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Energy, history, and the humanities: against a new determinism

Thomas Turnbull

Department 1, Max Planck Institute for the History of Science, Berlin, Germany

ABSTRACT

The study of past 'energy transitions' are being reinterpreted as possible guides to a low-carbon future. But little is known about the historians who shaped how we understand our transition into a predominantly hydrocarbon-based energy system. Before energy history emerged as a subfield, historians John Nef, Edward Wrigley, and Rolf Sieferle already explained the Industrial Revolution as a result of coal use. In unleashing industrialism, they argued that coal took on an historically decisive role. These notions of energy determinism will be the central concern of this paper. In revisiting their lives and work, it will be argued that in pursuit of a low-carbon future, we should not ignore the grave concerns posed by fossil energy use nor slip into a crude form of energy determinism.

KEYWORDS

Energy history; industrialism; coal; energy transition

Introduction

We are in a crisis of energy abundance in which limits to growth appear climatic rather than material.[1] Historians have entered this uncharted territory, positioning themselves as 'important allies' to legislators, thanks to their ability to enrich 'prepackaged policy proposals' with the realities of prior experience.[2] History, they argue, demonstrates that past energy systems were determined by culture as much as science and engineering.[3] Necessary corrective action is also cast in historical terms. We are told we need a 'low carbon industrial revolution'.[4] Alongside which, an emerging field of 'energy transition studies' considers past changes in patterns of fuel use as potential guides to a more sustainable future.[5] Amid a more general *energy turn* across the humanities and social sciences, we are witnessing the growth of a subfield of energy history.[6]

With growing awareness of the implications of anthropogenic climate change, the belief that 'energy might fundamentally drive history' has returned.[7] Accordingly, as the historian Andreas Malm points out, the well-worn subject of the British Industrial Revolution must be reconsidered as energy historical event of planetary consequence.[8] Such thinking is not confined to eco-Marxists such as Malm; Angela Merkel's favourite historian Jürgen Osterhammel has also cast coal as a central determinant of the industrial transformations which spread from Europe to encompass the world.[9] And it is not solely historians who think in such terms. Natural scientists have suggested the accumulated

CONTACT Thomas Turnbull tturnbull@mpiwg-berlin.mpg.de

consequences of fossil-fuelled industrialism are so great the very distinction between human and natural history has blurred and requires revision.[10]

In addressing the history making capacities of energy, this paper addresses the work of three historians: John Nef, Anthony Wrigley, and Rolf Sieferle, all of whom studied what Malm recently termed that 'unique archive of lessons' regarding the archetypal energy transition, from wood fuel to coal, known as the Industrial Revolution.[11] These historians are distinguished by being amongst the first to describe industrialism in energetic terms. Moreover, of importance to our current moment, each also attempted what historians Christoph Bonnueil and Jean Baptiste Fressoz have recently and critically termed 'energy history with a managerial approach'.[12] Which is to say, they attempted to apply their historical knowledge to energy related crises encountered in their own lifetimes. Whatever their success in doing so, given renewed interest in applied energy history, these interventions should be of more than academic interest.

However, it appears these canonical historians of energy are more often cited than read. Worse still, in a rush for applied relevance, energy historians seem to have given historiographical reflection a 'wide berth' in general.[13] Most of us have little idea of the origins of many of the central tenets of energy historical thought, and we risk reinventing various wheels and repeating mistakes. To resolve this, this paper argues for historiography as a form of *environmental* history. It is well known that Soviet historian Edward Hallett Carr famously told his students, 'before you study history, study the historian'.[14] Seeking more than juicy biographical details, Carr believed historiography could reveal how the environment, both intellectual and material, conditions historical thought. The historiographies presented here are intended to raise awareness of how also energy, as an important aspect of the environment, conditioned and constrained past thought. In tracing the historicity of such relations, perhaps we will be better able to transcend them and think differently about our energy future.

Histories of 'energy transition'

Where did the idea that history could be seen as a series of transitions between fuels come from? Bonnueil and Fressoz claim the term 'energy transition' became prominent in the 1970s as policymakers and thinktanks sought to 'spirit away' the more cataclysmic sounding 'energy crisis'.[15] In fact, the notion, if not the term, is significantly older. Between 1902 and 1927 German sociologist Werner Sombart published *Der Moderne Kapitalismus*. In the exhaustive detail characteristic of the German Historical School, he had described how sixteenth-century Europe had faced arboreal limits to growth. The continent's forests, a 'rich stock of stored solar power' were rapidly being depleted by 'wood-devouring' industries such as glassmaking.[16] Rather than stifling industrialism, solar limits encouraged inventive means of exploiting coal. The resulting industrial science of coal use unleashed the 'new energies' of steam, chemistry, and electricity, and allowed Europe to develop with historically unprecedented force.[17]

Moreover, in the early twentieth century, long before the term energy transition entered the lexicon of policy, it had described chemical changes that resulted from the addition of energy to a substance, such as molecular dissociation.[18] In specific instances transition was used to describe a shift from one fuel to another, acknowledging the interconvertibility of forces.[19] But the use of the term 'transition' to describe a shift in

society's predominant energetic substrate first became readily apparent in the demographic and developmental literature of 1950s North America.[20] As a political injunction, the term found its most influential advocate three decades later, in United States President Jimmy Carter. In a 1977 televised address he stated 'Twice in the last several hundred years there has been a transition in the way people use energy'; from wood to coal, and then coal to petroleum, facing constrained supply. He advocated a third transition to conservation and renewable sources of power.[21]

Amid the tumult of the 1970s energy crisis, Carter's proclamation encouraged a burst of energy historical thought.[22] Though the progressive teleology suggested by his three-stage transition implied soon attracted criticism.[23] Historians argued that smooth transitions between major fuel groups, like all forms of historical periodisation, were abstractions. Research instead revealed persistence and accretion of fuels and technologies over time.[24] Moreover, cautious of over determinism the more considered energy historians demonstrated how energy conditioned rather than determined history. Today, with climate change encouraging a 'neo-environmental determinism' in some quarters, those oversimplifying and overdetermining the dynamics of energy transitions, like climate determinists, similarly risk, to appropriate geographer Mike Hulme's words, extracting energy from 'the matrix of interdependencies that shape human life'.[25]

Energy and (in)determinism

Belief in energy determinism seemingly comes in cycles. A combination of thermodynamics and evolutionary theory helped encourage its first wave. In the 1860s philosopher Herbert Spencer cast society as an aggregate organism which evolved as with increased efficiency of energy use.[26] The geographers Halford Mackinder and Friedrich Ratzel, amongst many others, used Spencer's work to assert a determinative relation between environment and society.[27] Sharing Spencer's orientation, at the century's turn, chemist Wilhelm Ostwald proposed a theory of *Energieverhältnisse*, a general thermodynamics which saw energy as the ultimate source of order and function in society.[28] Inspired by both Spencer and Ostwald, around 1910 the North American historian Henry Adams outlined a more pessimistic theory of historical change based upon the idea that the entropy of the universe irreversibly increased as an adjunct to evolution.[29]

This first wave of energy determinist thought did not go unchallenged. For sociologists, Max Weber's acerbic review of Ostwald's simplistic energetic foundationalism proved a necessary corrective.[30] Meanwhile, geographers developed a unique sensitivity to all forms of overly deterministic thought due to their perceived association with Imperialism and, later, Fascism.[31] For historians, Adams's idiosyncratic entropic history failed on a number of fronts. First his understanding of entropy was considered outdated.[32] Second, his energeticism was so ardent that some dismissed it as an ironic *reductio ad absurdum* attack on Ostwald.[33] Moreover, history had long been an ideographic discipline, epitomised by philosopher Patrick Gardiner's observation, 'the historian's interest is directed upon particular events rather than upon universal laws.'[34]

These developments meant that, until recently, energy-determinism remained the preserve of non-historians and its adherents helpfully demarcated the limits of disciplinary orthodoxy.[35] However, today, given clear evidence of the consequences of the human use of energy, to continue to ignore the historical consequences of energy use would

commit a fallacy worse than misguided determinism.[36] Since the invention of James Watt's steam engine in the 1760s, as a by-product of industrialism, we have released an additional 1,800 billion tons of carbon dioxide into the atmosphere, causing alterations to Earth's climate that will last hundreds if thousands of years even if fossil fuel uses were to immediately end.[37] Fossil energy use has evidently transformed both human and natural history.[38] The central message of this text is to encourage historians to think more carefully about the relation between energy and history and how it can be substantiated beyond the twin poles of over- and under-determination.

Energy and industrial revolution

Rather than the 1970s, or even the late nineteenth or early twentieth century, a more persuasive starting point for sustained energy historical thought can be discerned at the point when a causal relation between energy use and industrialisation was first affirmed.[39] Today, as Malm suggests, the idea that coal proved a critical input to industrialism is widely accepted. But back in 1881, when the similarly politically engaged scholar, political economist Arnold Toynbee, first introduced the term 'Industrial Revolution' to the Anglophone world, energy played only a figurative role in his account.[40] In a famed lecture series at the University of Oxford, the 29-year-old had described how, from 1760 onward, Britain's unprecedented economic growth had been enabled by 'unparalleled stores of coal and iron'.[41] But he stressed that these stores had been the growth's medium rather than its cause.

In fact, the essence of Toynbee's revolution had been ideological. Industrialism had been unleashed by an idea: the gradual acceptance of 'competition' in place of 'the medieval regulations which had previously controlled the production and distribution of wealth'.[42] His biographer Alon Kadish argued Toynbee's Christian beliefs had prohibited him from employing materialist modes of explanation, and we can presume the same held for those based on energy.[43] It had entered his argument only metaphorically. Competition, Toynbee claimed, was akin to energy in 'resembling a great physical force which cannot be destroyed, but may be controlled and modified'.[44] Like the laws of thermodynamics, competition could not be fought against but only harnessed for human benefit.[45]

However, in 1926 Cambridge economic historian John Clapham attacked what he saw as the 'semi-legendary' accounts of the 'activist' Toynbee and his followers, whose passion for social reform, he believed, had distorted their perception of historical reality.[46] Toynbee, an activist and social reformer, had witnessed the immiserating effects of industrialisation whilst volunteering in East London's slums. From this perspective industrialism clearly appeared revolutionary if not even cataclysmic, as bodies and communities became dominated and disfigured by the unrelenting force of mechanisation.[47] Whereas, cloistered in Cambridge, Clapham developed his understanding of industrialism from statistical almanacs. This view suggested a gradual, localised, and smaller-scale affair.[48] Moreover, rather than pauperisation, he argued industrialisation had largely benefited the working class.[49]

Operating on the 'lower plane of commodities and comforts', Clapham advocated a cautious materialism.[50] This was far from Marxist materialism, which he considered overly idealised.[51] His was a moderate position, justifying empirical argumentation

rather than political radicalism. But however moderate, it led the discipline closer to an energy-based explanation for industrialisation. The almanacs he had consulted revealed coal 'behind and beneath the technical development of all the industries'.[52] Therefore, if not industrialisation's cause, Clapham viewed coal's ready availability and its low cost as one of its central preconditions.[53] It was this empiricism and belief in the myth-busting capacities of careful quantification which would inspire arguably the first historian of energy.[54]

John Ulric Nef

Writing in the *New York Review of Books* in 1965, historian Eric Hobsbawm suggested John Ulric Nef was one of few scholars whose name was 'firmly, often indissolubly, linked with a particularly problem, phenomenon, or period'. Though he had not attained adjectival status like 'Darwinian' or become a brand-name, as in 'Fourier Series', every history student, Hobsbawm argued, should associate Nef with 'industrial development in the sixteenth-century'.[55] Nef's monumental *Rise of the British Coal Industry* (1932) had presented evidence of a fourteen-fold increase in coal production and a significant increase in industrial production between the accession of Queen Elizabeth and the English Civil War, an event which he termed an 'early industrial revolution'.[56] For Nef, this meant Toynbee's belief in industrialisation as a decisive break in human history was 'essentially false'.[57] But today, alongside this attack on orthodox historical periodisation, given our ongoing crisis of energy abundance, Nef should be most remembered for placing energy at the forefront of historical explanation.

Nef was born to chemists John Nef and Louise Comstock. Nef's father founded the University of Chicago's chemistry department. Both sadly died before his sixteenth birthday, leaving him a considerable fortune.[58] Too young for conscription, Nef studied history at his father's university. Developing an interest in the growth of industrial capitalism, he moved to Harvard's economic history program in 1917.[59] There he worked for the somewhat environmentally determinist historian Frederick Jackson Turner, whom he later suggested 'undoubtedly contributed to an interest in the nature of historical causation'.[60] And it was around this period that he became interested in coal. At the time, the mines of Great Britain, from which industrialisation had first spilled, now faced a number of problems.[61] War had placed great demands on both mines and miners, while emergency control of the industry by government had brought the logics of private ownership into question. A related wage dispute encouraged Britain's mineworkers to lead a nationwide strike in 1921.[62] At the same time, petroleum was becoming a rival source of propulsive if not productive power.[63]

Nef left Harvard to independently study the origins of the seemingly waning coal age. In doing so, he and his wife Elinor (Née Mead) immersed themselves in European culture. Supported by considerable personal wealth they spent five years travelling, buying art, and befriending luminaries from artist Marc Chagall to poet T.S. Eliot.[64] But far from becoming a member of Hemingway's 'lost generation',[65] Nef used this time productively, discussing his interest in coal with British socialist historian R.H. Tawney. In his recently published a critique of industrial capitalism, *The Acquisitive Society* (1921), Tawney had cast industrialism as a 'nemesis' which had reduced human existence to 'a struggle for self-aggrandizement' at the expense of spiritual transcendence and

collective betterment.[66] Tawney's position on the coal crisis had been fashioned while he served on the Sankey Commission, a royal inquiry tasked with finding a solution to the tensions in post-war Britain's coal fields; sympathetic to the miner, he had voted for the nationalisation and modernisation of Britain's mines.[67] Looking to valorise the coal industry, Tawney supported Nef's intention to write its history, with the elder historian presuming it had began in the mid eighteenth-century.[68]

Discovering early industrialism

Sometime earlier, Conyers Read, Harvard's expert on the Elizabethan court, had told Nef that Port Books held at Britain's Public Records Office might offer a quantitative record of an earlier coal trade.[69] From the late sixteenth-century onward, Queen Elizabeth's treasurer Lord Buckhurst had overseen careful notetaking on the shipment of goods in and around England for taxation purposes.[70] Locating the books, Nef recalled how he 'laboriously extracted with my pencil, one by one, the items of coal in each ship'.[71] Between 1563 and 1685, he found a twenty-fold increase in just over one hundred and twenty years.[72] This careful transcription overturned Tawney's belief that Britain's coal industry had emerged in the 1800s. It had begun far earlier and on a far larger scale than anticipated. In his diary, Nef noted how he had been 'almost suffocated by the fog' of London during this period of archival work its severity providing an atmospheric trace of this nation's prodigious coal use.[73]

To corroborate his findings, Nef travelled across Britain collecting information on collieries and industry from myriad regional archives. On the basis of this evidence he estimated that between 1560 and 1710 Britain's yearly output of coal had grown from 200,000 to 3 million tons.[74] This feat had been achieved by as many as 18,000 'pitmen' working in hundreds of mines. Horse-powered gins had helped bring this mass to the surface, which was then distributed via a network of wagon-ways, coastal shipping routes, rivers, and canals.[75] Traces of this technologized and expansive industry led Nef to estimate that seventeenth-century industry had consumed around one million tons of coal per year, and that households may have used twice this amount for heating and cooking.[76]

In uncovering the impact of this influx of mineral coal, Nef also observed a 'sharp expansion' in industrial production between 1550 and 1700[77]: he described vast saltworks with pans of seawater and brine situated close to Northern coal seams[78]; and how Britain had begun to export glass for the first time thanks to a growing surplus of fuel.[79] Shipbuilding provided another indicator, as they had not only required timber but abundant combustive energy to produce pitch, treat timber and forge and cast nails, chains, and anchors. Noting an expansive reciprocity later historians would describe in terms of feedback, Nef described how the 'coal trade itself created demand for ships' and estimated that by the century's end there were around 1,600 vessels transporting the fuel around Britain.[80]

Well aware of the achievements of wood-based industry, Nef conceded that without coal industrial 'expansion would have begun, but it could hardly have continued'.[81] Coal provided access to a vast reservoir of productive power, allowing for both the production of surplus goods and accumulation of capital, hallmarks of the Industrial Revolution proper, long before the eighteenth century.[82] The two-percent annual increase in fuel

production Nef had discerned during this early industrial period was indeed comparable to that of the late eighteenth century.[83] But if his figures for total coal production between 1551 and 1901 are compared, early industrialism appeared insignificant in scale. Nef later deflected such criticism, suggesting absolute values had been less important than the invention of a 'new industrial structure', an accumulative dynamic between coal, industry, and capital.[84]

The rise of the British coal industry

In 1926 Nef returned to the United States, receiving his doctoral degree by submitting his thesis to the Brookings Graduate School.[85] After a year teaching at Swathmore College he came back to Chicago to teach European history at the university's economics department.[86] This was long before this department became known for an eponymous and influential school of liberal economic theory under the direction of Milton Friedman.[87] At the time, the department hosted a diversity of scholars, ranging in both methods and politics, from the neoclassical James Laughlin to institutionalist Thorstein Veblen.[88] There, Nef continued work on his book, employing Tawney's assistant and fellow economic historian Mildred Bulkley to verify its many references.[89] Finally, after ten years gestation, *Rise* was published. Of independent means, its author could reminisce that though most 'Americans remember 1932 as the year when the Great Depression touched bottom [. . .] For me 1932 generated a kind of magic. The seemingly endless coal book was finally in page proof'.[90]

It was a monumental piece of research. Its two volumes contained 938 pages of densely referenced text, numerous illustrations, maps, and 120 pages of appendices, and tabular data on large fold-out sheets which had been gleaned from three-hundred archival documents ranging from Port Books to court proceedings.[91] If his intellectual mentor had been Tawney, methodologically Nef was clearly heir to Clapham's careful empiricism.[92] Though mathematically simple compared to the sophistication of later economic history, Nef's work was remarkably quantitative for the time and was well-received.[93] Protégé of the French-led Annales School, Émile Coornaert, himself a quantitative scholar of the French wool industry, described the book as 'remarkable'.[94] Harvard's leading economic historian Abbot Payson Usher called it the 'most important contribution to modern economic history' made in many years.[95] No wonder, the book offered detailed quantitative evidence of the material and energetic substrate upon which the modern industrialised world had emerged.

Unqualified praise did not last. Revisiting *Rise* in the 1980s, economic historian John Hatcher maintained that though the book still commanded admiration for its 'torrent of citations', and because its conclusions 'broadly compare' to those of later historians, he concluded that 'the edifice [Nef] erected had insecure foundations'.[96] Cambridge economic historian Donald Cuthbert Coleman was less sympathetic, decrying Nef's numbers as 'statistically meaningless'.[97] He claimed missing data had simply been guessed at, that litigation records exaggerated capital investment, and that the ratios used to turn vernacular units of coal into modern tonnage units were highly inaccurate.

Today, whatever the veracity of its underlying data, *Rise* offers a remarkably detailed account of relations between energy and historical change that contemporary energy historians should (re)familiarise themselves with, both on its own terms and as an

historiographical artefact. In the following section, we will revisit Nef's central arguments, to see what remains of use and what has been superseded. In doing so, it will be argued that Nef's concern with the cultural transformations prompted by coal use rightly situates him as the progenitor of contemporary energy history and perhaps, given his wide range of interests, also the contemporary energy humanities.

A contested revolution in the use of fuel

What were the mechanics of Nef's observed coal transition? Wood had been the Elizabethan age's primary fuel. It was consumed in vast quantities for heating and cooking, refining sugar, firing clay, drying grains, cleaning wool, and boiling soap. Moreover, the manufacture of pitch, tar, gunpowder, metals and glass also consumed large quantities of partially combusted wood, or charcoal. Most combustion processes were highly inefficient, further contributing to the overall rate of fuel consumption.[98] Documenting ubiquity and inefficiency in wood use, Nef also noted many a 'lament of deforestation' made to Royal Commissioners during the reigns of Elizabeth and James I. Combined with some patchy evidence of increased wood fuel prices,[99] Nef took these somewhat scattered signs as evidence that 'between the accession of Elizabeth and the Civil War, England, Wales, and Scotland faced an acute shortage of wood'.[100]

Like early industrialism, the extent and severity of Nef's timber crisis has been significantly revised. Forest historian George Hammersley suggested that, rather than national, shortages were 'local and limited'. More recently cliometrician Robert Allen used newly discovered price data to dismiss the idea of a 'systematic constraint' to national timber supply, while environmental historian Paul Warde suggests timber crises were attitudinal rather than material and there was often no correlation between their assertion and material shortages.[101] And, as Matthew Paskins recently noted, controversies over timber supply were rarely solely about wood.[102] But for historians of energy, Nef's timber crisis is taken as a proposition that wood shortages led to coal-powered industrialism, as scarcity prompted price rises that encouraged substitution. This would suggest that the price-determining mechanisms of an unimpeded market are an important determinant of energy transition, with all the contemporary resonances this implies.[103]

Malm has recently criticised this scarcity as the 'mother' of transition arguments, which he terms 'Ricardian', in acknowledgement of the substitutive logics found in David Ricardo's theory of political economy. He does so in the belief that coal use had less to do with scarcity than the improved exploitation of low-cost urban workers.[104] He argues that evidence of abundant unutilised sites for waterpower suggests capitalists invested in more expensive but more mobile coal-fired industrial infrastructure so as to better exploit labour and accumulate capital.[105] His focus on cotton as a marker of industrialism, easily spun with the aid of flowing rivers, supports such a view. But more energy intensive activities, such as iron smelting, a must for large-scale mechanised industry, of course required abundant coal.[106] Moreover, while capital accumulation is an important aspect of the story, to suggest coal-powered industrialism was predominantly an outcome of capitalistic decision-making seems to contradict Malm's own commitment to historical materialism.

An other obvious distinction is that Nef addressed an earlier period of industrialism. As Malm acknowledges, Nef had in fact given a more nuanced account of the timber crisis than some of his critics suggest, one which, like Malm, acknowledged the expansive and exploitative impacts of capital accumulation.[107] Nef had argued timber shortages were felt acutely in the capital, where legislature and sovereign convened. This energy geography meant 'the replacement of wood by coal became a principal aim of state policy and inventive effort'.[108]

Revisionists agree. Wrigley claimed the dynamics of London's resource use exerted a tremendous influence over Britain as a whole.[109] Robert Allen used newly found price data to confirm the city was indeed an 'urban bottleneck' for timber supply.[110] William Cavert's history of London, as the world's first 'fossil-fuelled' city, documented how timber scarcity had been partly structural, with the woods that remained around London testifying to a lack of suitable means of transport and the forbidden riches of royal forests.[111]

So, alongside a specific constellation of the scarcity-price mechanism, Nef considered 'state policy' a central driver of coal transition. Demand for the resource in London and other cities encouraged the Crown to protect this new revenue source, as Lord Buckhurst's Port Books proved. The state imposed coal duties to limit export, but also broke up cartels, and protected 'sea coal' from piracy.[112] Another important policy inadvertently unleashed vast quantities of coal. The dissolution of the monasteries freed vast tracts of coal-bearing land from Church ownership.[113] Thanks to the marital mores of Henry VIII the coal-rich north opened to industrial exploitation.[114] Other policy levers came from below. Under pressure from the merchant class, from 1566 onward all minerals other than gold and silver became exempt from the *regale*, a law dictating their automatic royal ownership.[115] Given such political conditions, coal was primed to enter the maw of a nascent industrialism.

Britain's appetite for coal had first arisen thanks to the 'inventive effort' of its manufacturers. Surveying seventeenth-century industries, Nef distinguished between those such as lime-making and metallurgy in which coal was already used, to those in which substitution involved minor alterations to existing practices, as was the case with the manufacture of salt, saltpetre, alum, gunpowder, soap and other rudimentary chemical goods. A third category posed more significant problems. Noxious coal smoke could damage the taste or quality of certain items. To transition from wood to coal, such processes required minor alterations, such as casting coal into less noxious briquettes of coke or making glass in closed crucibles so corrosive fumes would not discolour molten potash and sand.[116]

Nef did not use the term transition to encapsulate these changes, instead describing 'something like a revolution in the use of fuel' in seventeenth-century Britain.[117] The revolution had no single cause. Geology and geography, changing ownership of mineral-rich land, state and mercantile initiatives, and the inventive effort of industry all played a role. But comparisons were drawn with transitions Nef observed in his lifetime:

> As today the high price of coal leads to the substitution, wherever possible, of oil or water power, so in Elizabeth's reign the high price of other fuels led to the substitution of coal, and also to a timber conservation policy, analogous to the coal conservation policy sometimes suggested to-day.[118]

We might conjecture that Tawney had drawn Nef's attention to the work of the 1918 British Coal Conservation Committee, whose final report had endorsed both electrification and nationalisation as means to save coal[119] Whatever, the specific referent, in making such comparisons Nef helped to establish the idea that major shifts in energy use shared generalisable properties which could be compared over time.

The habits of the British people

Nef's book not only explained the causes but also the effects of coal transition, it described how the fuel transformed the 'habits of the British people'.[120] In tracing the many relations between coal and behaviour which followed, *Rise* presaged later theories about the relation between energy and culture. From lining state coffers, to forging iron and treating wood, its combustive power had accelerated national armament and helped produce a fleet of ships.[121] Perhaps most importantly, coal had begot coal. The Newcomen engine, developed in 1712, burnt coal to reciprocally pump water from mines, providing a feedback mechanism that expanded overall energy availability. While the will to accumulate this power encouraged the channelling and deepening of rivers and the laying of wooden 'wagonways' for transportation.[122] Nascent coal use had seemingly fostered technologies central to the later steam age.

Long before the historian Joel Mokyr's assertion that science had created the intellectual preconditions in which industrialism could occur, Nef described how coal conditioned a specific 'scientific spirit'.[123] The earliest proceedings of the Royal Society had discussed new methods for finding and transporting coal, and sought to explain spontaneous subterranean fires in certain seams. In one case, Nef's enthusiasm for coal-based explanations led him astray. He argued that natural philosopher Robert Boyle had compared the combustive properties of wood with those of coal, when in fact he had compared the mineral with 'shining wood', a bioluminescent mould.[124]

Nef's coal-centrism would lead him to argue that the fuel was critical to the emergence of modern capitalism, a term Nef meant in a moderate Marxian sense.[125] Memorably he had described an ambitious colliery in Culross, Scotland, sunk offshore with its shaft descending a mile under the sea.[126] Maintaining such infrastructure, with its drainage channels, pumping engines, 'gins' for lowering miners and raising coal, and paying the salaries of labourers below and above ground, was highly capital-intensive. Profits from such ventures directly contributed to the growth of capital by rewarding those able to take financial risks.[127] His painstaking research into colliery finances revealed how mines were generally owned 'by a sort of family agreement' between wealthy individuals, rather than joint-stock investors.[128] This structure persisted long into the twentieth century, perpetuating a distinct allocation of wealth and political power in Britain.[129]

Demand for fuel increased demand for capital, creating a cyclical mechanism whereby the two accelerated the growth of one another. Though the overarching argument was partly derived from Sombart's work, Nef's formulation presaged Malm's later use of political scientist Elmar Altvater's term 'fossil capital' to describe a form of 'self-sustaining growth [...] welded to the consumption of fossil fuels'.[130] Like Malm, Nef saw iniquities in this dynamic. As miners and mineworkers became increasingly alienated from such capital-intensive means of production, a 'cleavage between capital and labour' emerged.[131] The ongoing consequences of this division had been readily apparent

when Nef was in London during the General Strike of 1926. The largest collective resumption of labour in British history had been triggered by mineworkers' refusal to accept wage reductions. Tawney, Nef's host, acted as spokesperson for the miners while Elinor Nef collected money for their families.[132]

But coal's political culture had not been wholly inegalitarian. Nef believed the wealth it afforded meant Britain had suffered less from the Absolutism which terrorised Continental Europe. Colliery owners and merchants had asserted the rule of law to protect their wealth. The related English Civil War could be thought of as a conflict fuelled by coal revenue and fought, on occasion, over energy supplies: In 1643 Royalists seized control of Newcastle, using their control over the River Tyne to impose an energy embargo on London's Parliamentarians for two years. Meanwhile, from the Parliamentarian perspective, the Crown had exploited the coal trade as an extra-parliamentary means of funding.[133] In exploring these ambivalent political consequences of coal use, Nef came close to Timothy Mitchell's later thesis: fossil energy allows for both genuine forms of egalitarianism and their restriction.[134]

Nef's tendency to find coal at the root of almost all aspects of Britain's industrial supremacy did not go unnoticed.[135] His conclusion anticipated such criticism. Given the risk of lapsing into new forms of energy-determinist thought today it is worth quoting in full:

> Coal was not the primary, in the sense of being the original, factor. It may be doubted whether it will ever be possible to isolate a primary factor in this sense. But there are factors which can justly be regarded as primary in that the process by which the ultimate triumph of industrial capitalism was assured would have been fundamentally different without them. One of these is the rise of coal industry. [136]

Coal did not determine industrialisation but conditioned its outcome in specific ways. Its overarching *structure*, reciprocal growth between energy and capital, predated coal use, but its abundant power sustained this relation beyond the limits of wood-fuelled industry.[137] In this qualified way, we must rightly recognise Nef as one of the first historians to empirically demonstrate, while not isolating, the role of coal as an agent of historical change. The novelty of his energo-historical argument was not lost on a subsequent generation of historians.[138]

Less well acknowledged is Nef's role as the progenitor of contemporary energy humanities, a discipline which asserts the formative role energy plays in shaping myriad aspects of our lived and shared experience.[139] Like contemporary energy humanities scholars, already in the 1930s, Nef believed an interdisciplinary approach was necessary to trace the myriad relations between energy and culture he had begun to uncover.[140] Moving far from the jurisdiction of economic history, he later wrote of the impact coal had on art, describing how the materialism it encouraged found expression in 'worldly romance' of the kind found in Shakespeare. This, Nef believed, had been at the expense of the beauty and transcendence found in contemporaneous French art.[141] The deeper one went into coal's history, the broader he believed the scope of inquiry must become. Toward the end of his career, he would argue that afull history of coal needed to be 'integral', more art than science, and encompassing 'individual human realities', spatial perception, literature, and aesthetics.[142]

Metaphysical revisionism

Nef had concluded his magnum opus with a criticism of the methods and insights of economic history. In subsequent decades his dissatisfaction grew. The Second World War left him looking for a lesson to draw from having 'spent some ten years' proving industrial civilisation had been dependent on 'the burning of coal'.[143] Past the age of conscription, and enjoying the company of distinguished European émigrés in Chicago, Nef had become chairman of the Economic History Association. From this position, he warned members they had a responsibility to ensure the future of an 'insecure' Western Civilization.[144] His contribution was a two-paper programme for educational reform.[145] In it, he argued that coal had allowed 'the creation of a new world, with its great emphasis on material values'.[146] Unhappily, the war showed how this coal powered materialism had combined with extreme nationalism and diminishing moral values.[147]

Coal had not created a fulfilled humanity, but torn it asunder. But Nef saw signs that its materialist consequences were faltering. After the First War, coal production had virtually halted, partly due to the use of petroleum and hydropower, but mainly due to a global fall in demand.[148] Drawing on his awareness of the 'history of fuel', Nef thought the coal age was ending and a new economic order emerging. Beside the aberration of the Second War, he thought industrial growth was slowing, and that society might abandon the competitive pursuit of physical wealth and longevity in favour of a 'general love of mankind'.[149] Of course, we know this to be wrong. The war was followed by an unprecedented acceleration in the consumption of materials in the West, powered by a sea of oil.[150] But what had prompted Nef's sudden materialist apostasy?

Raised an atheist, Nef had undergone an epiphany, encouraged by Catholic philosopher Jacques Maritain, whom he first met in 1933.[151] Maritain was famed for a book *Art and Scholasticism* (1930) which had called for a return to medieval standards of beauty. More generally he was a leading advocate for a revived form of Catholicism that looked to antiquity and America for authority rather than fascist Rome.[152] Their friendship encouraged art loving Nef to reconsider the lesson of *Rise*.[153] Rather than merely modernity's progenitor, Nef now implored his readers to 'reconsider the meaning of the industrial revolution and the nature of the society which it helped to destroy'. Medieval society, in his view, had possessed 'high moral standards', and a 'love of beauty' that had been essential to industrialism but had been eroded by the materialism unleashed.[154] Nef now regretted his own fall under the 'spell of the quantitative data', believing such narrow empiricism obscured the true depth of historical experience.[155]

Somewhat unexpectedly his disenchantment was encouraged by his employer. Having joined the University of Chicago's economics department in 1931, he had befriended university president Robert Maynard Hutchins, a thirty-year-old lawyer chosen to lead the university during the uncertainties of the Great Depression. Hutchins himself, disillusioned by active service in the First World War, had found solace in the work of philosopher Mortimer Adler.[156] Adler, also a follower of Maritain, had spent the last decade advocating for the study of the 'great books' of Western Civilisation, particularly Thomas Aquinas' *Summa Theologica* (1485), a manifesto for a rationalised form of Christianity and a counterblast to fashionable pragmatism.[157]

Hutchins invited Adler to Chicago in 1930, and the two implored students taking their 'General Honors' course to pursue wisdom rather than knowledge.[158] Hutchins would go

on to publish a manifesto calling for higher education reforms and the study of scholastic metaphysics, the 'highest principles and causes' that lay beyond the material world. Such an education, he believed, offered the best chance for societal renewal.[159] Looking to realise his programme, Hutchins instituted a wide-reaching program of university reforms including, perhaps most controversially, banning college football.[160]

The president's views challenged the academic precepts of specialization and positivism, provoking a number of faculty to oppose their leader's apparent disavowal of modernity. Hutchins was accused of trying to turn Chicago into a kind of 'medieval monastery'.[161] Worse still, leading pragmatist John Dewey, toward whom much of Adler's ire was directed, portrayed his pursuit of 'some fixed authority' in the past as somewhat fascistic.[162] For his part, Nef strongly supported Hutchins, applauding reforms which he believed had 'undermined the citadel of college triviality'.[163] Against widespread opposition, Hutchins and Nef, with the support of others, would be forced to attempt their rarefied vision for educational reform on a smaller scale.[164]

Institutionalising interdisciplinarity

Announced in 1942, the 'Committee on Social Thought' allowed Nef to pursue the interdisciplinarity he had touched on in *Rise*. Fellows were expected to be familiar with scholars ranging from Thucydides to Grotius, and to combine at least two subjects the 'disease' of specialisation had separated.[165] According to one account, the 'institution overwhelmingly reflected Nef's vision'.[166] It was he who largely funded it, and meetings often took place at his home over food and wine. By 1945, he had almost total control over the admissions process. In subsequent years, friends made in Europe such as Eliot and Chagall become fellows, joining other luminaries such as Saul Bellow and Hannah Arendt.[167] Looking to further institutionalise his worldview, in 1958 Nef established a Center for Human Understanding in Washington D.C., committing to no less a goal than World peace. In his view, the Cold War was an 'unreal' conflict, based on rival materialist ideologies. He believed both capitalism and communism served only to work against humankind's moral and spiritual salvation.[168]

To detractors, both organisations institutionalised Nef's self-congratulatory hubris and were considered to be staffed solely by his friends and intellectual allies.[169] In institution building in this way, Nef fostered a continuum of elite scholars who would argue for Christianized societal renewal.[170] Unsurprisingly, critics came to see the Committee as an incubator for a new form of liberal conservatism, a view encouraged by the addition of libertarian economist Friedrich Hayek to the payroll in 1950, and the later intermingling of personnel with the neoconservative movement of the 1960s.[171] In 1953 Nef had even joined the infamous Mont Pèlerin Society, the brain-trust of Neoliberalism, of which Hayek was founder and honorary president.[172] However, besides promoting his own work and responding to invitations he appears to have been a largely inactive member.[173]

By the 1970s, an emeritus, Nef's obligations were reduced to chairing the Committee.[174] This was a decade of energy crisis. A combination of an oil embargo in 1973, a peak in natural gas discoveries, and technological stasis in electrical power production had contributed to a general constriction in energy supply.[175] Nef saw in this an opportunity to pitch an article to *Scientific American*. In a familiar move, he rebranded his sixteenth-

century timber crisis as an 'Early Energy Crisis', an event which had 'much to do with the crisis we now face'.[176] Reiterating earlier arguments, he outlined coal's role in a recursive process of industrialisation, technological development, and economic growth. Blending this with his anti-materialist views, he claimed the productive and acquisitive forces unleashed in the sixteenth-century had led to the energy crisis of the 1970s.

Reflecting his late career interest in metaphysics and aesthetics, Nef had cast the ongoing energy crisis as one of values rather than energetic want. Invoking the sensation caused by Jay Forrester's recent computational forecast of societal collapse, *Limits to Growth* (1972), Nef argued previous generations' 'dedication to beauty' had 'been important in setting reasonable limits to economic growth'.[177] Somewhat cryptically, he therefore claimed the solution to the energy crisis lay 'in a renewal and an amplification of the standards of beauty'.[178] What reads like an esoteric idea from an elderly academic, perhaps overly enamoured with his art collection, makes more sense if understood as an invocation of a distinct notion of beauty. Here, beauty was understood as the embodiment of specific virtues.[179] To be truly beautiful, Nef had written elsewhere, society must exhibit 'a sense of humanity, a deep belief and faith, as well as the highest order of intelligence'.[180] These were the 'enduring values' Nef considered preconditions for societal harmony. However impractical, the idea that metaphysical values might alleviate a physical crisis is not one often heard today, despite its potential wisdom.

Edward Anthony Wrigley

Edward Anthony Wrigley was born in 1931 in Chorlton-cum-Hardy, a Manchester suburb. Son of a Unitarian minister and a teacher, he came from humbler stock than Nef. Retrospectively, much could be made of the fact his maternal grandfather had been a coalminer in Cannock Chase, Lancashire. Attending school first in Wales, as a wartime evacuee, and then Macclesfield, he would move on to study history and geography at Cambridge.[181] Combining the two subjects as a postgraduate, he hoped to challenge the idea that the natural unit of economic analysis should be the often-arbitrary demarcations of nation states.[182] Geographers had long advocated studying regions instead, areas marked by shared environmental properties such as river valleys, in which complex amalgams of human and environmental determination took place.[183] Wrigley would later argue that the study of centuries old regional reciprocities had been 'as much a victim of the industrial revolution as the peasant'.[184]

He believed the steam engine had created new and vastly expanded relations between humans and their environment which demanded a new and more systemic form of analysis. Wrigley would attempt such an approach in his doctoral thesis. He identified a suitable region running from Pas-de-Calais to the Ruhr. Geologists knew it as the upper part of the Hercynian complex, the remains of an ancient forest that had stretched across the West of Europe for over two-hundred miles. Three-hundred million years earlier in the Carboniferous period its densely packed trees had fallen and eventually formed a vast seam of coal.[185] Now a heavily industrialised belt that extended into three countries, he hoped this geologically distinct region might reveal the dynamics of industrialisation in a manner not dependent on national initiative.[186]

Wrigley spent the academic year 1953–1954 at Nef's Committee on Social Thought.[187] Sadly Nef's wife Elinor had recently died and Wrigley rarely saw his intended mentor.

However, he recalled benefitting from the University of Chicago's libraries and the advice of Hayek, who had joined as visiting professor three years earlier, and had given a memorable lecture on Mandeville's *Fable of the Bees* that year.[188] Significantly, around this time, Wrigley rejected Nef's methodological approach, expressing a scepticism about the idea that records of industrial output provided a sufficient indication of industrialisation. Not only incomplete and inconsistent, such data gave no real indication of the efficacy of coal use.[189] Rather than relying on such material, he proposed instead to measure the ratio between coal production and population growth across the Hercynian complex.

His hypothesis was that population could be used a measure of industrialism. His reasoning was that an agricultural society was constrained by the productivity of soil and availability of land. By contrast, coal granted access to punctiform reservoirs of unparalleled productive power, offering its dependents 'almost no limit to possible growth'.[190] Tracing the ratio between coal use and population growth, his method revealed how its rates closely mirrored the gradient of coal's distribution. The coal-rich Ruhr had been more densely populated than the less mineralogically-endowed Belgium. Divided into eight constituent coalfields, the region demonstrated that population growth seemingly even fluctuated with the amount of coal a miner dug in a year.[191]

His thesis demonstrated that, before the First World War, patterns of industrialisation had seemed to depended on proximity to coal rather than national policy. Such a distribution was historically contingent, as before widespread electrification, railways, and canalisation, it made more sense to convert coal into productive power *in situ*, hence industry and population clustered around coalfields.[192] Though an obvious conclusion, this was typical of post-war geography. Researchers sought to meticulously *explain* rather than describe observable dynamics using statistical methods. Given Wrigley's obvious aptitude for such work, in 1957 he was awarded a lectureship at Cambridge's geography department, an institution at the heart of this 'quantitative revolution'.[193]

Energy demography

In the late stages of his doctorate, following a period spent working with demographer David Glass at the London School of Economics, Wrigley became interested in the work of Louis Henry, the head of France's *Institut National d'Études Démographiques*. A demographer rather than a historian, Henry was interested in pre-contraception fertility ('natural fertility'), a metric considered useful for administering to the growing populations of France's colonies.[194] To produce this data he developed a method for reconstructing patterns of natural fertility based on registers of births, deaths and marriages found in French parish registers dating from before industrialisation. The life course of each married couple was recorded on a *fiche de famille*, a 'family reconstruction form' with a sub-section recording offspring. Forms could then be grouped by parish or by family name ('nominal record linkage') to build up a corpus representing an entire community.[195]

Wrigley hoped to apply Henry's method to England's parish registers, a record which went back further than those of France. In doing so, he recalled how he had travelled to damp churches in order to persuade local officials to let him view their musty parish register. On a trip to Colyton, an East Devon village, he found a remarkably complete

register documenting the demography of a parish from 1538 to 1837. It revealed that population growth had been persistently 'checked' by environmental limits, just as Thomas Malthus had predicted.[196] This undermined Nef's 'early industrialism' thesis, as he had assumed subsequent researchers would unearth evidence of significant population growth during this supposed boom period.[197] In fact, this small sample led him to believe seventeenth-century societies had 'no chance of fructifying into a steady expansion in production and real incomes' due to the fact they had been 'overfishing', consuming resources at a rate prohibitive to long-term growth.[198]

However, it was unclear if Colyton reflected a national trend. Helpfully, in 1964 Wrigley had co-founded the Cambridge Group for Population and Social Structure (CAMPOP) with social historian Peter Laslett, with the intention of undertaking large-scale historical demography.[199] Writing in the *Cambridge Review* a year later, it was clear Wrigley considered historical demography a discipline of contemporary importance.[200] Having achieved a growth rate of over two percent, in 1960 the global population had reached three billion people, prompting a series of warnings of coming starvation, overcrowding, and societal collapse.[201] His belief in the need to apply historical knowledge to contemporary problems was complemented by his co-founder Laslett's commitment to democratising knowledge, a goal he pursued via his radio show, the 'Third Programme'. In two BBC programmes titled 'The Numerical Study of English Society', broadcast in 1966, they appealed for listeners' help in developing an unparalleled data-set of the nation's historical demography.[202]

Local historians and amateur genealogists responded with enthusiasm and set about collecting information from the parish records of England's churches. To process the data Wrigley employed Roger Schofield, a historian and computer programmer.[203] Schofield specified how the data should be structured and cleaned to become machine-readable, with duplicates and untenable relations weeded out.[204] This attempt to turn qualitative data on family structures into a large-scale quantitative data set remained a remarkably labour intensive process.[205] By 1974, 404 registers of population data had been transcribed by over 227 volunteers.[206] This sample accounted for just 4 percent of England's 10,000 parishes. To gain a more comprehensive picture Wrigley and Schofield would carry out a type of simulation called 'back projection'.[207]

Beginning with data gleaned from the first comprehensive national census, that of 1871, their simulation took five-year steps backward, iteratively re-modelling these figures in accordance with the demographic dynamics revealed by the 404 recorded Parish registers.[208] Estimated deaths were added to the dataset and estimated births subtracted. Migration was measured by comparing birth and death rates for each cohort and assuming any discrepancy represented movement in or out of England.[209] Simulated values were then tested against patchy census data going back as far as 1801.[210] Beyond this, the simulation relied on the veracity of the underlying 404 registers with no external validation other than an error margin gleaned from prior validation.[211]

As the final dataset contained 3.7 million records, despite the project's final publication having a voluminous 256-page appendix, the reader had to trust in data held on a magnetic tape somewhere in Cambridge.[212] But transparency's loss was empiricism's gain.[213] The exercise revealed an initial period of population growth in the sixteenth century, followed by decline and then stagnation until 1741. Then growth not only resumed but became so rapid and sustained that England's population had doubled by 1821.[214] Earlier demographers already had some sense of this dramatic nineteenth-

century increase, but evidence of population stasis in the seventeenth was new. Far from a booming early industrial revolution, as Nef had believed, the mid seventeenth-century now appeared an 'anomalous interlude of stagnation'.[215]

Simulating transition

Wrigley's data was used to structure a computer model. Represented schematically, this 'Dynamic Model of Population and the Environment' presented the demographic variables gleaned from both registers and back projection as nodes. Causal relations were represented as edges. Relations could be positive or negative. For instance, increased 'fertility' would positively increase the value of the node 'population size'; demographic nodes were linked to nodes representing 'real income' and 'food price', with that coming from the work of others.[216] All values were calculated via differential equations and were largely interdependent. For instance, demand for labour depended on demand for goods, itself a product of increased real wages. In effect, the model represented the major dynamics of England's political economy via a series of dependent feedback loops.[217] In assuming this structure, it was as if, as one reviewer suggested, its authors saw historical demography in 'cybernetic terms'.[218]

Simulation runs revealed patterns. During centuries sixteen and seventeen, there were sufficient negative feedbacks to demonstrate Malthus's idea that there were inadvertent or intentional 'checks' on societal growth.[219] As population increased, food became scarce and prices rose, constraining further growth. This classical system seemingly lacked 'sufficient momentum to break clear'.[220] But, among other changes, when the simulation was run with data for centuries eighteen and nineteen, the positive feedback between population size and food prices which had previously constrained population disappeared around 1800 (Note the disappearance of the connection between population size and food price in Figures 1 and 2). As population grew food prices remained more-or-less static. Stranger still, wages grew alongside demand for secondary and tertiary goods.[221] For the model's makers it was as if the 'historic link between population growth and price rise was broken'.[222]

Less than a decade after Jay Forrester's *World3* simulation had forecast the collapse of twenty-first-century civilisation due to the limits to growth presented by overpopulation, pollution, and scarcity, Wrigley's team had published the results of a more complex simulation to show how such constraints had first been transcended.[223] What had allowed limits to growth to be overcome around 1800? If the model's underlying logic was reversed, this dramatic shift in the system's dynamics presumably indicated a significant change in resource availability. Demographic data had provided a work-around that avoided the pitfalls of productivity data, allowing logical assumptions about shifts to society's underlying resource base to be made with some confidence. Just as Wrigley had surmised in 1962, the model demonstrated how England's population could only deviate from Malthusian norms when the production of food and goods were no longer constrained by the limits of solar powered agricultural productivity.[224]

Back then Wrigley had argued that coal had served to 'liberate production from the physical limits' imposed by agriculture's areal mode of production. Well-versed in political economy, Wrigley had noted how economists of the time, from Adam Smith

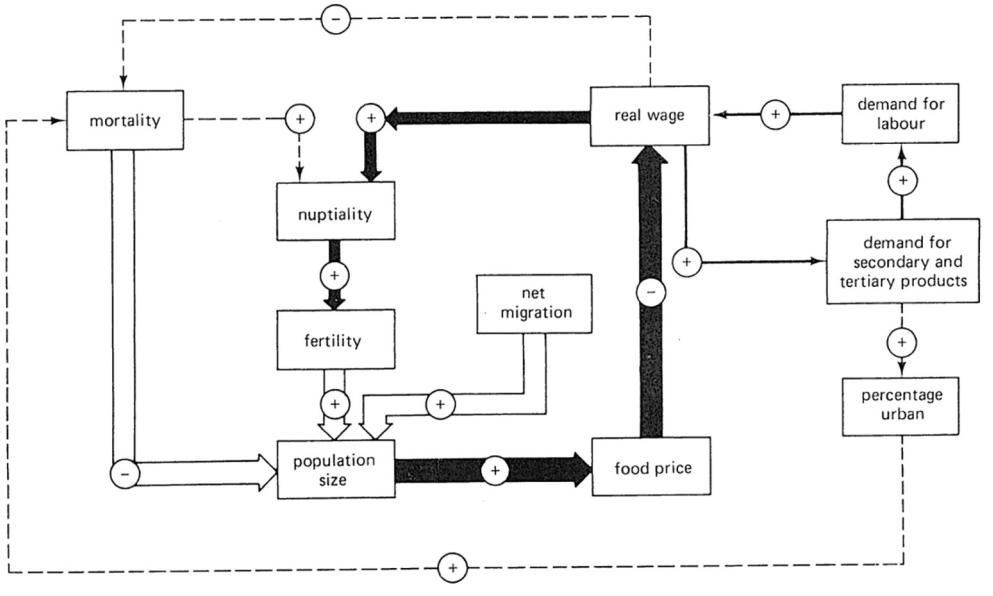

Figure 1. Limited growth: A feedback diagram representing 'England in the late sixteenth century' on the basis of Wrigley and Schofield's Dynamic Model of Population and the Environment. Source: E.A. Wrigley and R. S. Schofield, *The Population History of England, 1541-1871: A Reconstruction*. Cambridge: Cambridge University Press, 1989 [1981], 468. Reproduced with permission from Cambridge University Press.

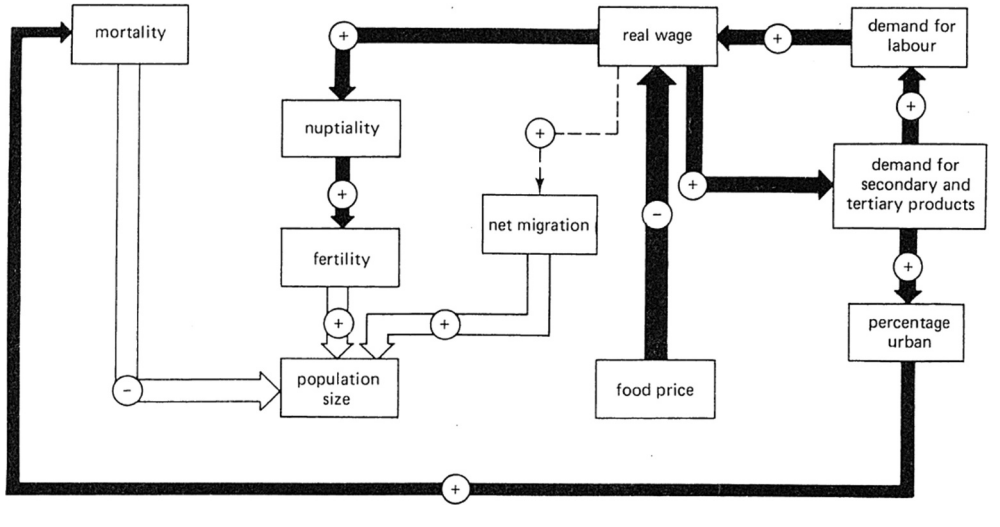

Figure 2. Limits transcended: A feedback diagram representing 'England in the early nineteenth century' on the basis of Wrigley and Schofield's Dynamic Model of Population and the Environment. Source: E. A. Wrigley and R. S. Schofield, The Population History of England, 1541-1871: A Reconstruction. Cambridge: Cambridge University Press, 1989 [1981], 474. Reproduced with permission from Cambridge University Press.

to John Ramsay McCulloch had reinforced the idea that the agricultural system was

homeostatic and imposed limits to growth. In the immediacy of lived experience, Wrigley claimed they had failed to notice that, in their own time, industry had begun to move from such an 'areal' dependency, constrained by the availability of land, toward a system in which 'punctiform' coalmines and productive 'networks' of shipping routes, railways, and canals allowed areal limits to be transcended.[225] By 1981, the demographic model could be used to make the same argument about the critical role played by coal, though it contained no underlying data on energy use.[226]

But what triggered this shift to coal? Far from a period of material scarcity, as Nef had argued, Wrigley had discerned a prosperous society that had bumped against the productive limits of the organic economy. Before 1800 England had been an 'advanced organic economy' in which the productivity which ultimately derived from the sun had steadily increased thanks to selectively bred crops, advances in agronomical science, the growing availability of imported goods, and the increased use of animal labour. Besides a brief mid seventeenth-century interlude, this improved agricultural system had supported a population increasing at a modest rate at the same time as, on average, household income rose.[227] In contrast to Emmanuel Le Roy Ladurie's 'immobile' Languedoc peasants, whose growth was constrained by the vicissitudes of harvests, Wrigley and colleagues had shown that English society had broken free of such homeostasis.[228]

Providing a helpful comparison, Wrigley's data pointed out that his own generation, that of the supposedly Swinging Sixties, had on average married earlier than any other generation of the past 450 years. Before industrialisation, matrimony was constrained by material circumstance. In times of poor harvest marriage occurred comparatively late if at all, resulting in fewer children; whereas prosperous periods encouraged early and regular marriage, making children more likely. In effect, Wrigley had come to see nuptiality as a 'great valve' controlling both the rate and structure of population.[229]

What did this have to do with energy? It appeared the small 'nuclear family' was not an outcome of an inorganic, coal-rich society. Drawing on Laslett's more qualitative, anthropological approach to understanding household structure, Wrigley argued that a small household structure was far more common in pre-industrial England than previously thought.[230] Such families had greater per-capita purchasing power than large families, creating greater demand for secondary goods, which were generally the fruits of coal-based industry rather than solar agriculture. This led him to an extraordinary conclusion. In creating households that could afford industrial goods, the '"control" mechanism' of marriage had been the principle driver of industrialisation.[231] As his fellow economic historian Jan de Vries noted, in place of scarcity, Wrigley explained the emergence of coal-based industrialism on a subtle 'nuptiality-driven demographic-economic interaction'.[232]

Wrigley spent the rest of the decade expanding upon this argument. In 1988 he published *Continuity, Chance, and Change*, becoming the first of our authors to describe the Industrial Revolution in terms of 'transition'.[233] However, like later critics, he cautioned against thinking of a clear segue between 'organic' and 'inorganic' systems, an abstraction which failed to do 'justice to the intermingling of the two in historical reality'.[234] His work also became more explicitly ecological. He now described how coal use had unleashed 'the energy value of uncountable billions of trees', unlocking 'tens of millions of years' of photosynthesis.[235]

Such explanations were unorthodox. The late 1980s were the highpoint of the 'wave of gadgets' theory of industrialisation. Joel Mokyr had attributed industrialism to Britain's post-Enlightenment culture of 'technological creativity'.[236] He directly attacked Wrigley's argument, suggesting he misunderstood the causative dynamics of industrialism.[237] Like Toynbee, Mokyr considered coal use as a consequence of the industrial revolution rather than its cause.[238] Mokyr even argued industrialisation would have occurred in its absence. Human ingenuity, he claimed, would have provided suitable alternatives, though he did not explain what these might be.[239] It has since been argued that Mokyr's anti-materialism reflected a widely-held belief in the supposed revolutionary potential of information technologies during the 1990s.[240] Unfashionably for the time then, Wrigley still maintained that only coal could 'produce energy on the scale needed' for industrialisation.[241]

The world came round to Wrigley. In 1992, following a meeting in Rio, the United Nations issued a statement noting the climatological consequences of 'historical patterns of unsustainable consumption'.[242] In 2000, the British Government published a review of the economic costs of climate change, the *Stern Review*, and which raised the idea of 'historical responsibility' for past emissions.[243] Whatever their status amongst economic historians, energy-based accounts of industrialism were clearing gaining credibility elsewhere .[244] Moreover, the early 2000s were notable for the heightened relevance of the once obscure subfield of climate history. Historians of climate had spent the past fifty years assembling sufficient data to begin making credible claims about relations between weather and climate and human history. Hard-won evidence of the historicity of pre-industrial climate found itself on the frontline in conflicts between global warming denialists and believers.[245] Wrigley's acceptance of the risks of anthropogenic climate change might may have been encouraged by his own work. Back in the 1980s his model had revealed a 'surprisingly rich' result when he had examined climate as a factor of mortality.[246]

Energy history was increasingly recognised as the precursor to a new and unprecedented chapter in the history of Earth's climate. The affirmation of this relation would radically alter Wrigley's view of industrialism. In contrast to Nef's romanticism, he had once seen pre-industrialised life as a 'singularly bleak form of existence' in which the 'bulk of the population normally experienced periodic want and the lowest ranks often spent their lives in misery'.[247] Only coal had provided sufficient productive power to make the alleviation of poverty a possibility for the first time. As Nef had also observed, the Miner's strikes of the 1920s manifest a belief that coal-derived wealth should be more equitably distributed.[248] Such resistances provided an important impetus to the early formation of Britain's welfare state, those taxation-derived public services which had so greatly benefitted Wrigley's generation.[249]

But by 2010, the joint-warmest year on record at the time, Wrigley conceded that though the many 'powers which were released by the industrial revolution have proven unambiguously beneficial' the 'attendant dangers are not trivial'.[250] Employing the language of climate science, he warned of a disastrous historical 'tipping point', a non-linear shift in global climatic stability, if fossil fuel use continued.[251] Building on this, his last book, written as an emeritus, rebranded industrialisation as 'sustainable economic growth' with heavy irony. Industrial life and all it afforded had been a 'fool's paradise' built on depleting fossil fuel stocks. Without supplies of alternative energy of equal

magnitude, he warned, this apparent achievement would prove to be 'the precursor of an overwhelming tragedy'.[252]

A younger generation have accused Wrigley of furthering an 'insular' account of industrialism which ignores Britain's exploitation of overseas possessions.[253] In 2000 historian Kenneth Pomeranz borrowed the notion 'ghost acre' from Swedish food scientist Georg Borgström, using it to quantify the productive consequences of this territorial expansion. In 1815 Britain's colonies had provided as much as thirty million extra acres of productive land, surpassing the estimated 15 million acres of forest that year's coal consumption represented. As such, he believed colonies rather than coal better explained Britain's iniquitous economic 'divergence'.[254] Wrigley responded, arguing that access to vast quantities of sugar and cotton had been a sign of an expansive coal-powered economy rather than its cause.[255] Moreover, if his work manifest an insularity, this was excused by others as an outcome of method. The simulation at the core of his life work had required England to be represented largely as a closed system.[256] Moreover, his later commitment to the planetary and climatological implications of this necessarily insular history does not clearly counteract accusations of parochialism.

Wrigley's systems theoretical approach precluded mono-causal explanations. Neither energy availability, overseas territories, the accumulation of capital, nor demographic structure *determined* the course of industrialisation alone. Instead, it had been an outcome of 'the nature of the feedback between [all] the components of change'.[257] Today, with our increasing awareness of the fact that climate change is just one of many out-of-kilter planetary dynamics, there is a move toward somehow combining historical knowledge into predictive models of the Earth system.[258] In approaching a systemic, multi-causal explanation for the emergence of industrialism, Wrigley's work offers an important precursor to these efforts, pointing to the requisite sophistication required for the meaningful integration of human and Earth history.

Rolf Peter Sieferle

Our third protagonist, Rolf Peter Sieferle, was born in Stuttgart in 1949. His parents separated, and he was raised by his mother with the trappings of bourgeois comfort. He spent his early years unhappily at a boarding school before moving to Heidelberg to study history and sociology.[259] In 1968, as elsewhere, West German universities were a ferment of radicalism. Sociologist Jürgen Habermas, who had studied student movements whilst a professor in Heidelberg, would describe this generation's 'particular sensitivity to the untruth of prevailing legitimations'.[260] Burdened with their parents' possible complicity with Nazism and their own capitulation to American led administration, universities were seen as potential 'forces of social change'.[261] German-American sociologist Herbert Marcuse had been the campus hero. His spirited keynote at the 1964 *Deutscher Soziologentag*, held in the city's castle, attacked Max Weber's canonical argument about the supposed relation between reason and capitalism, providing an important rallying point for an emerging New Left.[262]

For his part, Sieferle was bookish, supposedly reading three hundred pages a day, but also politically engaged.[263] Aged nineteen he was elected to the West German *Sozialistische Deutscher Studentenbund* (SDS) where a former associate recollected that 'while other red-bourgeois children in the Neckarauen', a patch of meadows popular with

students, 'learnt to throw Molotov cocktails against police while talking about Marx, [Sieferle] read it'.[264] By 1977 this studiousness resulted in a doctoral thesis in which he argued Marx's concept of revolution was defunct. Revolutionary consciousness had failed to materialise because Germany's post-war economic miracle had softened all but the most radical factions.

Another problem, as he later recollected, was that the 'environmental crisis and limits to growth had entered the political scene'.[265] The German edition of *Limits to Growth* (*Die Grenzen des Wachstums*) appeared in 1972, provoking concerns among leading members of the ruling Social Democratic Party (SPD). The publication's predictions were somewhat affirmed by the 1973 oil crisis, which was experienced acutely in the increasingly auto-mobile West Germany.[266] Sieferle recalled realising that 'Marxist categories did not help us understand these new issues.'[267] Marx had famously argued that transforming the ownership structures of the means of production would allow society to transcend physical limits. Even if this were true, environmentalists now saw pollution as much as a problem as scarcity.[268] Abandoning the politics of his youth, Sieferle came to believe Marxism espoused a misleading 'anti-naturalistic intellectual bias'.[269]

Having defended his thesis, in 1980 he joined a research team called AUGE (*Arbeitsgruppe Umwelt, Gesellschaft, Energie*) at the University of Essen. An interdisciplinary working group directed by physicist-philosopher Klaus Meyer-Abich, AUGE continued a longstanding strand of anti-nuclear scientific activism in West German academia.[270] Meyer-Abich's doctoral supervisor, physicist Carl-Friedrich von Weizsäcker, had founded the Association of German Scientists (*VDW: Vereinigung Deutscher Wissenschaftler*) in 1959. These physicists, some of whom had been accused of involvement in wartime nuclear weapons research, now acted as counter-experts, campaigning against the development of nuclear technologies from prominent research institutes.[271] The stakes had been raised when, a year after the oil crisis, the West German government committed to a fifteen-fold increase in nuclear power by 1985. Formed the year of that commitment, AUGE continued in the anti-nuclear tradition of the VDW, carrying out research into alternative means of providing energy.[272]

Sieferle's group leader Meyer-Abich was concerned with the social compatibility of proposed solutions to the energy crisis, which he saw as split between a high-energy nuclear scenario, with all the political authoritarianism this implied, and a scenario based on alternative energy and conservation, which he hoped might foster a more progressive politics.[273] This was the intellectual context toward which his second book, *Der Unterirdische Wald* (1982) was directed. A comparative history of coal-powered industrialism in Britain and Germany, the book was explicitly pitched as an intervention into the 'current debate on the future path of the industrial system'.[274] However, the deflating lesson Sieferle's work offered to activist scholars such as Meyer-Abich was that past energy transitions had been characterised by contingency: 'No one ever opted for the industrial revolution or the fossil energy system'.[275] Coal transition had occurred as a result of myriad individual decisions with little sense of their collective outcome.[276]

Methodologically, Sieferle had combined traditional textual interpretation with ideas drawn from systems theory.[277] Systems thinking offered him a 'heuristic', a means for gaining perspective on the non-human world and a basis from which he believed a scientifically defensible form of history could be written.[278] Further inspiration came from epidemiological, climatological, and environmental historians of the 1970s;

specifically William McNeill, Emmanuel Le Roy Ladurie, and Alfred Crosby, all of whom integrated scientific forms of explanation in their work. In doing so, Sieferle believed they had transgressed the 'dominant boundaries of social constructivism' which characterised the discipline at large at the time.[279] Persistently contrarian, Sieferle believed explanations based on social theory had to be abandoned if historians hoped to contribute to the alleviation of environmental crises.[280]

Sieferle's book set out the dynamics of a 'Solar system' in which the sun controlled the energy supply within Earth's 'biosphere'.[281] Converted into organic matter via photosynthesis, this energy was collected by hunters and foragers, and following the Neolithic agricultural revolution, farmers. This continued largely unchanged for most of the Holocene. System parameters were ultimately dictated by sunlight falling on Earth's surface, a measure which varied only according to a society's 'dependence on territory'.[282] In German-speaking Europe, Sieferle argued, limits to growth appeared around 1800. Despite previously abundant forests, rapid population increase after the Thirty Year's War, and profligate wood use, partly encouraged by subsidised timber prices, fostered shortages of wood. Alongside contemporaneous evidence of widespread malnutrition, Sieferle believed he had identified a solar energy crisis.[283]

How had this crisis been alleviated? Sieferle argued German speaking Europe had largely imitated British industrialism, using coal to circumvent the limits of a solar-areal energy system. But it had done so within a different 'social ecology'. In contrast with the relatively economically liberal Britain, in Central Europe greater expectation was placed on the ruling class to help alleviate want. Sieferle claimed this paternalism encouraged a more top-down transition.[284] For example, Frederick the Great had attempted to normalize coal-use by installing coal heaters in his army's garrisons, and had offered subsidies to industries such as brewing and saltpetre manufacturing to encourage coal use. Berlin's Firewood Comptoir had used its power to set fuel prices to do the same.[285] As compared to Britain, Sieferle surmised, Germany's coal phase in had 'occurred later, was slower, and was mediated by the state'.[286]

Sieferle borrowed the memorable title 'underground forest' from a 1693 treatise *Sylva Subterranea* written by a Brandenburg jurist Johann Philipp Bünting. Mining of all kinds had been somewhat taboo since Antiquity but, on behalf of his patron the Elector of Brandenburg, Bünting had recast coal as a sign of divine providence. At the time, a lack of timber and food had encouraged a belief that the world was drifting towards its end. In such a context, the treatise sought to publicise the benefits of coal use and suggest its provision was a sign of God's 'omniscient goodness and mercy', a means of delaying the coming day of judgement.[287] In order to make the fuel more appealing, and demonstrating an alchemical tendency to draw analogies between substances, Bünting described coal not as artefact from a sulphurous underworld but an artefact of a 'subterranean forest'.[288]

Returning to the 1980s, Sieferle described how the exploitation of subterranean forests had meant the 'ecosystem of the English economy no longer extended to north-eastern Europe' from where iron and timber had been imported, 'but back into the Carbonaceous period': in this way, a 'territorial' energy system had been transformed into a 'temporal' one.[289] To illustrate his point, and reflecting a long tradition of calculating wood mass in German forest science, Sieferle estimated that by 1821, Britain and Germany consumed so much coal, that it was as if, that year, they burnt an imaginary forest covering the entire landmasses of the two nations combined.[290] Given the timescale required for the

geological formation of coal, Sieferle stressed that its alleviation of the constraints of the solar-areal energy system would prove a 'singular phenomenon in world history'.[291]

By the late 1970s, limits to energetic growth had already begun to appear. Environmentalists had become increasingly concerned with *Waldsterben*, the dieback of Central European forests. This arboreal epidemic was widely blamed on the pollution that resulted from increased lignite combustion following the oil crisis.[292] As tracts of forest died, as a result of the combustion of their subterranean alterity, Sieferle's argument proved volatile. At a conference on 'Energy and History' held in Essen in 1981, an equally contrarian historian from Bielefeld, Joachim Radkau, questioned Sieferle's claim that an eighteenth-century timber crisis had been heroically resolved by an increasingly capitalistic society.[293] He cast Sieferle's claim as part of a wider genre that promoted the idea of a simple determinative relationship between wood-scarcity and coal-use, and which encouraged the wrongful idea that capitalism progressed in a natural and progressive manner.[294]

The *Holznotdebatte*, as it was known, became highly charged; not only because forests were seemingly succumbing to flue gases at the time but also because some associated a supposed German affinity with forests as an idea promoted under National Socialism and increasingly popular with an ascendant New Right.[295] There was also degree of academic axe-grinding going on. Radkau, a committed Weberian, later admitted that one of his aims had been to challenge 'pseudo-ecological' historians who believed they had transcended their anthropic perspective by adopting natural scientific methods.[296] For his part, Sieferle hoped ecology could undermine a relativism he associated with social theory. Ostensibly about trees, their disagreement revealed a schism between a scientistic form of environmental history and a subjectivist, sociological approach.[297]

Energo-Lamarckianism

In the 1990s, Sieferle further developed his thinking at the Vienna School of Social Ecology. Led by Marina Fischer-Kowalski, the group distinguished themselves from human ecologists by focusing upon the non-human or extra-human factors in societal evolution.[298] The group's approach was strongly influenced by sociologist Niklas Luhmann. Combining systems theory and sociology, he cast society as a system which engaged 'functional differentiation', acts of ontological distinction between itself and its environment.[299] The Vienna School sought to overcome such divisions by studying the connective tissues of energy, matter, and information that sustained society.[300] At the time, Sieferle became increasingly interested in Luhmann's notion of 'cultural evolution', acts of symbolic communication which distinguish human evolution from that of other species.[301] It affirmed his earlier finding that Germany had altered its metabolic base by imitating British industrial practices. The evolution which followed had occurred in a rapid Lamarckian fashion, over a lifetime rather than the generations required in Darwin's scheme.[302] As such, Sieferle would come to the conclusion that cultural differentiation could be understood in evolutionary terms.[303]

Before ending his own life, Sieferle had prepared a number of texts for publication, amongst them was a short pamphlet *Finis Germania*. It offered a deeply pessimistic account of Germany's response to the so-called 'refugee crisis' of 2015. The coalition government had agreed to admit 800,000 refugees, predominantly from Syria, a move

which Sieferle cast as a misguided act of penance for the Holocaust. Itself a crime which, Sieferle believed, Germans had been led to believe was exceptional amongst all those of the twentieth-century.[304] Printed by *Antaios*, a right-wing publishing house, the book's popularity caused great controversy in the *feuilleton*, the German literary press. Its eloquent but provocative claims had coincided with electoral successes of an ascendant right-wing party, *Alternative für Deutschland*. As its author's infamy grew *Der Spiegel* removed the book from its best-sellers list and cast its author as an extremist, generating further controversy.[305]

Sieferle had been far from an outsider. As well as editing the sustainability studies journal *Gaia*, he had held professorships in Mannheim and St. Gallen, Switzerland. In preceding years, he had also advised German's leading advisory council on climate change with regard to history's role in realising a 'climate-friendly' society.[306] In this role, he had argued that:

> The transition to a "climate-friendly society" must be understood as an element of a broader transition that leads out of the structural non-sustainability into which humanity has fallen in the course of industrialization. It is therefore nothing less than the formation of a socio-metabolic regime based on permanence, at the same time as preserving and developing political, social and cultural standards, as they have formed in the last 200 years.[307]

Retrospectively the political implications of this advice are illuminating. Employing the urgent imperative of climate change and the well-meaning language of sustainability, his call for the stabilisation of socio-metabolism manifest a distinct vision of cultural conservatism.

This interest in updated forms of conservatism built on prior work. In 1995 Sieferle had published on the Weimar Republic's 'Conservative Revolution', an intellectual movement he presented as a retooled school or form of conservatism adapted to the pace of an accelerating modernity. A paean rather than polemic, the book sympathetically assessed the writings of Ernst Jünger, Oswald Spengler and Werner Sombart, amongst others; relaying their attacks on democracy, which was described as an outmoded form of bourgeoise humanitarianism, and Marxism, with approval. Throughout Sieferle sought to distinguish what he perceived as this progressive right-wing radicalism from 'morally bankrupt' National Socialism.[308]

Combining his interest in political thought with that of environmental history, in *Finis Germania* he described how a lifetime's historical research had shown human existence was not 'cosmically stable and identical' but could vary as a result of circumstance.[309] Mocking the language of social constructivists, he claimed that such differentiation meant all cultures were indeed relative to one another. But, according to his belief in sociocultural evolution, each could be 'neatly arranged in a line of progress'.[310] Quite what Sieferle meant by progress is unclear. He held a deep ambivalence toward post-war Germany's material achievements. Later in the text, with heavy sarcasm, he bemoaned the ephemera of industrial modernity, acidly remarking that each discarded plastic bottle could be seen as a 'salutation of love to our fellow citizens'.[311]

Sieferle expanded on the relation between industrialisation and migration more explicitly in *Tumult*, just before his suicide. Having once been a radical mouthpiece of '68ers, the journal had split into a left and right faction, the latter ossifying into an echo chamber for reactionary thought.[312] Lamenting the emergence of what he termed

a 'multi-tribal' Germany, Sieferle argued, just as he had in 1982, that industrialisation had depended on fortuitous geological circumstances. Accordingly, the wealth and security coal had afforded had emerged from 'certain historical, and especially cultural and institutional preconditions that are not easy to imitate or create'.[313] Germany, of course, had successfully imitated the coal-powered industrialism of Britain, but even this had been 'highly improbable'.[314] The result had been the development of social democracy and the Welfare state, but the survival of these generous legacies of coal-powered industrialism, he argued, were incompatible with the demands mass migration would impose.[315]

This justification for territorial protectionism on the basis of energy scarcity was perhaps unsurprising. Area had remained a persistent concern in Sieferle's work.[316] In 2007, in the journal *Gaia*, he had argued the spatial emancipation that fossil fuels had granted was coming to end as a result of the coming climate crisis. The inescapable fact that the 'area of resource extraction was the most important resource' would once more become evident as humankind attempted to transition into a lower-carbon energy system. Given their comparatively low energy density, the massed use of biofuels or solar photovoltaics would involve the 'return of area' as the ultimate constraint upon societal development.[317] Others had made similar arguments about the areal requirements of a low-carbon energy system, but only he felt it necessary to combine them with an exclusionary nationalism.[318]

In doing so Sieferle echoed nineteenth-century geography's preoccupation with *Lebensraum*. Translated as living *space*, the term Raum has thick connotations in the original German.[319] In 1882, zoologist turned geographer Friedrich Ratzel had argued that the evolution of aggregate organisms, such as society, required sufficient space. Energy was central to his explanation. Influenced by Ostwald, he had described how the sun 'set in motion' earth's geochemistry, allowing the soil to nurture plants, nourish animals and grant life to humans, 'double beings' half solar and half terrestrial.[320] As areal repositories for energy, evolution could be assured via the seizure of more land and more concentrated energy sources.[321] Thanks to geographer Karl Haushofer, Ratzel's notion was used by Adolf Hitler in *Mein Kampf* to naturalise his territorial ambitions.[322] Worse still, when such expansion reached its limits, it was used to justify the freeing up of space within the body politic by exterminating those considered inferior.[323]

We can only hope Sieferle was unaware of proximity to Ratzel's rightly 'disgraced concept'.[324] Even so, the historian was uncharacteristically myopic in failing to consider the possibility that spatial limits to growth might reappear in the form of people displaced from the very hydrocarbon-rich regions which Germany and other nations had long exploited. It does not take much cosmopolitanism to appreciate that the expansive power of European colonialism was largely powered by coal.[325] Moreover, following the establishment of concessionary agreements between Anglo-American oil companies and autocratic leaders of the Middle East in the early 1900s, a large part of the unrest in this region could be explained as an outcome of Western Europe and North America's appetite for oil. For this very reason, dependent states had long participated in the suppression of democratic and egalitarian movements throughout this oil-rich region.[326]

Sieferle's argument assumes greater irony given that some have identified fossil-fuelled climate change as a factor which helped trigger Syria's exodus.[327] Such a view has not gone uncontested, its critics rightly suggest such a view overdetermines the role of

climate and underestimates social factors, such as that presented by the tyrannical mismanagement of Syrian President Bashar Al-Assad.[328] However, to too closely endorse such social forms of explanation risks the opposite mistake, under-determining the climate's role in a period of Syrian history in which the country had experienced its longest drought on record.[329] Just as there is no simple relation between climate and society, there is none between energy and society. To do justice to such relations, in a manner required at this historical moment requires acceptance of an interpretative pluralism.[330]

So, if energy history is to remain a humanitarian discipline, as it should, we must not endorse new forms of energy determinism as Sieferle did. We must not use quotients of energy to naturalise inequality, nor bulwark cultural racism. In casting history as an energy-determined survival of the fittest, despite his erudition, Sieferle had fallen back on an outmoded form of explanation best left in the nineteenth century. He had also forgotten a lesson he had drawn from an earlier reverie. In the 1990s, while exploring an abandoned open-cast lignite coalmine in Borna near Leipzig, he had sensed 'revolutions of a telluric dimension' amid its eddies of sparkling lignite dust. This environment in flux, buffeted by the passage of time, revealed the fundamental lack of any 'stable origins' in both the passage human and natural history.[331] In this moment, Sieferle seemed well aware of the inadequacy of arguments that oversimplified the reciprocal determinations which occur in an incessant process of vibration between environment and society.

Conclusion

What lessons can be learnt? Historicisation of energy historical thought reminds us that energy history, and the conclusions it has reached, have been shaped by contemporary mores in a way which both affords and delimits historical understanding. For example, Nef's early work expressed the positivistic enthusiasm of early quantitative economic history, building on a foundation of Marxian materialism and Sombartian concern with the systemic capacities of capitalism. Curiously, his religious conversion caused a rejection of such grounded explanations in favour of non-materialist values and metaphysical speculation. Wrigley's work, by contrast, moved in step with the quantitative pre-occupations of post-war geography, making use of computers to transform historical demographic data into a diagnostic tool for identifying shifts in society's energetic substrate. Later, with growing evidence of anthropogenic climate change, his somewhat laudatory energy historical thesis was revised to accommodate the ambivalences posed by fossil fuelled abundance.

These two authors attempted to avoid unfounded or crude assertions of energy's determinative role. Mis- or unread, their arguments have at times encouraged others to make over determined statements about the history-making capacities of energy. On closer inspection, both Nef and Wrigley can be (re)read carefully as exemplars of how to make a persuasive yet qualified argument for energy as an inter-dependent historical agent. Sieferle's scholarly life course, ever contrarian, rejected a youthful Marxism for a form of systems theory fused with ecological history. Despite his clear erudition, and moments of reflective agnosticism, the result was an energy-based theory of cultural evolution that lent itself all too easily to a prejudicial form of social Lamarckianism. If

energy history is to remain humanistic, it is imperative that its concern with energy and climate should not allow prejudicial forms of environmental determinism to creep in. As generations of climate historians have taught us, energy, like climate, conditions rather than determines history's course.

And what of applied lessons? A general sense of crisis loomed over these authors' lives and work: From the Great Depression to the Second World War, energy crises, crises of values, the climate crises, and the so-called refugee crises. The prevalence of crises lent legitimacy to the idea that past solutions might, in some way, be applicable to present concerns. By and large this proved to be a mistake. There appears to be no general lesson one can draw from the history of energy, just as there is no single lesson to learn from history in general. If the lives and work of these historians teach us anything, it is that beyond the strictures of thermodynamics there are no simple imperatives one can identify in the relation between energy and society. Such relations have been created in the past, and will be created anew. This should encourage us. Our future is not pre-ordained, rather there is great potential to redefine society's relation to energy.

Notes

1. Latour, "On a Possible Triangulation"; and McGlade and Ekins, "Geographical Distribution."
2. Hirsh and Jones, "History's Contributions," 106.
3. Sabin, "The Ultimate Environmental Dilemma."
4. Pearson and Foxon, "Low Carbon Industrial Revolution?"
5. Markard, "The Next Phase," 632.
6. Beltran, "Pour"; Szeman and Boyer, *Energy Humanities*; and Barry "Thermodynamics", 110.
7. Zachmann, "Past and Present Energy Societies," 9.
8. Malm, *Fossil Capital*, 22.
9. Osterhammel, *Transformation*, 637–67.
10. Steffen et al., "The Anthropocene," 842–3.
11. Malm, *Fossil Capital*, 42.
12. Bonneuil and Fressoz, *Shock of the Anthropocene*, 122, 253.
13. Gismondi, "Historicising Transitions," 197.
14. Carr argued "the historian who is most conscious of his own situation is also more capable of transcending it" and that the historicization of interpretation allowed the historiographer to appreciate how the "tyranny of environment" conditioned historical thought. Carr, *What is History*? 44.
15. Bonneuil and Fressoz, *Shock of the Anthropocene*, 101–102.
16. Sombart, *Der Moderne Kapitalismus*, Vol. II, 1143–1148.
17. Sombart, *Der Moderne Kapitalismus*, Vol. III, 97–102.
18. Araújo, "Emerging Field," 112.
19. Such as the "the transition from coal to oil" in the Navy. Zimmermann, *On Ocean Shipping*, 178.
20. Basosi, "A Small Window," 339.
21. Laird, *Solar Energy, Technology Policy*, 113–5; and Laird, "Avoiding Transitions, Layering Change," 111–31.
22. Donovan, "Preface," 243–5.
23. Olby, "Social and Political Aspects," 1–3.
24. "Energy transitions, like technological transitions, are overlapping and experienced slowly," Clark, *Energy*, 28.
25. Hulme, "Reducing the future," 247.

26. McKinnon, "Energy and Society," 448.
27. Livingstone, "Evolution, Science, and Society."
28. Stewart, "Sociology, Culture, and Energy," 337.
29. Adams, *Letter to American Teachers*. On Adams see White, "Dynamo and Virgin Reconsidered."
30. Stewart, "Sociology, Culture, and Energy," 335.
31. Meyer and Guss, *Neo-Environmental Determinism*, 1.
32. He leaned on a classical "law" like conception of entropy just as a statistical explanation emerged. Brush, "Thermodynamics and history," 539.
33. Munford. "Henry Adams," 79–85.
34. Gardiner, *Nature of Historical Explanation*, 64.
35. Examples include sociologist Cottrell, *Energy and Society*, anthropologist Adams, *Paradoxical Harvest*, and chemist Ubbelohde, *Man and Energy*.
36. Mirroring the fallacy of climate indeterminacy in Hulme, "Reducing," 246.
37. MacKay, *Sustainable Energy*, Fig. 1.4. 6; Fröhlicher et al., "Continued global warming", 40.
38. Summerhayes and Zalasiewicz, "Global warming," 194.
39. I thank Daniela Ruß for raising this idea with me.
40. Beyond the English language, the term's origins are contested; Coleman attributes it to Friedrich Engels. Coleman, *Myth*, 6–18.
41. Toynbee, *Lectures*, 121.
42. Ibid., 85.
43. Kadish, *Apostle Arnold*, 43–44.
44. Toynbee, *Lectures*, 20.
45. Ibid., 20, 250.
46. Clapham, *Early Railway Age*, vii.
47. Hartwell, "Interpretations," 230.
48. Clapham, *Early Railway Age*, vii–viii.
49. Between the 1920s and 1970s debates over "the material effect of the Industrial Revolution on the industrial working class sustained more scholarly controversy than any other within the confines of modern British history," Weaver, "The bleak age," 29.
50. Clapham, *Machines and National Rivalries*, 507.
51. Usher, "Sir John Howard Clapham," 148–54; Clapham, "On empty economic boxes"; and Clapham, "Cambridge Inaugural Lecture," 63.
52. Clapham, *Free Trade and Steel*, 99.
53. Clapham, *The Early Railway Age*, 42.
54. Nef suggests he first came across Clapham's work in the nineteen-twenties, oddly, in a response to a letter novelist H.G. Wells wrote to the editor of *The Adelphi*. Nef, *Search for Meaning*, 67.
55. Hobsbawm, "A Christian Materialist," 20.
56. Nef, *Rise*, 20. Nb. refers to Volume 1 of 2 unless otherwise stated; Nef, *Conquest*, 170.
57. Nef, "The Industrial Revolution reconsidered," 276.
58. Philosopher George Herbert Mead was appointed as his guardian. He would marry Mead's niece Elinor Castle. Nef, *Search for Meaning*, 5–8.
59. Cole, "Economic History," 561.
60. Nef, *Search*, 7; Turner famously argued that North America's open "frontier" had created a rugged, individualistic sensibility, and a disregard for efficient resource use in favour of an expansive mode of production, see Coleman, "Science and Symbol."
61. Anonymous, "Leonardo da Vinci Medal," 442.
62. Ibid., Thomas, *Enlightenment and Authority*, 193; and Supple, *British Coal Industry*.
63. Supple notes the decline in coal fired shipping tonnage from 1913 to 1929 was from 90 to 60.8% of the global total. Though he adds, "Much more serious [. . .] was the extensive attainment of continuing economies in the direct use of coal." Supple, *British Coal Industry*, 282–283.

64. Rosenband describes Nef's autobiography as "annoyingly elitist." Rosenband, "Conquest," 369.
65. The phrase Gertrude Stein used to describe the frivolous lifestyles of those who had reached adulthood at the end of World War One. Hemingway, *The Sun Also Rises*.
66. Tawney, *Acquisitive Society*, 47, 53–55; Terrill, *R.H Tawney*, 86.
67. Terrill, *R.H Tawney*, 86.
68. Nef, "Intellectual Life," 12.
69. Nef, *Rise*, xiii.
70. Nef, *Cultural Foundations*, 12–13.
71. Ibid., 12.
72. Nef, *Rise*, 60; for detail see Appendix D., 380–90.
73. He also wrote of his anticipation for the fresh air of the South of France. Nef Jr. Papers, "Life in London, 1922–1923." Subseries 1, Box 2, Folder 7.
74. Nef, *Rise*, 20. See also *Rise* Appendix B, 353–368.
75. Nef, *Rise*, Table II, 21; these figures come from the years 1684–1685, and 1697–1698. On pitmen, see *Rise*, 140; on infrastructure: Gins, 375, Wagonways, 384, Ships, 388. Nef estimated 3–4000 ships were involved in the British coal trade by the end of the seventeenth-century, 172.
76. Ibid., 220.
77. Ibid., 164; on metals see 172.
78. Ibid., 177–8.
79. Ibid., 184.
80. Ibid., 172.
81. Ibid., 184.
82. Ibid.
83. Nef, *Search*, 28.
84. Nef, *Conquest*, 170.
85. Soon to be America's first "think tank." Nef, *Search*, 102.
86. Thomas, *Enlightenment and Authority*, 106.
87. Rutherford, "Chicago Economics," 33.
88. Nef, "James Laurence Laughlin." On the later "Chicago School" see Rutherford, "Chicago Economics."
89. Nef, *Search*, 78. On Bulkley's work see Berg, "The first women."
90. Nef, *Search*, 141.
91. Nef, *Rise*, Vol. II, 333–453.
92. A debt acknowledged, Nef, *Rise* XIV.
93. McCloskey, "Useful Economics?"
94. Coornaert, "Revue," 181–182.
95. Usher, "Two Notable Contributions," 179.
96. Absence of evidence was taken as evidence of absence. Nef had only 7 records of coal shipments from Newcastle to London before 1591 which implied a dramatic increase as compared to the better documented 1590s; while litigation documents likely exaggerated capital expenditure in pursuit of remuneration. Hatcher, *History*, 257, 484–5, 560.
97. Coleman, "The Coal Industry," 344.
98. Nef wrote of "a lack of experience in methods of economising fuel," Nef, *Rise*, 192.
99. The data was scant, coming just from records made by a company of dyers in London and the Earl of Rutland's estate, ibid., Nef, *Rise*, 157–8.
100. Remediation included a 1615 Royal proclamation that had banned glassmakers from using wood and charcoal. Nef, *Rise* 161, 192, 195.
101. For a review see Hatcher, "From Abundance to Scarcity"; Hammersley, "The Crown Woods"; Thomas, "Energy Crisis"; Allen "British Industrial Revolution"; Warde, "Early Modern "Resource Crisis"."
102. Matthew Paskins notes "timber supply was never simply about trees." Paskins, "Woods for the State," 234.

103. Warde, *Ecology*, 7.
104. Malm, *Fossil*, 71.
105. Ibid., 91.
106. Deane, *First Industrial Revolution*, 112.
107. Malm, 321–2.
108. Ibid., 195.
109. See note 211 below.
110. Allen, "Timber Crisis," 473.
111. Cavert, *Smoke of London*, 21–24.
112. Ibid., 25. The Dutch tried to intercept the collier fleet in 1653.
113. Ibid., 133–44.
114. The Mons coal basin in Belgium remained under ecclesiastical ownership and its coal unexploited at this time, Ibid., 135.
115. Ibid., 268, 318.
116. Ibid., 211–8.
117. Ibid., 20. Covered in detail in Nef, *Rise,* Chapter 3, "Substitution of Coal," 190–215.
118. Ibid., 163.
119. Tawney, "British Coal Industry"; and Hannah, *Electricity Before Nationalisation*, 62–64.
120. Nef, *Rise*, 22.
121. Nef, *Rise*, Vol. II, 207; a brief allusion to the "coal and colonies" thesis proposed in Pomeranz, *Great Divergence*.
122. Nef, *Rise*, 243.
123. Mokyr, *Lever of Riches*; Ibid., 256.
124. Ibid., 254. McCapra, "The Chemistry of Bioluminescence," 247.
125. Hobsbawm considered Nef's Marxism "second-hand" and of a "Kantskyan type," which implied a moderate doctrinaire anti-Bolshevism. Hobsbawm, "A Christian Materialist," 21.
126. Nef, *Rise*, 367–68; on the Culross mine see Adamson, "A Coal Mine."
127. Ibid., 350–79.
128. Ibid., 49.
129. Edgerton, *Rise and Fall*, 109–10.
130. Malm, *Fossil Capital*, 325; Altvater, "Social and Natural"; while an even earlier iteration of such thinking can be found in Sombart, *Der Moderne Kapitalismus*.
131. Nef, *Rise*, 448.
132. Nef, *Search*, 77. Terill, *R.H Tawney*, 78.
133. On the 1664 embargo see Nef, *Rise*, 25, 284–8. Nef noted "using the coal trade as a means for raising funds without parliamentary consent, had more to do than has been realized with bringing about the Civil War," Nef, *Rise*, Vol. II, 207. On this, see Thomas, *Enlightenment and Authority*, 225.
134. Mitchell, *Carbon Democracy*, 18.
135. "Some indulgence must be allowed to enthusiasm in peroration based on such extensive and careful research." Rees, "The scope of economic history," 229.
136. Nef, *Rise*, Vol. II, 330.
137. See note 84 above.
138. Thomas lauded Nef's "energy interpretation of the Industrial Revolution"; Allen praised his attempting to "conceptualize history as a sequence of stages based on energy use"; Malanima considers Nef "the first historian to consider energy as principle cause of industrialisation'; Warde considers Nef "the starting point for all discussion" on energy and industrialisation. Thomas, "Toward an energy interpretation", 1; Allen, "Was there a timber crisis", 469; Malanima, "The Path", 2; Warde, *Ecology*, 7.
139. Nef, *Rise*, 22; Nef, "Art," 306.
140. This argument was later made explicitly in Nef, "The Rise of the Coal Industry," 72. Nef believed he had founded the World's first interdisciplinary research institute, *Search*, 102. On the Committee on Social Thought see this essay, pages 25–26. On interdisciplinarity in the energy humanities see Szeman and Boyer, *Energy Humanities*, back cover.

141. Nef, "Histoire économique."
142. Nef, *Rise*, 72. Nef, "The Rise of the Coal Industry," 68; Nef, "Histoire économique et Histoire intégrale," 7.
143. Nef, "Civilization at the Crossroads," 291.
144. Nef, "Responsibility of Economic Historians," 1.
145. Thomas, *Enlightenment and Authority*, 446.
146. Nef, "Civilization at the Crossroads," 1.
147. Nef, "The Industrial Revolution reconsidered," 29.
148. Supple, *The History of the British Coal Industry*, 283–4.
149. Nef, "Civilization at the Crossroads," 291, 299.
150. Lane, "American Anthropocene," 12.
151. Thomas, *Enlightenment and Authority*, 244; and Hammond, "Transcendental Commitments of Economists," 16.
152. Thomas, *Enlightenment and Authority*, 250.
153. Maritain's notion of "integral humanism," an expansive faith-based view of human history, influenced Nef's later call for integral history; compare Maritain "Integral Humanism" and Nef, "Histoire économique."
154. Nef, "The Industrial Revolution Reconsidered," 9, 27.
155. Nef, *Cultural Foundations of Industrial Civilisation*, 36; xi. Nef claimed his disenchantment had begun "amid the smell of old paper," where, tabulating statistics on coal, he found himself "touched by a belief that, without the heart and the imagination, the mind can easily become a dogmatic, dreary and even sterile instrument." Nef, *Search for Civilization*, ix.
156. Dzuback, "Hutchins, Adler."
157. Lacy, *Dream of a Democratic Culture*, 25–26. On Adler's view on Aquinas, see Thomas, *Enlightenment and Authority*, 117.
158. Kagey, "Metaphysics and Mr Hutchins."
159. Hutchins, *Higher Learning in America*, 98.
160. McNeill, *Hutchins' University*, 97.
161. Nef, "The University of Chicago," 412.
162. Dewey cited in Ashmore, "Robert Maynard Hutchins," 72.
163. Nef, "The University of Chicago," 419.
164. The other founders were Frank Knight and anthropologist Robert Redfield. McNeill, *Hutchins' University*, 120.
165. Nef, "Committee on Social Thought," 679.
166. Thomas, *Enlightenment and Authority*, 556–61; and Molella, "Memorials," 919.
167. Bellow was invited in 1963, Arendt sometime between 1956 and 1963. The two did not get on. Leader, *The Life of Saul*, 616–9; 703.
168. Nef, "Historical Unreality of the Cold War," 93.
169. McNeill, *Hutchins' University*, 120–121; on Hayek see Mitch, "Morality versus Money"; on Wrigley, see below.
170. Greif, *Age of the Crisis*, 41.
171. Thomas, *Enlightenment and Authority*, 576–588.
172. Mirowski and Plehwe, *Road*. For an indication of Nef's involvement, see Horn and Mirowski, "Rise of the Chicago School," 139–63.
173. The folder contains numerous invitations from society president Bruno Leoni, and secretaries George Roche and Jean-Pierre Hamilius though Nef seems to have politely turned the majority down while using the opportunity to promote his new book to fellow members. Nef, Jr. Papers, Box 78, Folder 7, Mont Pèlerin Society, 1965–1975
174. The Center was dissolved in 1968.
175. Lifset, "A New Understanding."
176. Nef, "An Early Energy Crisis," 140.
177. Ibid., 151.
178. Ibid.
179. Thomas, *Enlightenment and Authority*, 250.

180. Nef, *United States and Civilization*, 239.
181. A pairing more common in France, encouraged by the thinking of Paul Vidal de La Blache, Davis, "Ladurie," 111.
182. Guinnane, "Interview with Tony Wrigley"; and Macfarlane "Interview with Tony Wrigley."
183. Livingstone, *Geographical Tradition*, 260–304.
184. Wrigley, "Changes," 10.
185. Wrigley, *Industrial Growth*, 31.
186. Ibid., 8.
187. Wrigley, *Industrial Growth*, ix. Wrigley was a William Volker fellow, on the Volker fund see Hoplin and Robinson, *Funding Fathers*, 25–32.
188. Macfarlane, "Interview."
189. Wrigley, *Industrial Growth*, 56–8.
190. Ibid., 4. See also Wrigley, "Supply," 3.
191. Ibid., 6.
192. Wrigley, *Industrial Growth*, 6.
193. Haggett, "Local Shape of Revolution."
194. Rosental, "Novelty," 123.
195. Henry and Fleury, "Des registres paroissiaux," 144.
196. Wrigley, "Small Scale," 28.
197. Nef, *Rise*, 107.
198. Wrigley, "Family Limitation," 107.
199. Wrigley, "Small Scale," 29.
200. Wrigley, "Population Problem," 333.
201. Lam, "How the World Survived," 1232.
202. Laslett, "Numerical Study," 1–13.
203. Schofield, "Computing, Statistics, and History."
204. Wrigley and Schofield, "Nominal Record Linkage."
205. Carus and Ogilvie, "Turning Qualitative into Quantitative," 909.
206. Volunteers were named on 7 pages of the final publication's appendices, Wrigley and Schofield, *Population History of England*, 485–92.
207. Oeppen, "Appendix 15," 715–30.
208. Ronald Lee, an historical demographer from Berkeley helped develop the back-projection method, first using it to test Wrigley's Colyton data. His belief in its shortcomings left Jim Oeppen to take it further. Lee, "Reflections on inverse projection," 1–9.
209. Wrigley and Schofield, *Population History of England*, 195.
210. The first Census had been carried out in 1801 but 1871 was the first to contain all county data, making national backcasting possible from that year. Higgs, *Making Sense*.
211. Mokyr, "Three Centuries."
212. Wrigley and Schofield, *Population History of England*, 11.
213. On "epistemic opacity" see Humphreys, "Philosophical Novelty," 618.
214. Wrigley and Schofield, *Population History of England*, 211.
215. Ibid.
216. Phelps-Brown and Hopkins, "Seven Centuries."
217. Wrigley and Schofield, *Population History of England*, 465.
218. Gaunt, "Population History of England," 142.
219. As demonstrated in the model by the nodes accounting for wages and demand for primary, secondary, and tertiary goods. On the continuing relevance of Malthusian checks see Mayhew, *New Perspectives*, 4.
220. Wrigley and Schofield, *Population History of England*, 465.
221. Ibid., 478.
222. Wrigley and Schofield, *Population History of England*, 403.
223. On the reception of *Limits* in Britain see Turnbull, "Simulating the Global Environment" 285–291.
224. Wrigley and Schofield, *Population History of England*, 466.

225. Wrigley, "Supply of Raw Materials," 7.
226. Wrigley and Schofield, *Population History of England*, 466.
227. Ibid. Later expanded upon in Wrigley, "The Transition," 435–480.
228. Smith, "Periods, Structures and Regimes," 212–213.
229. Wrigley, "Small Scale," 29.
230. On Laslett's approach see Carus and Ogilvie, "Turning Qualitative into Quantitative," 896.
231. Ibid., 30; Wrigley would later term this "structure of aggregate demand"; see Wrigley, "Energy", 136.
232. De Vries, "Energy," 1386; This demographic argument makes it hard to see Wrigley as a "thermodynamic Ricardian" as Malm suggests. Malm, *Fossil Capital*, 15.
233. The Industrial revolution marked "the *transition* from an advanced organic to a mineral-based energy economy"; author's emphasis. Wrigley, *Continuity, Chance and Change*, 28.
234. Ibid., 29. A concession alluded to in the book's subtitle, "the *Character* of the Industrial Revolution," Ibid., front cover, author's emphasis
235. Wrigley, "Davidson Lecture," 14; on contested notions of transition see Turnbull, "Shock," 4.
236. Temin, "Two Views," 63; and Mokyr, "Industrial Revolution," 12.
237. Mokyr claimed "causality may have run not from resources to technology but in the opposite direction," Mokyr, *Lever of Riches*, 160.
238. Wrigley, Mokyr chastised, veered into environmental determinism. Mokyr, "Introduction: Industrial Revolution," 33.
239. "In the absence of coal, the ingenuity applied to using it would have been directed toward replacing it," Mokyr, *Lever of Riches*, 160; Such conclusions were to be expected, as the models used to demonstrate this argument were based on neoclassical economic theory, in which the price mechanism ultimately determined consumer behaviour. McCloskey, *Bourgeois Dignity*, Chapter 22; Clark and Jacks, "Coal,"
240. Albritton Jonsson, "Industrial Revolution," 683.
241. Wrigley, "Davidson Lecture," 17.
242. United Nations, *Agenda 21*, 3.
243. Stern, *Economics of Climate Change*, 432.
244. Fouquet, "Lessons from Energy History."
245. Emmanuel le Roy Ladurie believed historical climatologists could only begin to write climate history, history in which climate assumes a credible ecological-historical role in the early 2000s. Davis, "Taking the Temperature," 103.
246. Wrigley and Schofield, *Population History of England*, 396. Temperature data came from Manley, "Central England Temperatures" which contains a record of monthly mean temperature as far back as 1659.
247. "Perhaps the most important single result of the industrial revolution has been to make poverty problematic in a sense that had never previously been true." Wrigley, "Davidson Lecture," 12.
248. Supply, *British Coal Industry*, 478.
249. Edgerton, *Rise and Fall*, 425–28.
250. Wrigley, *Energy*, 2.
251. Ibid., 2. An idea also grounded in systems science. Russill, "Climate Change Tipping Points."
252. Wrigley, *Path to Sustained Growth*, 205.
253. Nawaz, "Review: The Path to Sustained Growth," 336.
254. Pomeranz, *Great Divergence*, 276; on Borgström see Sörlin, "George Borgström," 51–53.
255. Wrigley, "The Transition," 471.
256. "The clarity of Wrigley's vision of the English industrial revolution depends in part on its greatest limitation: it is highly self-contained; it takes place in England, and only in England." De Vries, "Review,"1386.
257. Wrigley, *Energy*, 55.
258. Chakrabarty, "The Planet," 1.

259. Further biographical details can be found in the exemplary Grossarth, "Am Ende Rechts," unpaginated.
260. Habermas, *Rational Society*, 25.
261. Ibid., 36.
262. Walter, "Weigerung und Eschatologie"; and Marcuse, "Industrialization and Capitalism."
263. Schmid, "Über den Gipfeln," unpaginated.
264. Grossarth, "Am Ende Rechts," unpaginated.
265. Sieferle, "Marx's Ecology," 1.
266. Seefried, "Towards the Limits"; and Gross, "Reimagining Energy and Growth"; Garavini, OPEC, 88-125.
267. Sieferle, "Marx"s Ecology," 1.
268. Benton encapsulated the contradiction when he stated Marxism involved a "denial of *naturally* imposed limits, but recognition of historically transitory *socially* imposed limits." Benton, "Marxism and Natural Limits," 58.
269. See note 265 above.
270. Interestingly Meyer-Abich's thesis on Niels Bohr was reviewed by Thomas Kuhn. Kuhn, "The turn."
271. Not least, the Starnberg Institute, see Seefried, "Ohne Atomkraft leben?"; Nelkin and Pollak, *Atom Besieged*, 90–93; Lorenz, *Protest*, 108.
272. Gross, "Reimagining Energy and Growth," 531.
273. Meyer-Abich, "Energy Issues and Policies."
274. Sieferle, *unterirdische Wald*, 1. Author's translation herein.
275. Sieferle, *unterirdische Wald*, 15.
276. In 1977 Austrian journalist Robert Jungk coined the term "Atom Staat" to describe the authoritarian politics protecting nuclear power might entail. Milder, *Greening Democracy*, 3.
277. Sieferle, *unterirdische Wald*, 14.
278. Sieferle, "Energy System," 9.
279. Reference will be made to the translated and updated version of Sieferle's original text. Sieferle, *Subterranean Forest*, viii.
280. Ibid., vii.
281. Sieferle, *unterirdische Wald*, 17.
282. Ibid., 19–20.
283. Sieferle, *Subterranean Forest*, 140.
284. Ibid., 73–74.
285. Ibid., 164.
286. Ibid., 139.
287. Sieferle, *Subterranean Forest*, 183.
288. Bünting believed coal grew underground rather than having been formed in a finite quantity over geological timescales. Ibid., 104.
289. Sieferle, *unterirdische Wald*, 43–5, 119.
290. Sieferle, *Subterranean Forest*, 104, 156; on quantification in forestry science see Lowood, "The Calculating Forester."
291. Sieferle, *Subterranean Forest*, 45.
292. Siemann, *Umweltgeschichte*, 8.
293. Radkau traces this optimistic view of capitalism back to Werner Sombart. Cioc, "Impact," 107.
294. Radkau, "Holzverknappung und Krisenbewußtein."
295. Imort, "A Sylvan People."
296. Radkau, *Wood*, 5.
297. Schenk, "Holznöte im 18. Jahrhundert?" 377.
298. Fischer-Kowalski and Weisz, "Archipelago," 8.
299. Ibid.; Luhmann, "Differentiation of Society," 30.
300. Fischer-Kowalski, "Society's Metabolism."
301. Sieferle, "Energy System," 10; and Sieferle, "Cultural Evolution," 315.

302. Sieferle, "Energy System," 10.
303. "Much speaks for the view that in functional terms cultural evolution is equivalent to organic evolution," Sieferle, *Subterranean Forest*, 5.
304. Sieferle ambiguously flirted with holocaust denial though avoided explicitly making such a claim. Delius, "Die Märtyrer-Inszenierun," unpaginated.
305. Garton Ash, "It's the Kultur, Stupid"; and Caldwell, "Germany's Newest."
306. See note 263 above.
307. Sieferle, *Lehren*, 1.
308. Sieferle, *Konservative Revolution*, 24–28.
309. Sieferle, *Finis Germania*, 35.
310. Ibid., 36.
311. Sieferle, *Finis Germania*, 62.
312. *Tumult* was founded in 1979, supposedly at Michel Foucault's suggestion. It marked the New Left's transition to French poststructuralism. Appearing sporadically over the years, in 2013 it re-appeared with the subtitle *Vierteljahresschrift für Konsensstörung* under the editorship of Franck Böckelmann and became an intellectual ally of the German New Right. Others continued in a non-aligned journal subtitled *Schriften zur Verkehrswissenschaft* in 2018.
313. Sieferle, "Deutschland, Schlaraffenland," 26.
314. Ibid., 24.
315. Sieferle, *Das Migrationsproblem*.
316. Sieferle, Krausmann, Schandl, and Winiwarter, *Ende der Fläche*.
317. Sieferle, "Die Rückkehr der Fläche," 161.
318. Smil, *Biomass Energies*, 17.
319. Klinke, *Cryptic Concrete*, 68.
320. Ratzel, *Anthropogeographie*, 377.
321. Ibid., 296.
322. Abrahamsson, "On the genealogy," 40.
323. In his excellent survey of *Lebensraum*, geographer Ian Klinke argues the concept was manifest architecturally in National Socialism's concentration camps and bunkers. Klinke, *Cryptic Concrete*, 68.
324. Abrahamsson, "On the genealogy," 37.
325. Barak, *Powering Empire*, 15.
326. Garavini, *Rise and Fall*, 25; 316–317.
327. Kelley et al., "Climate Change," 3241.
328. Selby et al., "Climate Change," 238.
329. Gleick, "Water," 332–335.
330. One such account of the Syrian case argues for climate change as "a background factor that amplifies the impact of ideology and unsustainable water and agricultural policies." Daoudy, *Origins*, 15.
331. Sieferle, *Rückblick*, 9.

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ORCID

Thomas Turnbull http://orcid.org/0000-0002-5266-4189

Archive

John Ulric Nef, Jr. Papers 1840–2008, University of Chicago Library (Nef Jr. Papers)

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