Jean-Baptiste Fressoz

MORE *AND* MORE *AND* MORE

'Gobsmacking'
ECONOMIST

An All-Consuming History

PENGUIN BOOKS

More and More and More

Winner of a *Nouvel Observateur* Award, a Fondation pour l'écologie politique Award, the Prix du jury Turgot and the Prix du Sénat 2025

Selected as an *Economist* and *Financial Times* Book of the Year

'This truly is a radically and very necessary new history of energy. A rich, unnerving, funny and utterly compelling account, it destabilizes our understanding again and again. With uncanny examples, he makes the invisible obvious, and shows how the obvious was made invisible by forms of understanding in which even climate activists operate. This remarkable material and intellectual history will change our minds about one of the most important challenges humanity currently faces, indeed it gives us a new way of thinking about the profound challenge decarbonization represents' David Edgerton, author of *The Shock of the Old*

'Fressoz provides a corrective to the lazy thinking that surrounds our current predicament' Henry Sanderson, *TLS*

'We all know the energy transition away from fossil fuels is needed to keep the climate safe. But this eye-opening book shows our understanding of past transitions is delusional. Far from moving definitively from wood to coal to oil and gas, we have continued to binge on all forms of energy. Somehow, this has to stop' *Financial Times*, Books of the Year

'An honest account of energy history would conclude not that energy transitions were a regular feature of the past, but that what we are attempting – the deliberate exit from and suppression of the energetic mainstays of our modern way of life – is without precedent. This is the argument of Fressoz . . . If we are to grasp the scale of what lies ahead, the first thing we have to do is to free ourselves from the ideology of the history of energy transition . . . Fressoz doesn't wish to dismiss the possibility of change. The point, rather, is to dereify it' Adam Tooze, *London Review of Books*

'An implacable critique of the "stagist" history of energy. Jean-Baptiste Fressoz brings to light the intertwining of energies and materials . . . in an erudite and scathing book' *Le Monde*

ABOUT THE AUTHOR

Jean-Baptiste Fressoz is a historian of science and technology, previously at Imperial College London, now based in Paris at the Centre national de la recherche scientifique. He is the author of *The Happy Apocalypse*, *The Shock of the Anthropocene* (with C. Bonneuil) and *Chaos in the Heavens: The Forgotten History of Climate Change* (with Fabien Locher).

More and More and More

An All-Consuming History

JEAN-BAPTISTE FRESSOZ

Translated by the author

PENGUIN BOOKS

To Michel and Josette, Cecilia, Leonor and Esteban

PENGUIN BOOKS

UK | USA | Canada | Ireland | Australia
India | New Zealand | South Africa

Penguin Books is part of the Penguin Random House group of companies
whose addresses can be found at global.penguinrandomhouse.com

Penguin Random House UK,
One Embassy Gardens, 8 Viaduct Gardens, London SW11 7BW

penguin.co.uk

Penguin
Random House
UK

First published in French under the title *Sans transition: Une nouvelle histoire de l'énergie*
by Éditions du Seuil 2024
This translation first published by Allen Lane 2024
Published in Penguin Books 2025
001

Typeset by Six Red Marbles UK, Thetford, Norfolk
Printed and bound in Great Britain by Clays Ltd, Elcograf S.p.A.

The authorized representative in the EEA is Penguin Random House Ireland,
Morrison Chambers, 32 Nassau Street, Dublin D02 YH68

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

ISBN: 978–1–802–06731–6

Penguin Random House is committed to a sustainable future
for our business, our readers and our planet. This book is made from
Forest Stewardship Council® certified paper.

FSC
www.fsc.org
MIX
Paper | Supporting
responsible forestry
FSC® C018179

Contents

Preface

This book was born out of an unease felt when reading general histories of energy. At a time when coal consumption has just experienced major growth on most continents, academic works, representing the state of the art on the subject, are *still* telling stories of transitions between energy systems. The main arguments in this book matured in the intellectual atmosphere created by David Edgerton at the Centre for the History of Science, Technology and Medicine at Imperial College London, where I began my career in 2011. His *The Shock of the Old* is a major book that redefines the field of the history of technology, broadening its scope and interest; a book whose lessons for the climate issue had yet to be learned. Finally, the writing of this book was made possible by the time and intellectual freedom offered by the Centre National de la Recherche Scientifique and the École des Hautes Études en Sciences Sociales in Paris, and I would like to thank all their staff.

Thanks also to the many colleagues who, in one way or another, encouraged me to pursue the argument of energy symbioses: David Edgerton, Christophe Bonneuil and Charles-François Mathis who discussed, commented on and enriched previous version of this text, and also Dominique Pestre, Sabine Barles, Simon Schaffer, Soraya Boudia, Romain Huret, Franck Aggeri, Stefan Aykut, Harry Bernas and Béatrice Cointe, together with Christophe Cassen, Amy Dahan, Michel Damian, Jawad Daheur, Giuliano Garavini, Frédéric Graber, Sebastian Grevesmühl, Elie Haddad, Ciaran Healy, François Jarrige, Jean Jouzel, Michel Lepetit, Thomas Le Roux, Fabien Locher, Sophie Lhuillier, Valérie Masson-Delmotte, Antoine Missemer, Raphaël Morera, William Oman, Thomas Piketty, Antonin Pottier, Daniela Russ, Vincent Spenlehauer, Alessandro Stanziani, Thomas Turnbull, Adam Tooze and Paul Warde. Many thanks to

the editorial teams and anonymous reviewers of *Annales des Mines*, *Revue d'histoire moderne et contemporaine*, *Revue d'histoire du XIXe siècle*, *Histoire et mesure* and *Terrestres*: their feedback helped me to clarify the argument of this book. Thanks also to the team at Penguin, particularly Simon Winder, and to my copy editor Charlotte Ridings.

In recent years, I had the pleasure to teach energy history to students in Paris at the École des Ponts et Chaussées and the École des Hautes Études en Sciences Sociales. Special thanks to those who worked under my supervision on related subjects: Nelo Magalhães, Gaëtan Levillain, Sam Allier and Jules Calage.

Finally, I had a lot of interesting discussions with some of the people involved in the story I'm telling. In particular, I would like to thank Nebojsa Nakicenovic, Cesare Marchetti's assistant in the 1970s, who played an important role at the International Institute for Applied Systems Analysis (IIASA) and within Group III of the Intergovernmental Panel on Climate Change (IPCC), Jean-Charles Hourcade, with whom I had many discussions on the last chapter of this book, and Youba Sokona, the current vice-president of the IPCC, who encouraged me to explore the disturbing history of its third group.

I have presented the arguments of this book on numerous occasions and in a variety of settings, not only academic and scientific, but also associative, governmental and international. Each time I have been struck by the interest aroused by a discussion based on figures, without taboos or positions of principle. On all these occasions, I have never received any serious objection to the thesis of energy symbioses, which seems original only in the light of a very strange standard historiography. The point of this book is not to say that the transition between energy systems is impossible because it did not happen in the past. The point is rather to take a fresh look at history in order to identify the factors that lead to energy accumulation – symbiotic processes that are still with us and that are not about to disappear.

Introduction: A Symbiotic History of Energy

> It is possible that effects [of global warming] become significant before the middle of the next century. This time scale is similar to that required to redirect, if necessary, the operation of the world economy, including agriculture and the production of energy.
>
> (World Meteorological Organization, Declaration of the First World Climate Conference, Geneva, 1979, p. 2.)

This book tells a new story of energy, one that makes it possible to understand the radical oddity of the notion of *energy transition*. Instead of presenting the succession of energy systems over time, it explains why all primary energies have grown together and why they have accumulated *without* replacing each other. Instead of considering energies as separate entities in competition with each other, it reveals the history of their entanglement and interdependence. The stakes could not be higher, as these symbiotic relationships explain the permanence of primary energies right up to the present day and constitute major obstacles on the road to decarbonization.

This book also offers the first history of the 'energy transition', not as a historical and material phenomenon but as a futurology, a technological project and a way of understanding the dynamics of change. It explains why stage-theory reasoning has been applied to a field – energy and the material world – that did not lend itself to it at all. It recounts the strange trajectory of the energy transition, a heterodox and mercantile futurology – a mere industrial slogan – which, from the 1970s onwards, became the future of experts,

governments and companies, including those that had no interest whatsoever in seeing it happen.

This book is certainly not a critique of renewable energies. It does, however, explain why the concept of energy transition is preventing us from thinking properly about climate change. For half a century now, this notion has produced more scientific confusion and political procrastination than anything else. Transition projects a past that does not exist onto an elusive future. To have any chance of forging a climate policy that is even remotely rigorous, it is essential to have a completely new understanding of the dynamics of energy and materials. That is the aim of this book.

In search of transitions

The notion of energy transition makes a radically strange future seem natural. Yet it is from history, a false history, that it draws its persuasive force and its appearance of plausibility. As if echoing the transitions of the past – from wood to coal, then from coal to oil – we should now, in the face of global warming, be making a third transition to nuclear power and/or renewable energies. The climate crisis demands that we continue the history of capitalism and innovation, even accelerate it, to hasten the advent of a carbon-free economy. Thanks to the transition theory, climate change calls for a change of technology, not a change of civilization. The history of energy, its chronological routines, its stagist narratives of the past – the age of wood, the age of coal, the age of oil, the organic economy and the mineral economy, the first and second industrial revolutions – has played a discreet but central ideological role in the creation of this comforting future.[1]

Let us start by stating the obvious. After two centuries of 'energy transitions', humanity has never burned so much oil and gas, so much coal and so much wood. Today, around 2 billion cubic metres of wood are felled each year to be burned, three times more than a century ago.[2] Wood currently provides twice as much energy as

nuclear fission, twice as much as hydroelectricity, and twice as much as solar and wind power combined (2019 figures).[3] Wood remains an essential source of heat for the poorest third of the world's population – 2.3 billion people – who are also the first victims of pollution. But rich countries have also seen their consumption of wood energy increase: the United States burns twice as much as it did in 1960, and Europe three times as much as it did at the beginning of the twentieth century.[4] However, historians have been most interested in wood when it seems to disappear: its alleged ousting from the English energy mix in the nineteenth century has been the cause of more spilled ink than its rise throughout the world since 1950.

The same bias applies to coal: historians have mainly written about the situation in Europe in the nineteenth century, even though this is neither the main place nor moment in coal's history. The overwhelming majority (95 per cent) of coal was mined after 1900, and most of it was mined outside Europe (86 per cent).[5] Medium-sized Asian powers such as Australia and Indonesia currently extract twice as much coal as the giants of the 1900s such as Britain and the United States. In many ways, coal is a new energy. The strongest growth in its history occurred between 1980 and 2010 (+300 per cent), leading to an increase in its share of the global energy mix, to the detriment of oil. It was also in the 2010s that the number of miners reached its peak.[6] Lastly, coal-fired power stations are on average younger (around fifteen years old) than atomic power stations (thirty-two years), and are often much more efficient.[7] Coal was the great energy of the 2000s: it fuelled the internet revolution, which is basically just another electron network, just as much as the industrial revolution.

While China plays a central role – each year it burns fifteen times more coal than England at its peak and more than France throughout its history – this country is exceptional only in terms of its size. Since 1980, coal consumption has increased tenfold in China, but it has multiplied by 12 in Taiwan, by 11 in Vietnam, by 10 in the Philippines, by 8 in India, by 7 in Turkey, by 6 in South Korea and by 50 in

Indonesia. India, South Africa and Poland all have electricity mixes that are more coal-intensive than China's. And coal is not just the energy of development. Between 1980 and 2010, coal consumption doubled in the United States, Japan and the Gulf States, before falling back, mainly because of the rise of natural gas. Bush's America consumed four times as much coal as Roosevelt's.

That leaves us with Europe. The first to enter the 'coal age', Europe is also, we are told, the first to escape from it. This European exception, like so many others, needs to be put into perspective. The decline in coal use that began in the 1960s looks like a long, slow and cautious retreat. In 2020, Europe still consumes 400 million tonnes of coal a year, and the continent's major industrial power, Germany, remains one of the world's leading producers of lignite, the most polluting of fuels. Angela Merkel's Germany consumed three times as much coal per year as Bismarck's Germany. What is less well known is that Europe is also a world leader in manufacturing mining equipment, and it is partly thanks to European machines that world coal production soared in the twenty-first century.[8] Last but not least, the European Union, like all rich countries, engages in large amounts of foreign trade, and more than a quarter of the manufactured goods it imports are based on coal energy. However 'green' their energy systems may be or become, the rich countries, for the simple reason that they are rich, are resolutely on the side of the big coal consumers.

If we take into account the coal incorporated into imports, the UK would consume around 50 million tonnes – instead of the 9 million officially burned.[9] One study even puts that figure at 90 million tonnes – almost as much as on the eve of Margaret Thatcher's assault on the country's mines. Similarly, France consumes not 6 million tonnes of coal a year but rather 70 million, a quantity close to its peak extraction in the 1960s.[10] Whatever the accuracy of these figures, the important point is that in a globalized world, the decarbonization of a national economy is a difficult phenomenon to measure and that the 'transition' of the rich countries of Western Europe away from coal is, in part, a statistical artefact linked to a convenient

convention: the attribution of CO_2 emissions to the countries producing the goods and not to the consumers.

Other imputation criteria would produce different results.[11] Let's take the case of Switzerland. This prosperous country has never been a major coal consumer, and its last mines closed in 1945. But it should be noted that its prosperity is partly due to the fact that Switzerland is part of a global economy that still consumes a lot of coal. For too-well-known reasons, international mining companies such as Glencore have their headquarters in Switzerland. They control the extraction of at least half a billion tonnes of coal per year. What's more, 40 per cent of the international coal trade is conducted in Switzerland, with Trafigura being a key player in this field. In total, at least a billion tonnes of coal contribute directly to the prosperity of the Swiss Confederation, which is quite a lot for a country of 8 million inhabitants.[12] Other similar examples include Luxembourg, home to ArcelorMittal, the world's leading steel company, or Norway, with its luxury electric cars bought with oil revenues.

The epic of energy transitions

Despite its fundamental dynamic of accumulation, the history of energy is generally told as a series of transitions or shifts in energy systems, on the scale of nations, continents or even the world as a whole. In what has become a genre in itself – the epic of energy transitions – we generally find the same chronological structure: initial chapters deal with muscle power, wood and water power in the pre-industrial era; central chapters deal with coal and steam in the nineteenth century; this is followed by chapters on oil, electricity and nuclear power (gas is often less studied); and finally, concluding remarks on the transition to 'green' energy in progress or to come. As each era is defined by the new – a bias common to the history of technology, rightly highlighted by the historian David Edgerton – massive phenomena are erased, such as the rise of renewables in the

nineteenth century, biomass and muscle power in the twentieth century, and the recent rise of coal.[13] 'King coal reigned for about seventy-five years, before ceding the throne to oil in about 1965' wrote a leading figure in American environmental history recently.[14] The transitionist model is so deeply rooted that even a book of reference such as *Power to the People* contains some questionable assertions. For example, oil and electricity are presented as two 'energy transitions', whereas electricity increases coal consumption and oil does not necessarily reduce it.[15] The case of Vaclav Smil is also revealing. A leading expert on energy issues, he is currently one of the most influential voices warning of the enormity of the challenge represented by a global transition away from fossil fuels in thirty years' time. But his scepticism about the current transition does not prevent him from reiterating in his historical epics on energy the classic narrative of a modernity made up of transitions.[16]

Of course, there are other ways of telling the story of energy. Professional historians generally prefer to focus on a particular energy source. There is a wealth of literature on coal and oil, and other works on wood, hydroelectricity and, more recently, wind and solar power. The problem with these approaches is that they are 'mono-energetic'. They study one form of energy separately from others and from materials in general. However, we cannot understand much about the history of coal without studying the history of the wood used to extract it. Similarly, the rise of oil in the twentieth century is inexplicable without concrete, steel and, by extension, coal. This book aims to show the importance of a host of objects and techniques – mine props, railway sleepers, oil pipes, creosote, plywood panels, concrete mixers, dump trucks, cardboard boxes, wooden pallets, etc. – that are absent from standard accounts and yet are key to understanding the material history of energy.[17]

Since the 2010s, a number of historians have sought to renew the genre by challenging the primacy of economics, relative costs and resource availability in favour of the political determinants of 'energy transitions'. In *Fossil Capital*, for example, Andreas Malm explains the spread of the steam engine in England in the 1830s as a

result of capitalists' desire to escape the locational constraints imposed by water power. Steam enabled them to move production to the cities to better exploit the abundant labour force that resided there.[18] In his famous book *Carbon Democracy* – to which we will return in Chapter 6 – Timothy Mitchell also offers a political account of the switch from coal to oil: the fluidity of oil is said to have enabled capitalists to circumvent the power and demands of European miners at the end of the nineteenth century.[19]

While the desire to inject politics into the somewhat smooth narratives of the economic history of energy is laudable, it should be stressed that these authors are repeating the standard transitionist story, and even exacerbating it by applying chronological periodization derived from the history of politics to the history of energy. As far as Malm's thesis is concerned, historians have shown that the steam engine of the 1830s was more a symbol than a trigger for 'fossil capital'. In nineteenth-century Britain, coal was burned primarily to produce domestic and industrial heat, and secondarily for steam and mechanical power. From the seventeenth century onwards, the demand for heating had led to a gradual increase in the price of firewood and a corresponding increase in coal mining. It should be added that steam did not replace hydraulic power. In fact, the use of water power in the British textile industry remained stable during the nineteenth century. Steam engines were used especially where rivers were overcrowded with watermills, like in Manchester.[20] Industrialists who were able to do so used both a water turbine *and* a steam engine. In France, for which precise administrative statistics are available, in 1860 half the companies using steam had another engine too, usually hydraulic, and steam engines were often used to pump water into the reservoirs when rivers were running low.[21] As for the hypothesis that capitalists had a particular appetite for urban crowds, it seems contradictory to the many projects to relocate industry to the countryside, synonymous with relative social calm. In the United States, in Massachusetts, textile capitalists had no difficulty in prospering thanks to hydraulic power, by completely transforming the River Merrimack.[22]

Timothy Mitchell's book comes up against the same stumbling block: oil does not bypass miners because, simply, it does not replace coal. Oil is used primarily to power cars, which in turn require a lot of coal to manufacture. Moreover, in the twentieth century, electricity gave coal a new economic centrality; the number of miners declined not because of oil but because of productivity gains in the mines. The attraction of the 'political' history of energy, which is also its flaw, is that it tends to present climate change as a capitalist conspiracy. This apparently radical but ultimately reassuring story underestimates the immensity of the climate challenge. Getting out of carbon will be far more difficult than getting out of capitalism, a condition that is probably necessary but certainly not sufficient.

A major criticism of transition epics has come from historians with a thorough knowledge of nineteenth-century modes of production, and consequently less impressed by coal and steam than their energy-specialist colleagues. They showed the importance for industrialization of energies that are wrongly regarded as traditional: whether human muscle, water power in factories, wood in the iron and steel industry, animals in transport, agricultural work or as industrial mechanical power.[23] But as a critique of transition, this history of technological persistence remains middle of the road.[24] The idea that traditional energies would 'resist' in the face of fossil fuels still takes the transitionist narrative too seriously. To understand the history of energy, we need to get rid of both Schumpeterian Darwinism – the too-simple idea of 'creative destruction' – and the dialectic of winners and losers. In the nineteenth and twentieth centuries, renewable energies did not put up barriers to fossil fuels, but progressed and developed thanks to them. As we shall see, coal and oil greatly increased the production of wood and its availability for energy purposes. Renewables improved thanks to steel and cement, two materials that are closely dependent on coal, enabling them to capture diffuse energies much more efficiently. In France, the steel turbines of the 1900s produced three times as much energy as the wooden mills of the 1800s, at a much lower cost, even before the rise of the large hydroelectric dams that were obviously dependent on oil

Wind turbines at the Chicago World's Fair in 1893. By the end of the nineteenth century, at least a million windmills were pumping water in the Great Plains of the Midwest. The development of wind turbines is inextricably linked to that of fossil fuels. Wind turbines have benefited from advances in metallurgy, sheet metal stamping, ball bearings, steel tube production and cement. Their lubrication system was inspired by that of car casings, and, between the wars, the blades took on their modern shape thanks to advances in aviation. Conversely, in the arid regions of Texas, wind turbines were used to supply water to locomotives burning coal.[25]

and coal for their construction.[26] Similarly, oil and gas have made it possible to increase agricultural production and hence the availability of human energy. For these and many other reasons, the story we tell in this book is not one of resistance, or even of additions, but of the entanglement and symbiotic expansion of all energies.[27]

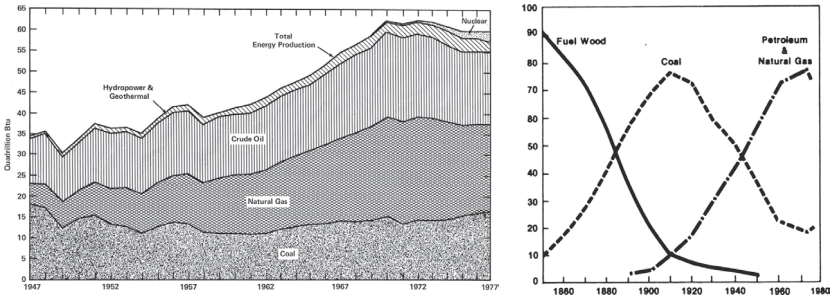
When every tonne counts

There is no reason why historians should choose transition as the main motif of their accounts. Energy sources are as much symbiotic as they are in competition, and their symbiotic relationships explain

why, over the course of the nineteenth and twentieth centuries, primary energy sources tended to add up rather than substitute each other. This observation leads to an obvious question: how is it that the idea of transition has become so widely accepted? Why did this future without a past became the future of governments and experts from the 1970s onwards? And how has it rubbed off on historians' accounts of the past? The last four chapters of this book will provide detailed answers to these questions. Let us simply mention for the moment that if the concept of transition poorly describes past transformations, it is because that was not its purpose: the idea comes not from an empirical observation of the past, but from anticipation of the future; it comes not from historians, but from futurologists. The history of energy was born out of futurology: it was to estimate future consumption that the first works on the quantitative history of energy were carried out. It is also in order to anticipate changes in the energy mix that certain experts, proponents of the atom, have considered energy dynamics not in absolute but in relative terms. From this matrix, historians have inherited certain ways of thinking about and representing energy. They have chosen to focus their analyses not on absolute values but on changes in relative shares, and they have adopted, without too much reflection, the lexicon of certain futurologists of the 1970s: expressions such as 'energy system' and 'energy transition'.

More often than not, historians have been content to characterize the transition in qualitative terms, as the shift from one 'technical system', to another, with all the economic, social, political and cultural consequences that this would entail. When we see the flagrant errors in the history of energy made by the French historian Bertrand Gille, who introduced the notion of *système technique*, we understand that this latter notion must be handled with care.[28] Its main problem is that by focusing on the 'coherences' linking techniques, materials and energies in each period, 'technical systems' have fostered a discontinuous vision of the history of energy, based on the dynamics of technological substitution.

The divergence between history in relative terms and history in



Two ways of representing the US energy mix: in absolute terms on the left, and in relative terms on the right. This second method appeared in the mid-1970s, first in the energy forecasting field and then in the US administration after the 1973 oil crisis. It was also at this time that a new body of expertise focused on transition was born. (Energy Information Administration, 'Annual Report to Congress', 1978, p. 2 and Executive Office of the President, *National Energy Plan, 1977* (Cambridge, MA, 1978).)

absolute terms is not just a matter of academic debate on the interpretation of modernity. It is also about the politics of history in the face of climate change. Since the 2000s, some experts have been searching for clues and fragments of answers in the history of energy to address the most pressing contemporary questions: how long could the transition take? How can we speed up the process? What is the role of the market? of the state? of innovation? Historians have willingly lent themselves to this game, and we have seen colleagues who specialize in the Industrial Revolution offering advice on transition, even though they have only ever studied energy additions.[29]

History – although not historians – also occupies a prominent place in an academic field that emerged in the 2000s: *transition studies*. The founding article, written by the sociologist Frank Geels, studied the spread of steam navigation in the nineteenth century in order to infer a theory of transition supposedly useful for decision-makers.[30] This article, which recycled Schumpeterian studies of innovation, was surprisingly successful. Currently, another author, Benjamin Sovacool, is working to spread a reassuring discourse: the

long-awaited energy transition could happen much faster than those of the past, with 'evidence' such as the rapid deployment of a handful of technologies ranging from air conditioning in the United States to butane stoves in Indonesia, to natural gas in the Netherlands.[31] As with steam navigation, it is difficult to discern the link between the success of a few polluting technologies and the current challenge of decarbonization. The sleight of hand of transition studies is to equate transition with the diffusion of innovation and to reformulate the quantitative studies of innovation, common since the 1970s, in the lexicon of sociological theories. This prolific literature is fuelled by the ambiguity of the word 'transition' (technological? energetic? relative? absolute? deep? shallow?) and by endless discussions between approaches ('multi-level perspective', 'socio-technical transitions', 'large technical systems', 'social construction of technology', 'actor-network theory') that are theoretically different but really very close.[32] But this doesn't matter; because of their optimistic and constructive tone, well-funded by the European authorities and in vogue in business schools, transition studies have acquired a scientific weight out of all proportion to their empirical contribution. In its March 2022 report, Group III of the IPCC drew on this literature to make the strange assertion that 'energy transitions can occur faster than in the past', and that 'a low-carbon energy transition needs to occur faster than previous transitions'.[33] What is most worrying here is not so much the extent of the influence of transition studies as the fact that a stagist and false history of energy can thus pass all the validation procedures put in place by the IPCC.[34]

Faced with the climate crisis, we can no longer be satisfied with a history written in relative terms. A 'transition' towards renewables that would see fossil fuels diminish in relative terms but stagnate in terms of tonnes would solve nothing. We can no longer be satisfied with the vagueness of transition and its innumerable epithets, nor with the misleading analogies between the pseudo-transitions of the past and the one we need to make today. The climate imperative does not call for a new energy transition, but it does require us to

voluntarily carry out an enormous energy amputation: to get rid, in four decades, of the proportion of the world's energy – more than three-quarters – derived from fossil fuels. To think that we can draw some useful analogies from history dramatically underestimates the novelty and scale of the climate challenge.

The history of energy recounted in this book is different from accounts that have gone before, in that it is concerned with absolute values rather than relative dynamics; it deals less with the replacement of engines and more with the persistence of materials; it does not separate the production of energy from that of materials; it does not recount the epic struggles between energy systems but rather the alliances and mutually supportive relationships that exist between them. We will see how energy sources are in a symbiotic relationship as much as a competitive one, and how these symbiotic relationships explain why, over the course of the nineteenth and twentieth centuries, primary energies have tended to add to rather than substitute each other. The 'transitionless' history that this book proposes does not mean that nothing changes – quite the contrary – but that change is better understood when we leave behind the stagist narratives of the material world.

As we have said, the history of energy is often called upon to 'illuminate' the present. The approach of this book is exactly the opposite: it is the contemporary challenges of transition that throw a harsh light on the gaping holes in our historical understanding of energy. The slowness, even the stagnation, of the much-desired transition necessarily renders the 'great transitions' of the past suspect. The material and energy imbroglios revealed by industrial ecology and life-cycle analyses point to fundamental entanglements that historians, overly concerned with periodization, systems, dynamics and modernity, have left in deep obscurity.

1.

A History of Energy by Candlelight

In 2018, the Nobel Prize in Economics was awarded to two Americans, William Nordhaus and Paul Romer, for their work on climate and innovation respectively. The message of economics to the rest of the world was unambiguous: it is through innovation, through the 'creative destruction' so dear to Joseph Schumpeter, that we can effectively combat global warming. At the awards ceremony, Paul Romer chose to illustrate this thesis with an edifying story about light. He referred to an article written twenty years earlier by 'his friend Bill' (Nordhaus), notable for measuring the collapse in the price of light from Roman oil lamps to contemporary light bulbs.[1] The fight against global warming, Romer explained, had to be part of this story of innovation, growing efficiency and increased well-being. From this vision of technological progress, economists drew an almost unique recommendation: the carbon tax, designed to put companies on the right track of 'green innovation'.[2] In addition to the tax stick, there is the carrot of subsidies to help companies break free from their 'path dependency', a path that would lead them down the fossil fuel-dead end. Instead of moping around, Romer concluded, all we need to do is point 'our innovative efforts in a slightly different direction'. And that '[decarbonizing the economy] will be so easy that looking back it will seem painless'.[3]

This rather surprising understatement is based on a widespread error that tends to confuse technology with innovation.[4] Since climate change is caused by second nature as a whole, by all the techniques and infrastructures accumulated in the world over the last two centuries, acting on the technological frontier, 'slightly modifying' the direction of corporate R&D as Romer suggests, will obviously

change the quantity of CO2 emissions only marginally and in the distant future. Innovation is preventing us from having an adult conversation about climate change. Even though it is constantly invoked in relation to climate, innovation is, in reality, simply a way out, a procrastination tactic. Instead of wandering around dreaming about hydrogen-powered aircraft, nuclear fusion or the third industrial revolution, we should be basing climate policy on existing, available and cheap technologies, on the relevance of their use and on the fair and efficient distribution of CO2 emissions.

Romer's understatement reflects a strange intellectual phenomenon: the extraordinary success of the simplistic idea of 'creative destruction'. It is striking to see the extent to which this shortcut has been taken seriously by countless experts and economists, including experts on 'energy transition'. Not only is this idea generally false from the point of view of the history of technology – the new does not make the old disappear – but as far as climate change and the environment are concerned, it is entirely and totally refuted by the history of materials. In fact, it was refuted even before Schumpeter formulated it.

As an American forester remarked in 1928, whatever the technological innovations – and he was thinking of cement-and-steel skyscrapers – 'raw materials are never obsolete'.[5] Work in ecological economics has confirmed this remarkable conjecture.[6] Any serious discussion of climate change should start from the somewhat worrying observation that technological innovations have never, right up to the present day, caused any flow of material consumption to disappear. Over the course of the twentieth century, the world's range of raw materials expanded, and each was consumed in increasing quantities.[7] Of the major raw materials, only the use of sheep's wool has fallen, because of the diffusion of synthetic fibres, which is not good news for the environment. The total weight of materials used by the economy has increased twelvefold, and after the year 2000 there was a further acceleration, far greater than the famous 'great acceleration' of the 1950s.[8] For the time being, therefore, substitution processes have always been trumped

by the expansion of markets, by rebound effects and by the reorientation of raw materials to other uses.

This chapter takes the supposedly illuminating example chosen by Romer to understand the climatic failure of technological futurism. Even in a field – artificial light – where progress and efficiency gains have been spectacular, in a field that has been turned upside down by a real technological revolution – namely electricity – 'creative destruction' has ultimately destroyed nothing in terms of material consumption. Quite the contrary.

Modern candles

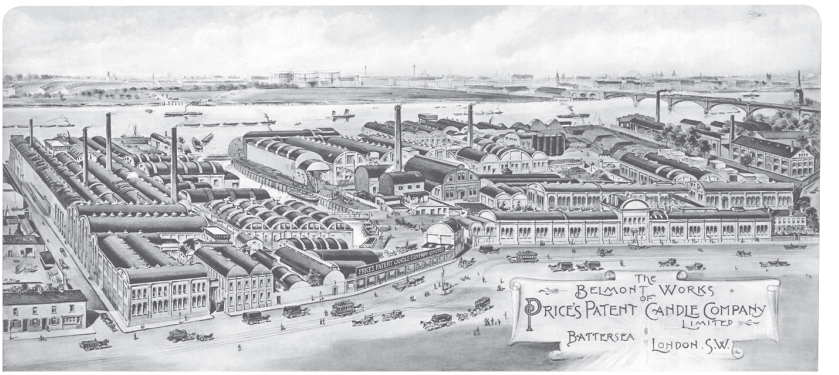
The material history of light is different from the history of lighting technologies and has nothing to do with the edifying history proposed by the new Schumpeters of the climate. In the picture painted by Nordhaus of the benefits of economic freedom guiding inventors, it is gas that is bizarrely presented as the essential breakthrough between 1820 and 1850, even though very few people were using it at the time.[9] 'There were virtually no new devices and scant improvements', writes Nordhaus, 'from the Babylonian age until the development of town gas in the late eighteenth century.'[10] Presenting gas as progress poses another problem. The process consisted of distilling coal in cast-iron vessels heated with coal. The gas obtained was stored in a gasometer before being distributed through a network of lead pipes. At the outlet of the gas burner, a mixture escaped that was mainly composed of hydrogen, which had little lighting power. Between the losses in heating the retorts and the leaks in the network, the efficiency of the process was disastrous.

In 1819, a chemist wisely pointed out that if the oil lamp had been invented after gas, everyone would have admired this simpler, less capital-intensive, less dangerous and more efficient innovation, which also used a renewable resource – seed oils. Until the end of the nineteenth century, history did not prove him wrong: the real advances in lighting in the 1800s were not in gas, but in lamps and candles. These

techniques were just as 'modern' as gas and, in many respects, superior to it – their efficiency, as we shall see, was much higher. The stearic candle, which was invented *after* gas, is the result of advances in organic chemistry and the extraction of stearin, a fatty acid that remains solid at 60°C. Stearic candles are nothing like the tallow candles of the eighteenth century: they don't drip, smoke or smell.[11] From the 1830s onwards, candle factories sprang up all over the world, first in the major cities of Europe, then worldwide by the end of the nineteenth century.[12] From fuel to wick, the candle was a veritable cornucopia of innovations. Candle production, taking place both in small workshops and in gigantic factories, was mechanized with machines using compressed air to remove candles from their moulds.[13] The main economic interest of the candle industry is that it converted just about any organic fat – slaughterhouse waste, cooking residues, etc. – into a product with high added value.

Much more than gas, the candle was a global technology. Palm oil from West Africa was particularly sought after by candle manufacturers for its richness in stearin. Both French and British imports quadrupled between 1850 and 1900, with around half going to candle factories.[14] Great Britain, world leader in coal-gas consumption, also consumed a lot of palm oil – four times as much as France: gas and candles were clearly not mutually exclusive. To capture the greasy windfall from Africa, candle factories moved to the ports: the two leading candle companies of the nineteenth century – Price's Patent Candle Company in Liverpool and Fournier in Marseilles – exported candles to the four corners of the world. Great innovations were born from the candle: it was in a chemical laboratory working for the pioneering Parisian company L'Étoile that the Italian chemist Ascanio Sobrero synthesized nitroglycerine for the first time – he was looking for a use for glycerine, a residue from the extraction of stearin. Alfred Nobel, who was apprenticed to Sobrero at the time, benefited immensely from his colleague's discovery.[15]

Without going into too much detail, the oil lamp was also completely reinvented from the end of the eighteenth century onwards. Hollow cylindrical wicks and glass tubes increased the flow of oxygen



Candles are just as 'industrial' as gas and because they were much easier to transport than gas their production was far more concentrated. In France in the 1870s, there were around a hundred candle factories, including three very large ones, and almost five hundred gas factories. In England, Price's Patent Candle Company, based in London and Liverpool, dominated the market. It reached its peak at the beginning of the twentieth century: its Battersea site in London covered 5 hectares, employed 2,300 workers and produced 160,000 tonnes of candles a year using palm oil and petroleum wax.

and made the flame much brighter. The first people to see these new lamps were amazed.[16] The fuel – mainly rapeseed oil, with petroleum making its appearance in the 1860s – was purified more effectively using powerful acids. The regular feeding of the wick was improved by numerous inventions in the field of mechanics and sealing. A visitor to the 1834 Paris Industrial Exhibition noted that 'lamp-making has now become as difficult a science as algebra'.[17]

The materials behind the techniques

It's easy to see why gas didn't replace lamps or candles in the nineteenth century, but rather supplemented them in a modest way, its use concentrated in cities, and by the bourgeoisie, factories, theatres and shops. The transition from organic to mineral sources of lighting did not really start until the very end of the 1800s, with kerosene

lamps and candles made from petroleum paraffin. But the important point is that this 'transition' in no way prevented increased consumption of the original materials concerned. After petroleum replaced organic oils, consumption of palm oil, rapeseed oil and even whale oil continued to rise. Between the two world wars, global palm-oil exports increased fivefold (from 100,000 to 500,000 tonnes) for lubricants, soaps, food and pharmaceuticals. At the end of the twentieth century, with the rise of 'biofuels', the energy use of vegetable fats increased tremendously. Nowadays, French cars alone burn between 300,000 and 500,000 tonnes of palm oil a year, about as much as the world consumed in the 1930s. French motorists also burn between 2 and 2.5 million tonnes of rapeseed oil, at least ten times more than all French candles and lamps in the mid-nineteenth century.[18] Similarly, once electricity had blown out the flame of gas burners, coal

Grand ball given by the whales in honour of the discovery of oil in Pennsylvania. (*Vanity Fair*, 20 April 1861.)

gas found many other uses for domestic heating and cooking, and coal has never been distilled as much as it is today, to produce coke for the steel industry, methanol and many other chemical products.

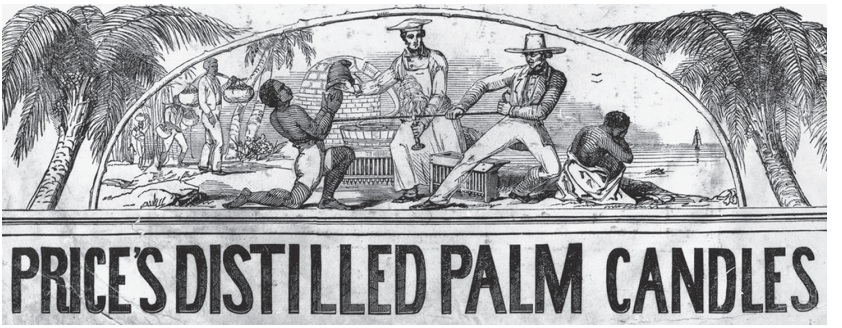
Then there is the case of whale oil, rightly famous as one of the rare historical examples of the disappearance of an energy source. But it is important to understand the significance of this exception. In his article, William Nordhaus does not hesitate to repeat an old cliché, dear to the hearts of American oilmen: oil saved the whales. Nordhaus even adds that the good fortune of these cetaceans was that, in the days of Edwin Drake and John D. Rockefeller, there were no environmentalists or impact studies to prevent the rise of the oil industry. There's no point in dwelling on this absurd argument, which has long since been refuted.[19] Let's just note that even before petroleum wax was introduced, there were several less expensive and far more abundant light fuels available than whale oil. Oil did not save the whales because innovations such as the stearic candle had already made spermaceti obsolete for lighting.[20] In England, according to the work of Roger Fouquet and Peter Pearson, at the beginning of the nineteenth century whale oil represented only 5 to 10 per cent of the light produced by candles.[21] In France, it was even less. At its peak, in the mid-1800s, six to eight ships brought back less than 2,000 tonnes of oil a year. Imports from the United States peaked in the 1840s at 5,000 tonnes, and then fell back below 1,000 tonnes for the rest of the century.[22] If whaling had been prohibited in 1850, an alternative would have been to increase rapeseed production by a few per cent, or to import slightly more palm oil.

In addition, the peak of the whaling industry was reached in 1960, a century after the advent of oil. In the twentieth century, during the so-called 'age of oil', three times as many sperm whales were killed (760,000) as in the nineteenth century (around 250,000).[23] Oil played a key role in this carnage: more powerful and more reliable boats powered with diesel engines chased whales to the furthest reaches of the southern hemisphere. Whale oil was no longer used as a source of light, but for many other purposes: margarine, pharmaceuticals, paint and explosives. Actually, petroleum *increased* the

demand for whale oil: top-of-the-range lubricants for gearboxes and machine tools used to contain between 5 and 20 per cent whale oil. Until the mid-1970s, aircraft turbojet engines were lubricated at least in part with whale oil. In 1970, with the prospect of the end of whaling, companies began to stock up, and it was then that spermaceti oil reached the highest price in its history. If anyone wants to credit a substance with 'saving the whales', it is the jojoba, a tree native to Mexico whose fruit produces an oil very similar to spermaceti.[24] And this transition took place only because it was imposed on the industry by the ban on whaling that non-governmental organizations fought so hard to obtain. Contrary to what Nordhaus writes, it was environmentalists who saved the whales, at least those few that had survived the carnage of the twentieth century.

The labour behind the materials

The history of light illuminates a second important point for this book: the blurred nature of energies. The names we give them – 'oil', 'petroleum', 'gas' – are linguistic conveniences that obscure material processes that are much broader, more intertwined and more composite than we think. Stearic candle production, for example, involved an enormous amount of human labour, mainly due to the extraction of palm oil. Depending on its quality, it took between 130 and 630 working days to produce one tonne of oil. With all the limitations inherent in this kind of calculation, it can be assumed that 1 calorie of human energy produced just 3 calories of palm oil.[25] The candle economy was based on very low labour costs and often on slave labour. It is no coincidence that African palm-oil exports began to rise after the abolition of the slave trade: European merchants, deprived of the triangular trade, saw in this commodity a new way of making the most of the labour force available in West Africa. The abolition of the slave trade did not mean the end of slavery, but rather its expansion in Africa itself. In the middle of the nineteenth century, a palm-oil merchant from Marseilles admitted that the stearic



Advertisement for Price's Patent Candle Company. The candle burns the rope of servitude. By offering a legal trade to African sovereigns, the stearic candle may have helped to dry up the sources of the slave trade, but palm oil was largely produced by slave labour. Price's Patent Candle Company directly employed 2,300 workers in Britain but the palm oil it used required tens of thousands of men and women in West Africa.

candle had certainly helped to dry up the slave trade, but only because the West African kings had an interest in keeping slaves on site to harvest and extract the oil.[26]

The European lights of the nineteenth century were therefore based partly on slavery in Africa, but also on many other workers, other materials and other sources of energy: on the toil of the peasants who grew rapeseed and poppy, on the mills that crushed oilseeds, on the millions of hectares of grassland in Europe and America used to fatten cattle.[27]

The emergence of fossil fuels adds a new level of complexity but does nothing to change the interweaving of materials and energies that lights up the world. Indeed, gas lighting was produced from coal extracted from mines, which in turn were significant consumers of lighting oil. In the 1860s, a miner extracted an average of 200 tonnes of coal a year with the help of 60 kilos of oil or candles. The gas itself therefore depended on a large quantity of organic light. The cost of lighting was considerable: less than the cost of labour and pit-props but more than capital remuneration.[28] Similarly, the petroleum that made European lamps shine at the end of the