as-usual (pretensions to decoupling gainsaid by rising emissions embodied in imports; steady-state situations a transient feature of crisis, such as in 2009; decline – notably in Eastern Europe in the 1990s – followed by rebound).[26] None undermines our definition of the object of historical inquiry.

The fossil economy has the character of a totality, a distinguishable entity: a socio-ecological structure, in which a certain economic process and a certain form of energy are welded together. It has some identity over time; contrary to the axioms of methodological individualism, the embryonic individual is suspended in its fluid. A person born today in Britain or China enters a preexisting fossil economy, which has long since assumed an existence of its own and confronts the newborn as an objective fact. It possesses real causal powers – most notably the power to alter the climatic conditions on planet Earth, but this only as a function of its power to direct human conduct. A factory manager will be pressured to obtain energy by plugging into the current from the nearest coal-fired power plant rather than building her own waterwheel. The company owner will send her commodities to the world market on cargo vessels, rather than sailing ships. A cashier may have little choice but to commute to the supermarket in a car – she certainly won't ride a horse – and if she wants to go on vacation, she will encounter intense advertising for flying as a transportation option. Moreover, none of these emitting actions would be possible without integration into the fossil economy: alone on an island, or living

in a country untouched by this economy, an individual could complete none of them. As such, then, the fossil economy is an altogether *historical* substance. It must have undergone its own birth once upon a time. The causal powers it now exerts are emergent properties: they were not always there. Agents must have created it through events amounting to a moment of construction, much as, once erected, a building's structure is now an enduring feature of the world; entrenched in the environment, it conditions the movements of the people inside. Eventually it appears indistinguishable from life itself: business-as-usual. But the fossil economy was once constructed and has since been reproduced and enlarged, and anything built over time can potentially be torn down (or escaped).[27]

So how did it all begin? Where would the search for a moment of construction lead us? While several countries could lay claim to being the cradle of modernity, capitalism, enlightenment or liberal democracy, the fossil economy has one incontestable birthplace: Britain accounted for 80 percent of global emissions of CO_2 from fossil fuel combustion in 1825 and 62 percent in 1850.[28] There is a margin of error in these figures, but they give us an idea of the proportions and trends, suggesting that Britain lost some of its paramountcy as the consumption of fossil fuels spread to other countries but continued to generate *more than half* of the world's emissions far into the nineteenth century. The origins of our predicament must be located on British soil.

Consequently, there has been a minor flurry of interest in revisiting the British Industrial Revolution for clues as to how all of this happened and, not the least, what to do now. An energy transition – most simply defined as 'a switch from an economic system dependent on one or a series of energy sources and technologies to another' – occurred at that time; we are heading towards another transition; thus, the argument goes, we need to learn from the past to proceed as best we can now.[29] If we think of the fossil economy not as a static building but rather as a train put at a point in the past on the current perilous track, we require knowledge of the switching mechanism to enter a safer course. The British Industrial Revolution here assumes the status of a unique archive of lessons. What do they say? 'First, the transition was slow. Second, it was driven by prices. Third, it required new technology.' Add human capital, scientific discovery, cooperation and narrow self-interest in equal measures and, concludes economic historian Robert Allen, a future transition to sustainable energy will also share these characteristics. Most importantly, 'people respond to price incentives.'[30]

One lesson often taken away from the switch to fossil fuels is precisely

that it was protracted, passing through several phases of stumbling experimentation, the agents slowly learning to master the novel form of energy – and hence the shift *away* from them should follow the same pace and refrain from 'pre-mature scaling up of technologies and industries'.[31] A transition must be given time. Even more critical, as we shall see, is the presumed lesson of prices: fossil fuels won the original race because they were cheapest, and the same advantage will now have to be secured for renewable alternatives if they shall have a chance. Moreover, if the British Industrial Revolution stands as a model for 'the second industrial revolution', or the green or the low-carbon or the sustainable one, yet another lesson seems unavoidable: 'The profit-motive of small and medium-sized enterprises rather than community action might drive innovation. The fact that' the instigators of the switches back then 'were competitive capitalists and became wealthy as a result' counsels us from assuming that 'only communal initiatives can drive radical change.'[32] Capitalists slowly unrolling technologies with lower prices: this is the manual to follow.

But any straight parallelism between the entry into and the exit from the fossil economy is spurious. It comes close to the fallacy of presupposing that the present is essentially the same as the past, allowing for an immediate transfer of precepts, such as when generals have drawn up their strategies from the lessons of ancient battles and suffered grievous defeat, forgetting the Heracleitan rule that you cannot step into the same river twice. As several scholars have pointed out, the transition now impending – if indeed it is – would be motivated by the urgent need to stave off or at least minimise catastrophic climate change, a danger humanity has never before confronted, and one which certainly did not figure in the calculations of early British industrialists. The most highly prized quality of renewable energy would be low or zero emissions of carbon dioxide: a public good, not a private benefit. Time is already characterised by being short. For these and other reasons, the next transition cannot share the canonical features of the British Industrial Revolution; above all, this time it would have to be *collectively planned*.[33] But it would face impediments. Measures necessary for an enforced, rapid, politically driven phaseout of fossil fuels may, as IPCC tersely notes in a 'Summary for Policymakers' from 2007, be 'difficult to implement' due to what the panel labels a 'key constraint': namely '*resistance by vested interests*'.[34] In these few words, a planet of antagonism briefly comes into view. So fossil fuels have to be discarded for human civilisation to endure and thrive – but there are 'vested interests' standing in the way. What are they?

Here might lie a better reason to revisit the Industrial Revolution. If the fossil economy is a train that never stops but always accelerates, even when approaching the precipice, the task is to pull the brakes (or maybe jump off) in time, and if there is a driver who seeks to keep this from happening, she has probably been seated in the locomotive for some time: we need to know who she is and how she works (or perhaps it is an automatic engine, a driverless construction – but the need would be the same). The interests that once put the train in motion may still be driving it. The previous transition, then, would be not so much a template for the next as *a key to understanding and removing the impediments*. We cannot know this for sure: it is a mere suspicion. It is, of course, conceivable that the initial reasons for taking up fossil fuels are entirely unrelated to the interest in clinging to them now, which might have taken over at some point along the journey. But if we want to know more about the propulsive forces of the fossil economy, its laws of motion and the interests invested in it, the beginning seems a good place to start.

Whether we frame this as a search for parables or for enemies, the underlying assumption is that meaningful action can be undertaken: it is not yet too late. But what if it is? 'If there's no action before 2012, that's too late', declared Rajendra Pachauri, chair of the IPCC, in 2007: 'What we do in the next two or three years will determine our future. This is the defining moment.'[35] What if that were no mere rhetoric, but an accurate forecast soon to be fully vindicated – then would there be any point in delving into the annals of the fossil economy? If any historical matters exist that would be of interest under sea levels two metres higher, this might be one of the few. Or, with Gardiner: there is a 'task of *bearing witness* to serious wrongs even when there is little hope of change'.[36] The militant reason for studying the history of the fossil economy has a meditative backup. Both boil down to, in the simplest possible terms, that one burning question: how did we end up in this predicament?

The Moment of Steam

So we return to the Industrial Revolution in the hope that it will divulge its reasons for welding growth to fossil fuels, the first of which was coal. But coal had been burnt in Britain for millennia. From the Bronze Age and the Roman occupation to the Middle Ages, fires of coal were appreciated for their intense heat, used, as we shall see, in the kindling of religious

ceremonies, the heating of homes, the cooking of food and the processing of some materials, notably iron in smitheries. Yet few would argue that the fossil economy emerged around the year 2000 BCE or 50 CE or in the thirteenth century. The union between self-sustaining growth and coal combustion existed at none of these times, because the former had yet to develop and the latter remained limited to heat generation. Britain had to wait for the Industrial Revolution to write out the growth formula *and* initiate a qualitative leap in the manner of coal consumption: the transformation of heat into motion, or the conversion of thermal into mechanical energy, by means of *the steam engine*.

In the first steam engines, coal was burnt in order to force a piston up and down in a vertical motion well suited for the pumping of water, but not much else. Another form of motion was called for: in the words of a mid-nineteenth-century treatise, 'of all sorts of motion, that which is most frequently required in the arts, is one of continued rotation. Mills in factories of every kind are impelled by machinery which receives its motion from a wheel.' It was the earth-shattering exploit of James Watt to connect the coal fire to the wheel. With the device he patented in 1784, Watt finally 'adapted the motion of the piston to produce *continuous circular motion*, and thereby made his engine applicable to all purposes of manufacture', as stated by another tract.[37] With this, the foundations of the fossil economy were laid down.

What could the rotative steam engine accomplish that the hearth and pump of old could not? Most obviously, it could impel a *machine*: the prime fulcrum of self-sustaining growth, increasing output per capita, raising the productivity of labour in a universal speedup that has yet to see its end. As a source of thermal energy, coal was useful for a range of processes requiring that input, but only as a source of mechanical – rotative – energy could it fuel the production of all sorts of commodities. 'Machinery is', explained the *Rees' Cyclopædia*, the most important compilation of technical knowledge in the early decades of the nineteenth century, 'the organs by which motion is altered in its velocity, its period, and direction, and thus adapted to any purpose'; once coal had been made to power it, the fuel could flow into the veins of an economy throbbing with expansion.[38] In this book, we shall study how the fossil fuel of coal was coupled to the machine through the rise of stationary steam power in the mills of Britain.

A rotative engine could also impel a *vehicle*, the second fulcrum of self-sustaining growth, likewise receiving motion from wheels, travelling across sea and land and transporting commodities – raw, finished – to and from

the mills. A sequel to this study entitled *Fossil Empire* will deal with mobile steam power on a global scale. Heat could work on materials with certain chemical properties; pumps could force up liquids. Machines and vehicles alone could fabricate and distribute the widest imaginable range of commodities; driving them with coal, the steam engine first made fossil fuels integral to growth across boundless expanses. Moreover, the combustion of coal in British cottages and smitheries never spurred *other* countries to adopt the fuel. Only the machine and the vehicle had the power to project the fossil economy out from the British Isles, through the pressures of economic competition and military invasion. A country flooded by commodities from steam-powered mills or attacked by the overwhelming force of steamboats would feel the whip of external necessity and perhaps seek to emulate the technology in order to save its industry or survive as a nation; as long as coal was primarily consumed within British households, distant communities had little reason to take notice.

The existence of coal seams in Britain – or indeed on any continent in the world – was evidently not a sufficient condition for the transition. The same goes for the rotative steam engine. Like strata in the rock, that artefact could not, as a mute physical thing, spark off something like a fossil economy by itself. The mere presence of the engine as certified in the legal rights of the inventor tells us nothing about the extent to which it was actually installed, its function in the economy or the propensity to emit carbon dioxide: the atmosphere does not feel the breath from a patent. History is stocked with inventions petrified into objects of exhibitions or fantasies in the style of da Vinci, and so the question of the steam engine is the question of *why it was adopted and diffused* – in Britain and, above all, in the cotton industry. There it supplanted the waterwheel. Before steam, the British cotton industry – the fast lane of the Industrial Revolution, in which self-sustaining growth first appeared – impelled its machines with water. So why did cotton capitalists turn from water to steam? By examining the causes of that original transition, we may come closer to an understanding of the mechanisms that launched, and perhaps still drive, the process now known as business-as-usual.

Seeing Power as Power

The word 'power' in the English language has a dual meaning: 'power' as in a force of nature, a current of energy, a measure of work; 'power' as in

a relation between humans, an authority, a structure of domination. The conjunction is not as close in other major European languages. 'Motive power' and 'absolute power' are 'fuerza motriz' and 'poder absoluto' in Spanish – no apparent connection there – while French distinguishes between 'énergie' and 'courant' on the natural side of things and 'puissance' and 'pouvoir' on the social, roughly equivalent to Kraft/Strom and Macht/Gewalt in German (hence Atomkraft but Weltmacht). Why have the two poles collapsed into one in English? An inquiry into such comparative European etymology is outside the scope of this study: we can only note the intriguing fact.

Do the two meet in reality? In spite of the semantic confluence in the Anglophone world, thermodynamic and social power are nearly always treated as 'distinct phenomena, a habit encouraged by the disciplinary structure of academic research', as observed in one recent attempt to bridge the gap.[39] Two authoritative works in the respective hemispheres exemplify the separation. In *Energy in Nature and Society: General Energetics of Complex Systems*, Vaclav Smil offers an exact definition of power as 'the rate of flow of energy', or 'W = J/s', where *J* is joule, *s* is second and *W* the unit of power: Watt from James.[40] Put differently, power is here understood as the rate at which work is done or energy transformed – and that is all there is to it, apparently, for in spite of the nominally transdisciplinary character of his work, Smil does not so much as notice that there is another meaning to the term, much less any actual movement between the two.

Turn to Steven Lukes's sociological classic *Power: A Radical View* and the other eye is shut. Here the overlap between 'horse power' and 'power struggles' is mentioned merely to indicate the terminological chaos surrounding 'power' in society: the nature of social power can only be distilled if cleansed of all associations with the mechanical phenomenon, in a first, essential act of analytical distinction.[41] In the dozens of dissections of the concept filling Lukes's pages, there is no hint at power being *at once* energetic and interpersonal, nor does he see any potential for plumbing the depths of social power by taking its mechanical base into account. The colloquial drift between the poles – reflexive, unnoticed and perfectly realistic – has its counterpart in a stern intellectual segregation. The English language might contain a basic truth from which scientific research has become estranged; in any case, it permits us to formulate a general hypothesis guiding the rest of this work: *the power derived from fossil fuels was dual in meaning and nature from the very start.* Steam as a form of superior power was just that. The two moments cannot be isolated

from each other, since they *constituted each other* in a unity, the opposites interpenetrating throughout.

It is proven beyond all reasonable doubt that global warming does not have natural causes. Solar radiation, volcanic outgassing, endogenous variations in the carbon cycle, and other similar suspects have been decisively cleared of responsibility for the rise in temperatures, the root causes firmly passed to the social side of the equation. Once we cross that line, we immediately encounter *power* – indeed, this happens as soon as we use the term 'fossil fuels'. They are, by definition, a materialisation of social relations.[42] No piece of coal or drop of oil has yet turned itself into fuel, and no humans have yet engaged in systematic large-scale extraction of either to satisfy subsistence needs: fossil fuels necessitate waged or forced labour – the power of some to direct the labour of others – as conditions of their very existence. If we take the message of climate science seriously, we should direct our attention to power in the dual sense, first of all in the process of labour. That is the point of contact between humans and the rest of nature, where biophysical resources pass into the circuits of social metabolism, where coal and oil and gas are extracted, transported, coupled to machines: burnt. The process is peopled. 'As a primary agent of energy and matter transformation through the labor process,' writes environmental historian Stefania Barca, 'workers are the primary interface between society and nature', wielding and subject to power.[43] *That* is the sphere where the fossil economy must have originated.

Neither environmental nor labour history has, for their own particular reasons, been very keen on connecting the dots of workers and the wider environment, class and climate. The same silence reigns in research on energy in the Industrial Revolution. Indeed, climate change as such remains primarily an object of natural science, recent spurts of interest in the social sciences notwithstanding. We are awash in data on the disastrous effects but comparatively poor on insights into the drivers.[44] Or, to paraphrase Marx: most climate science still dwells in the noiseless atmosphere, where everything takes place on the surface, rather than entering the hidden abode of production, where fossil fuels are actually produced and consumed. Natural scientists have so far interpreted global warming as a phenomenon in nature; the point, however, is to trace its human origins. Only thus can we retain at least a hypothetical possibility of changing course.