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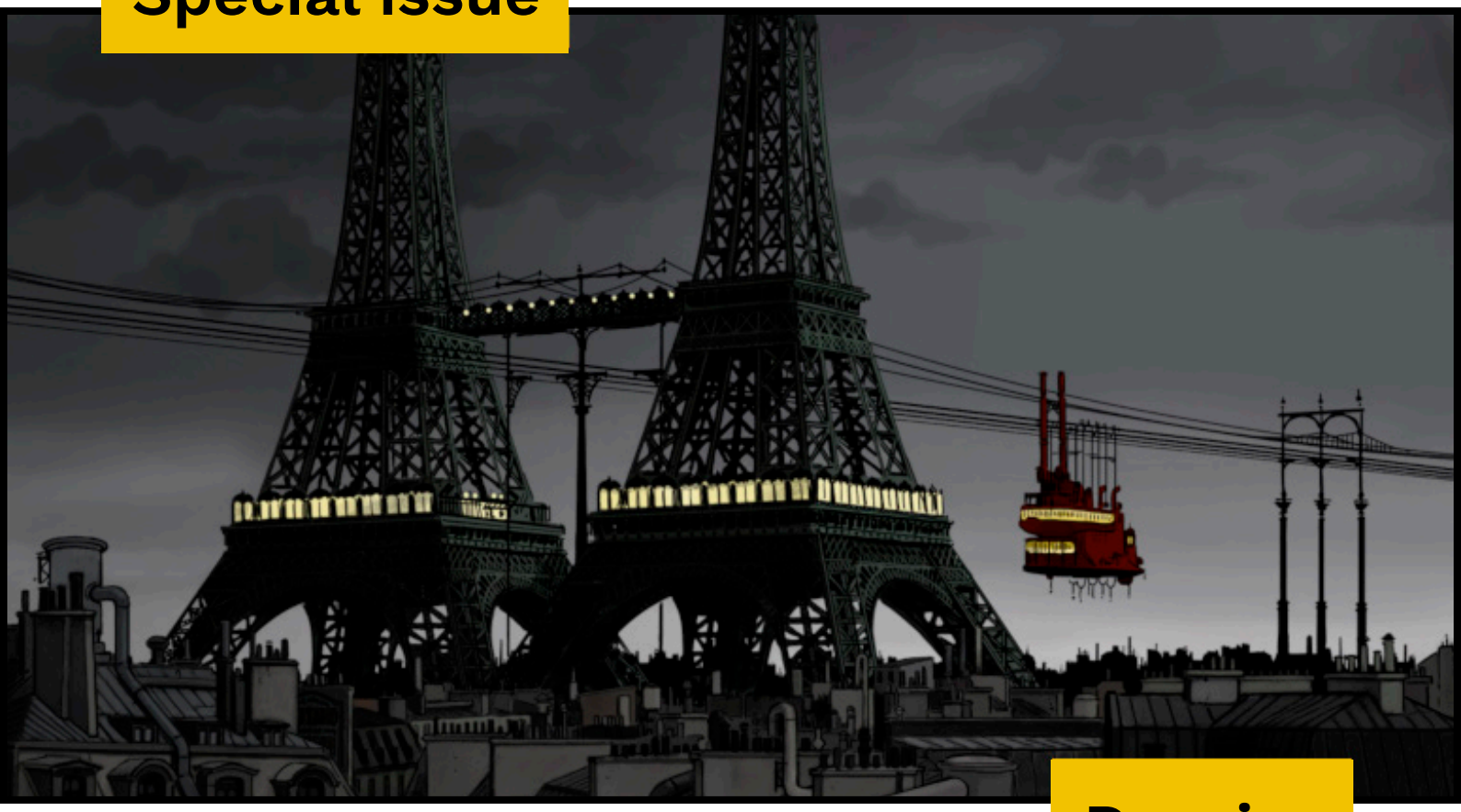

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Introduction: Energy in history, the history of energy

Abstract

Energy is a rich concept that can analyze much of the evolution of societies over time. Whether it be the means of production, forms of consumption, or periods of tension or scarcity, the quest for energy prompted humanity to go further in its search for new resources, to ceaselessly innovate, to share and conquer. While energy has been the basis of economic growth since the late 18th century, and even more so after 1945, its role cannot be reduced to the number of kilowatt-hours consumed. Energy-related issues actually affect major geopolitical, societal, political and environmental balances. Numerous new avenues connected to energy can be explored thanks to pioneering work surrounding questions of "gender," transition, and network transformation, all of which are subjects of the past that remain topical today, and that must be confronted in the future. Sometimes in competition and sometimes complementary, different forms of energy form an indispensable framework for historical evolution. The great complexity involved in grasping the phenomenon calls for increasing historical viewpoints with help from all of the social sciences.

Plan of the article

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1 The word "energy" is charged with hidden implications: it refers to a subtle something that has the ability to make nature do work. Energy now, as work formerly, has become something that individuals and societies need. It is a symbol that fits our age, the symbol of that which is both abundant and scarce" Ivan Illich declared in a 1983 lecture.[1] In his introduction the author systematically distinguished between the "E" of the physicist which is expressed in watts and joules, and a social construct, complex, historical and shifting, which is energy *in* society. It is true that the word "energy" has a history and only from the first half of the 19th century does it take on the meaning we know now. In Diderot and d'Alembert's *Encyclopédie*, the only meaning of the word relates to discourse and is synonymous with fortitude. In the following century, in the Littré dictionary, one has to wait for the *Supplement* to find the following (quite complex) definition: "Energy, Add://4° Term relating to mathematical physics, indestructible element in its numerical value, but liable to transmutations which make it appear in its three forms: work, half-strength, and calorie (Mechanics course of the Ecole des Mines)". Here it is truly humanity at work, humanity expanding or surviving, humanity in transition which is understood in its entirety through the rich word "energy". Without our going into too much theory, but adopting an empirical approach familiar to historians, it is clear that contemporary societies have seen their destiny inscribed and limited by the energy needs, be it to produce, heat, illuminate, transform or answer new needs. Technical and societal changes are in fact often symbolized by a new means of production of energy: Watt's machine, Tesla's electric motor, Lenoir's combustion engine or that of Diesel, the nuclear plant of Calder Hall, a wind field... Likewise, the new objects that transformed the world of work and the daily life of populations are nearly all objects requiring an energy supply, more or less large but always essential: the steam locomotive, the gasoline-powered car, the small electric engine, artificial lighting and all the means of communication from the telegraph to the smartphone. Marx, who was born two centuries ago, closely linked—in a Hegelian vision—the major (great) phases of exploitation by man to a source of energy, from ancient slavery to the railway, passing by the mill. In fact he distinguished between driving machines (production of energy), machines which transmit energy, and those which do work.[2] Leslie White (1900-1975) is an American anthropologist. He is remembered for his "law" (1943) which stipulates that cultural evolution depends on the amount of energy available annually per capita or, in other terms, that increasing the efficiency of energy at work reinforces cultural means.[3] For White, the history of humanity was divided into five stages according to the different sources of energy: muscular energy, animal energy, the agricultural revolution, fossil resources and lastly nuclear energy. The more contemporary periods, known as the first and second industrial revolutions, require extra energy to make boats and railways advance, and transform raw materials. The most recent acceleration, since 1945, is intimately linked to oil capacity. In short, one can debate the place of energy in social transformation but without this energy—too abundant or too scarce—societies would have had difficulty surviving and evolving.

2 And yet, is energy the forgotten item in the history of human society? The answer cannot be just yes or no. The history of energy is characterized on the one hand by a bibliography which is already large, sometimes scattered or ignored and on the other by a renewal of research on questions resonating with problems of today. The issue of energy is so broad, so complex that one can guess that throughout the world many researchers from all disciplines offer original approaches. For all

1 Ivan Illich, "L'énergie, un objet social", *Esprit*, n°8, 2010, 211 (translated from the English). Ivan Illich (1926-2002) has written in particular : *Énergie et équité* (Le Seuil, 1973 for the first edition). The author of the present article used the French translation.

2 Arnold Heertje, *Économie et progrès technique* (Paris: Aubier, 1979), 82.

3 Leslie A. White, *The Evolution of Culture. The development of Civilization to the Fall of Rome* (MacGraw Hill Books, New York, 1959, republished in 2007, Left Coast Press, California). Culture is to be understood as the sum of human cultural activities on Earth. White distinguishes technological, sociological and ideological culture, the first being to his mind the most important.

human societies have seen their development made possible, or limited by questions to do with energy resources, whether they are available on a given territory, to be exchanged or to be conquered. Of course, reducing the history of humanity to the sole question of energy would be absurd. Our intention therefore is to underline the role of energy in history as collective constraint, as a source of sustainability and complexity and as a factor of evolution.

3 In the lines below there is no discussion about drawing up a laborious catalogue of all the possible subjects and sub-subjects for approaching the history of energy. The task would be huge and worthy of the Danaides' cistern. There is no question either of drawing up a "state of the art" with bibliographies both bulky and necessarily incomplete. We would prefer to emphasize themes which open up new horizons, studies often little known by the general public, sometimes for reasons of language, sometimes for reasons of distribution. We will certainly try to underline the contributions of French-language authors but this is not our main aim. We wish to go beyond the subject of history. For the history of energy cannot only be defined by historians: the journals of economy, sociology, geography, the exact sciences... also have energy as a research topic, and more and more often, a multidisciplinary approach and a long-term perspective. In short, economy, sociology, politics, geopolitics... all rely on the history of energy to draw up a strong, informed analysis. A cross fertilization is all the more necessary as questionings are broader and broader: even if history is a global discipline, it requires fresh views and other contributions to understand a phenomenon as polymorphous as energy. Lastly, this history is constructed along the way: new perspectives appear, others are temporarily left aside. The history of energy is a pioneering front.

ENERGY, THE MATRIX OF CIVILISATION

4 If one were to add up research on wood, coal, city gas, hydrocarbons, hydroelectricity, nuclear energy, renewable energies...one would certainly be seized with giddiness and consider that this mass of research is sufficient. In reality, it is worth raising the requirement level and passing from *one* energy to energy in order to build new syntheses.[4] For, all the same, energy supposes *energies,* and consequently a choice *a priori.* But since antiquity have men really had the choice between several energies? For Aristotle, the question does not arise: " when shuttles fly on their own and plectrums play by themselves, there will no longer be any need for slaves" he wrote.[5] As for Marx he linked closely the source of energy to the social organization (in fact, for him, a type of exploitation): "By acquiring new productive forces, men change their mode of production, and by changing their mode of production, the way they earn there living, they change all their social relationships. The quern produces a society with a suzerain: the steam mill, a society with industrial capitalism."[6] We will not fall into too strict a determinism and seek in societies their capacity for adaptation, their energy choices, even if they are limited. Since the most distant times, men have dealt with a more or less wide range of sources of energy going from human or animal strength, the biomass, to fossil fuels, not to mention energy saving which is a preoccupation not only for our time. The more one advances in time, the more the issue

4 Energy, the matrix of civilisation: one can sum up in this way the vast work of Vaclav Smil and in particular his last great synthesis: Vaclav Smil, *Energy and Civilization. A History* (Cambridge : MIT Press, 2017). But also: Nina Möllers, Karin Zachmann (eds), *Past and Present Energy Societies. How Energy Connects Politics, Technologies, and Cultures* (Bielefeld: Transcript Verlag Science Studies, 2012). George Basalla, "Energy and Civilization", *in* Chauncey Starr and Philip C. Ritterbush (eds), *Science, Technology and the Human Prospect: Proceedings of the Edison Centennial Symposium* (New York: Pergamon Press, 1980), 39-52. Carlo M. Cipolla, "Sources d'énergie et histoire de l'humanité", *Annales Economies, Sociétés, Civilisations*, n°3, 1961, 521-534. Gildo Magalhaes (dir.), *História e Energia, Memória, Informação e Sociedade* (Sao Paulo: Alameda, 2012 José M. Martinez-Val, *La Energía en sus Claves* (Madrid : Fundación Iberdrola, 2004).

5 An interesting reflection on slavery and industrial society: Jean-Claude Mouhot, *Des esclaves énergétiques. Réflexions sur le changement climatique* (Seyssel : Champ Vallon, 2011).

6 Karl Marx, *Misère de la philosophie. Réponse à la "Philosophie de la misère" de M. Proudhon* (Paris : A. Franck, 1847). chapter XV of *Capital*, "Machinery and Heavy Industry" Karl Marx develops these ideas relying essentially on British examples.

of energy balance seems obvious, even if the emergencies were not all as urgent. A balance is to be found between the availability of resources and the changes brought about by technological evolution. The 18th century raised the question of the means in wood, for instance.[7] For in the last resort, energy choices are choices made by society. To consume much, to just consume, to consume meanly: these are modes of existence which differ radically. And when one has to move from one system to another, work methods, consumer habits, ways of residing and moving change. Energy is a trait of civilisation not so much because of the nature of the energies used but rather because of the way we produce and consume. The steam society was different from that of electricity, which itself will be different from the society of energy efficiency we have entered into. The same is true for location: the industrial zones were close to the sources of energy during the first industrial revolution[8] (and even later if one thinks of the Soviet combines), electrometallurgy was organized according to hydropower resources and today the big computer servers migrate towards cold climates.

5 So the energy system evolves, internally through its technical progress, externally because of social expectation. It is not only the sources of energy which change, but also the structures of transportation and distribution, the returns, the speeches, the reputations, etc. In short, if energy more or less shapes society, it is itself in tune with contemporary expectations. We must therefore go beyond technicalities to envisage a source of energy or a use of energy in its socio-economic context.[9] Between Edison's light bulb and today's led, there is not only technological progress, there is a discourse on energy efficiency in the context of a world anxious about its future. These global evolutions are not easy to understand. We certainly need archives, statistical data,[10] preferably long-term. A certain number of researchers have dared to adopt this quantitative approach which makes it possible to envisage in the long-term the quantities of energy absorbed and the distribution of sources of energy.[11] However the quest for figures prior to the 19th century is difficult, even in countries which have preserved old archives. And in the regions where the sources are still less reliable and rarely followed up, collecting figures can be a real challenge. Prices of energy are fundamental data not only for the consumer but also to explain the competition and the preferences between energies. Price must however be moderated according to budgets, the wish to distinguish oneself or local characteristics. Thus a new type of energy on the market is in general expensive and suffers awhile from its luxury image. The quantitative approach (concerning consumption, prices, exchanges...) will be balanced according to historical contexts, the wishes of customers, public policies and many other socio-economic factors. For energy is the daughter of its time.

CRISES, DEADLOCKS AND RENEWAL

6 Energy is thus a living, evolving and reactive system. And it is probably less linear than one might think. With hindsight, some uninformed minds might imagine the history of energy as an unstoppable machinery, a logical sequence of technical solutions adopted unanimously. In

7 Reynald Abad, "L'Ancien Régime à la recherche d'une transition énergétique ? La France du 18e s. face au bois", *in* Yves Bouvier et Léonard Laborie, *L'Europe en transitions. Energie, mobilité, communication 18-21e s.* (Paris: Nouveau Monde éditions, 2016), 23-84.

8 Edward Anthony Wrigley, *Energy and the English Industrial Revolution* (Cambridge: Cambridge University Press, 2010).

9 David Edgerton, *The Schock of the Old. Technology and Global History since 1900* (New York: Oxford University Press, 2007).

10 Many quality ressources are becoming available: retrospective statistical yearbooks (France 1966), global data (OECD, BP), works of historians: Angus Maddison, *L'économie mondiale 1820-1992, Analyse et statistiques* (Paris: OCDE, 1995) ; Dominique Barjot, *L'énergie aux 20 et 21e s.* (Paris: Presses de l'Ecole Normale Supérieure, 1991) ; Bouda Etemad et Jean Luciani, *Production mondiale d'énergie 1800-1995* (Genève: Droz, 1991).

11 The work of Roger FOUQUET provides excellent historical landmarks on the question of transitions: for example, Roger Fouquet "The Slow Search for Solutions: Lessons from Historical Energy Transitions by Sector and Service", *Energy Policy*, vol. 38, n°11, 2010. From the same author : *Heat, Power and Light : Revolution in Energy Services* (London: Edward Elgar, 2008).

reality, this evolution was marked by hesitation, crises and impasses. Wrong tracks, speeches with no follow-up and aborted alternative solutions must also be part of our research because they reveal the expectations of society. And if we think of failures, it is with the easy hindsight of those who can prophesy the past. Let us take an example: in the 19th century there was a strong belief in pressurized air which seemed simple to use, effective and universal; be it for the railway, electricity, industrial machines, the cold production or communications, a whole industry supported by a positive discourse developed (in some cases up until today). And yet, pressurized air is only granted a few lines in our textbooks, condemned because of its insufficient posterity. Likewise, there were gas refrigerators, competing against electricity, in the Salon des Arts Ménagers. Charcoal was long deemed to make better steel than fossil coal. The electric aircraft had its heyday at the end of the 19th century... We must include these missed opportunities so as not to transform a complex history into a clear path marked by determinism and simplification. Let us go further. Since the time-dimension is our horizon as historians, is the very concept of impasse relevant? The electric tram disappeared from many cities because it obstructed the traffic and was quite dangerous. Half a century later, it is experiencing a revival, if only to get rid of cars and develop public transport. Another example: it is a fact that air conditioning, which is very energy-consuming, will be one of the essential needs of the future due to global warming and increasing urbanization. Yet this usage is still widely perceived in certain countries as a luxury, and not yet as a comfort. We will have to change this view. In short, let us not present too soon a formatted history but rather move towards a certain proliferation linked to the needs and potentialities of a given time

7 As for crises, they can reveal characteristic traits of a society. Economic tensions have generally been accompanied by a lowering of energy-consumption (for example during the Great Depression). But there again we must broaden the perspective: it is not impossible that innovation in the field of energy should have played a counter-cyclical role. Industrial electricity and oil developed at the end of the 19th century at a time of economic contraction and this undoubtedly played a part in boosting the economy at the beginning of the following century. Another type of crisis: the fear of being in need. The lack of wood at the end of the Ancien Régime has already been mentioned. In the 19th century in 1865, W.S.Jevons wrote a book entitled *The Coal Question: an Inquiry Concerning the Progress of the Nation and the Probable Exhaustion of our Coal-Mines.* Not so long ago the peak-oil was forecast and dated, and with it came the threat of a shortage of oil. A history of energy forecasts, with or without figures, would be useful: pessimistic or Malthusian estimates have, in a number of cases, proved wrong. A detour through history enables us to confirm that the worst is not always certain. But energy crises can also take much more acute forms. Conflicts have provoked blockades, directly affecting the sources of energy: world wars, the Suez crisis, the Yom Kippur war, etc. Consumers kept the memory for a long time, their reflex being to quickly "fill up". Finally, electrical systems, although more and more interconnected, experience supply disruptions which are often spectacular. The electrical blackouts hit New York, Western Europe and more recently India.[12] The fear of total electricity failure has produced a few terrifying novels like *Ravage* by René Barjavel[13] (1943): it shows how the brutal and unexpected disappearance of electricity provokes the collapse of society and its values in a very short time.

TRANSITIONS AND BREAKS

Traditionally, history constructed by historians 8
unfolds according to distinct and individualized stages, punctuated by breaks or transitions. In this unfolding, where the evolution of energy is concerned, it appears that the most distant periods (the discovery of fire, the development of

12 David E. Nye, *When the Lights went out. A History of Blackouts in America* (Cambridge: The MIT Press, 2010).
13 Published for the first time by Editions Denoël.

crops and sedentarization) pose specific problems (dating, means used, the place of fire in the organisation of society)... and require much more research. For the most contemporary phase, this evolution is described as a succession of periods dominated by three industrial revolutions.[14] The 19th century is presented as the century of coal and rail, then the most advanced societies added innovations leading to breakthroughs, such as the internal combustion engine and the electric engine. The most contemporary stage can rely on nuclear energy and the recognition of the finiteness of the resources of the earth.[15] The contemporary period is thus marked by a double acceleration from the point of view of energy consumption: that linked to coal and steam in the middle of the 19th century, that, closer to us, with the take-off of oil-consumption. The 20th century is undoubtedly a break, above all after the Second World War and the acceleration of needs in energy due to greater mobility and rather energy-consuming ways of life. Vaclav Smil shows that a large American house in the year 2000 consumed energy which would have required 6000 slaves in ancient times.[16] It remains to be seen, if one accepts the concept of industrial revolution, how and why these transitions and energy-breaks happen. The advantages of certain types of energy and the drawbacks of others (technical characteristics, price, sustainability) apparently provide sufficient explanation. Coal is more abundant than wood (at least in some countries) and has a strong calorific power; electricity is more flexible and more effective than coal; natural gas performs much better than coal gas; oil is a concentrated energy well adapted to motor vehicles, etc.

9 Yet, coal was known long before Watt's engine (preceded by that of Newcomen), city gas was born around 1800,[17] electricity was not unknown since Volta and Faraday at the beginning of the 19th century, oil had been used for a long time but for low energy-consuming uses. In this list it is implied that energies were competing and that the best adapted ended up winning. But it would be equally justified and instructive to study the forms of energy from a *complementary* angle. On the one hand it is clear that energy transitions concerning the means of production are rarely substitutions. All the research shows on the contrary that sources of energy accumulated, in varying proportions. Transition signifies in reality the arrival of a new source of energy on top of the preceding energies. Coal continued to be used a lot at the end of the 19th century even if the second industrial revolution is supposed to have been based on oil and electricity. Complementarity is as apparent in the uses: before 1914, electric motor cars seemed to have as bright a future as motorcars with an internal combustion engine. In fact, the energy system became as it were more complex, unbalanced, then once again balanced. This is what Schumpeter had already said: "New does not come from old, but appears aside of old, competes against it until it destroys it".[18] Thus complementarity is often a stage of what one could call the many facets of energy transition. This is especially true since the men of the time compared, and experimented. Societies hesitated just as we hesitate between solutions the advantages of which are not properly assessed. Towards 1800, it was not obvious to choose a lighting mode. The development of electric lighting was in effect curbed by the invention of the incandescent mantle which gave city gas a real advantage in terms of brightness as well as very competitive prices.

10 The theme of transition is still very topical and it pleases historians for it contains the notions

14 François Caron, *Les deux révolutions industrielles du 20e s.* (Paris: Albin Michel, 1997). Also, François Caron, *La dynamique de l'innovation. Changement technique et changement social (16-20e s.)* (Paris: Gallimard, 2010).

15 Astrid Kander, Paolo Malanina, Paul Warde, *Power to the people. Energy in Europe over the Last Five Centuries* (Princeton: Princeton University Press, 2013). Roger Fouquet, Peter J.G. Pearson, "A Thousand Years of Energy Use in the United Kingdom", *The Energy Journal*, vol.19, n°4, 1998.

16 Vaclav Smil, "World History and Energy", *Encyclopedia of Energy*, vol. 6, 2004, 558. He adds that in the 19th century, a landowner would have needed 3000 workers and 400 horses.

17 See Jean-Pierre Williot's thesis, *Naissance d'un service public : le gaz à Paris* (Paris : Editions Rive Droite, 1999).

18 Joseph Schumpeter, *Capitalisme, socialisme, démocratie* (Paris: Payot, 1951), 40. It is the familiar notion of "creative destruction".

of time and change. But insofar as everything is transition, passing from one state to another, the term must not be overused. It should lead to some comparative studies so as not to wear out the concept too soon. Technical qualities, prices and commercial skill have all played a part in these stages of choice. But one can add an essential factor, hardly quantifiable but quite real: the field of images, positive or not. The media and public opinion can thus tilt decisions. For example, the rivalry between electricity and city gas at the end of the 19th century is reflected even in the Parisian music-hall: this opposition became a popular theme which showed very soon that the modernity of electricity had won over the old-fashioned image of city gas. The opposition between renewable energies and nuclear power also emerges through the development of strong images: the sun shines for all versus nuclear power marked with an original stain, the bomb. The contestation of nuclear energy in Germany was carried out with a sun on which was inscribed "Nein Danke". The energy tipping point is thus a question of opinion. To explain the enthusiasm or mistrust requires an in-depth study of society. The image can anyway be double, which does not make interpretation simpler: coal in the 19th century is perceived as indispensable, it is the " bread of industry", "King Coal", but it is also feared and deplored. The black towns of England or of the Ruhr harbour both an extraordinary activity and a certain despair. Oil may be "black gold" but it is accused of deteriorating both social relationships and the environment in the production areas. As a counterpoint, the peak of praise was no doubt reached around the fin-de-siècle electromania (in France, one celebrates the 'Fairy electricity')[19]. Every society, at a given time, prioritizes its preferences concerning energy according to criteria which are not always objective.

ENERGY, AN INSTRUMENT OF POWER[20]

Energy resources are not distributed equally throughout the world. As a consequence some countries export while others have to import more or less massively. The first consequence is that transportation of energy has developed since the 19th century. Wood was well adapted to transportation over land or by rivers for varying distances but rarely internationally. Coal opened a new era. Some countries benefited from their coal resources. It is well known that the proximity between coalfields and consumer areas in Great Britain was a decisive element for the "take-off " of the country and that the part played by English canals need not be demonstrated. The importance of coal is also mentioned in the recent work of Peter A. Schulman[21] who shows that the preoccupation with the supply of coal led the Americans very early on to the notion of "energy security". France did not benefit from such advantages: her coal was of inferior quality and transport was costly. The country was the first importer in the world between the two wars. Hydrocarbons followed this movement, amplifying it. Oil and natural gas (the latter can be liquefied and transported in tankers) draw a map of transport which gives 20-21th century energy a global and geopolitical dimension.[22] Oil remains today the most transported product. As a consequence, the straits of Malacca, the straits of Ormuz and the Suez Canal, are and remain places of tension which underlines the fact that energy transport reveals itself to be a fragile, as well as a strategic cord. In wartime, the energy blockade has proved to be quite effective. Underwater war in 1917 cut France from its oil supply. This attack almost cost the country the final victory. During that same war, central powers, rich in coal and poor in oil, tried in vain

19 On imagination and electricity: Alain Beltran et Patrice Carré, *La vie électrique 18-21e s. Histoire et imaginaire* (Paris: Belin, 2016).

20 Jean-Claude Debeir, Jean-Paul Deléage, Daniel Hemery, *Une histoire de l'énergie. Les servitudes de la puissance* (Paris: Flammarion, 2013).

21 Peter A. Shulman, *Coal and Empire. The Birth of Energy Security in Industrial America* (Baltimore: John Hopkins University Press, 2015).

22 Jean-Pierre Favennec, *Géopolitique de l'énergie. Besoins, ressources, échanges mondiaux* (Paris: Technip, 2009).

to stock up on oil, hence the importance of a country like Rumania, the only country in Europe to possess significant oil resources. The conflict between the United States and Japan, even before Pearl Harbour, started with the refusal of the Americans to supply oil to the Empire of the Rising Sun. Hitler's aims in war were not strictly speaking to do with energy, but his offensive towards Baku and Mesopotamia clearly had oil as an aim. Finally, we know the Germans, for lack of oil, developed a successful chemical industry in order to obtain synthetic oil. As a matter of fact, the technical history of weapons[23] is that of a race for power: an 18th century canon represents a kinetic energy of 300 000 joules against 20 joules for a traditional bow.[24]

12 Outside periods of war and international crises, there is, according to Montesquieu: "a general rule, which is that wherever the mores are gentle there is trade, and wherever there is trade, there are gentle mores".[25] In the case of energy, the traditional function of a transport network is of course to connect a buyer to a seller, customers to providers. If we follow Montesquieu it is a commercial, neutral and pacified link. However, the example of the transport network for natural gas in Europe in the second half of the 20th century enables us to draw apparently contradictory lessons. It is a network which effectively links East and West of Europe, the distant resources of Russia with the western borders of Europe. During the cold war, exchanges between the communist East and the capitalist West upset the American President who considered that his European allies were too dependent on Moscow. Nevertheless, this network developed independently of the oppositions between the great powers, following a mostly economic logic.[26] Conversely, Ukraine, in conflict with Russia over the tolls for the natural gas transiting through its territory, suffered supply cuts which consequently affected a certain number of countries in central Europe. Hence the present construction of a whole series of pipelines meant to insure the continuity of supply while avoiding Ukraine. The political dimension of the networks[27] (their justification?) must not escape us either.[28] The gas and oil network which linked the "sister countries" to ex-USSR ("Droujba", the oil pipeline of Friendship) had both a political and economic dimension: it was a means to reinforce the weight of the USSR. And featuring prominently among the major works planned by the European Union are networks for the transport of gas and electricity which should create more solidarity between European countries.[29]

FROM THE DISTRIBUTION NETWORK TO THE CONSUMERS

13 The distribution of energy is essential data which has probably not received all the research it deserves., The small companies which delivered coal and wood before the construction of networks are still a recent memory and have probably not disappeared from developing countries. For long, grocers delivered oil in five-litre jerrycans. But soon the gas pump replaced bulk. A pump became a petrol station, a meeting place if not a place to live, the symbol of a civilization of the car and mobility which has recently taken an electrical turn.[30] Some blind spots remain,

23 Clifford E. Singer, *Energy and International War. From Babylon to Baghdad and Beyond* (New Jersey: World Scientific, 2008).

24 Vaclav Smil, *Energy and Civilization. A History*, op. cit., note XXX, 364.

25 Charles de Secondat de Montesquieu, *De L'esprit des lois*, Book XX (Des lois dans le rapport qu'elles ont avec le commerce considéré dans sa nature et ses distinctions), chapter 1 (Du commerce), (Paris: Gallimard, 1995), 219.

26 Per Högselius, *Red Gas. Russia and the Origins of European Energy Dependence* (New York: Palgrave MacMillan, 2013). Jeronim Perovic, *Cold War Energy. A Transnational History of Soviet Oil and Gas* (London: Palgrave MacMillan, 2017).

27 A classic on the electric network: Thomas P. Hughes, *Networks of Power. Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983).

28 An interesting reflection: John G. Clark, *The Political Economy of World Energy. A Twentieth-Century Perspective* (New York: Harvester Wheatsheaf, 1990).

29 Vincent Lagendijk, *Electrifying Europe. The Power of Europe in the Construction of Electricity Networks* (Amsterdam: Aksant, 2008).

30 Joanne Brady, "Electric Car Cultures: An Ethnography of the Everyday Use of Electric Vehicles in the UK" (Master Thesis, Durham University, 2010).

outside the mesh of our knowledge: the businesses providing home delivery for fuel and bottles of liquefied gas... From the end of the 19th century, urban networks became regional then changed into national networks.[31] The ultimate electrical network is a universal network (like the post office or the telephone) branching out towards every customer. Its construction, its integration in the landscape deserves to be known. Especially as these distribution networks have become (more) intelligent: the integration of renewable energies and of digital capacity opens the way for *smart grids, smart cities* and intelligent meters. A network which, in spite of its highly capitalistic weight, has to adapt to transformations of a technical, legal and competitive order. Today's historians must analyse these 2.0 or 3.0 networks which are evolving as we watch. And they must understand the countries where there are no networks, or else embryonic ones, but which have other forms of distribution.

14 And at the end of these networks of varying sizes, there is the consumer. What would energy be without the consumer? Left aside for a long time, he has become the customer and as such can choose and has to be listened to. He may be industrial, agricultural, urban, isolated, etc. In each of these different economic or geographical positions, he will think differently.[32] Thus the chronology of the electrification of rural areas is quite specific according to the different European countries. On the side of industry, needs can be impressive: businesses known as electro-intensive (electrochemistry and electrometallurgy) have needs comparable to those of a town. At the other end of the scale, households were not, for a long time, really preoccupied by energy, because it only represented a small share of their budget. However, more recently, one discovers that a sizable share of the population lives in a state of energy insecurity, a new division in society which the authorities are increasingly taking into consideration. The more modest homes are in general described as "energy leaks" and this is where an important effort must be made which has as much to do with sound economy as with social justice. Finally, this customer is also a woman. Studies on energy still do not take gender into consideration very much.[33] No doubt, some thought has been given to task sharing but household appliances do not seem to have revolutionized male-female relationships.[34] Reflections on the contemporary world[35] show clearly that energy policy is not a neutral entity.[36] The roles attributed to women and men in the supply and use of energy are often different, the hardest tasks often falling to women. Going back in time, it is very probable we would find the same segmentation.

Let us leave the industrialized world: here, the 15
consumer is still generally unknown. For modernization (a very vague word) did not take place following a single model, derived from 19th century Britain and 20th century United States. What do we know of energy use in the course of thousands of years of history in Punjab or Southern Africa? To tell the truth, very little: probably because of the scarcity and incompleteness of sources, possibly also because Western or local historians have not yet integrated the "energy" dimension as central to the understanding of

31 Alain Beltran, Fabien Roques, Michel Derdevet, *Énergie. Pour des réseaux électriques solidaires* (Paris: Descartes, 2017).

32 David E. Nye, *Consuming Power. A Social History of American Energies* (Cambridge: The MIT Press, 1998).

33 An examination of the articles published in Gender and History reveals this in spite of the excellent quality of this publication.

34 Ruth Schwartz Cowan, *More Work for Mother. The Ironies of Household Technology from the Open Hearth to the Microwave* (New York: Basic Books, 1983); from the same author: "How the refrigerator got its hum", in Donald A. Mackenzie, Judy Wajcman, *The Social Shaping of Technology* (Milton Keynes UK: Open University press, 1999), 202-218. By the same author, "How the refrigerator got his Hump", Donald A. Mackensie, Judy Wajcman, *The Social Shaping of Technology* (Buckingham Open University), 202-2018.

35 For example ENERGIA, Newsletter of the ENERGIA International Network on Gender and Sustainable Energy, or published by the European Union, Martin Anfinsen, Sara Heidenreich, *Energy and Gender. A Social Sciences and Humanities Cross-Cutting Theme Report* (Cambridge: Shape Energy, 2017).

36 Riitta Räty, Annika Carlsson-Kanyama, "Energy Consumption by Gender in some European Countries", *Energy Policy*, 38/1, 2010, 646-649.

the evolution of societies. These regions are often only referred to in terms of delay and therefore of catching up. But didn't they live by adapting to environments where wood and water were no doubt scarce? We must for a moment distance ourselves from the industrial model, if only to understand it better. Adopting a world point of view[37] (global is probably very difficult) should enable us to envisage other routes,[38] other energy balances by relying on the new approaches of World History. If wood has decreased in the production of energy in Europe, China or India, the timeline of substitutions is not the same. Besides, the present world is also a very unequal world, where 10% of the world population monopolize around 45% of the consumption of energy. Did preceding periods, before the development of coal, experience such disproportions?

ENERGY, COMPANIES AND DEMOCRACY

16 One must not forget that the history of energy is also linked to the economic reality of companies. If many micro-companies have developed their activity on the scale of petty trade (for instance the installers, who remain largely unknown), what is striking historically is that the energy sector gave birth to very large companies. This was the case in the 19th century with the all-powerful mining companies, quite often linked to the railway companies: didn't the *Internationale* denounce the "steel and railway barons"? Then the oil sector gave birth to the Standard Oil Company or Shell, so formidable—practically retaining the monopoly—that the United States used their anti-trust legislation for the first time to break the John D.Rockefeller company into less powerful (in theory ...) companies. The post-war nationalisations in Europe created giants which were called British Gas, ENEL, Electricité de France or, in the oil sector ENI, Statoil or Elf-Aquitaine. It is usual to find, in the first ten companies of a country, electricity, gas and oil companies. Emerging countries are not left behind with Petrobas, Aramco or the Chinese companies which have rapidly reached a global size. The power of these societies is both a socio-economic and political stake.

17 The development of these large companies and the global issues of energy at a time of global warming have recently increased the thinking on the theme of the relationship between democracy and energy. Timothy Mitchell received a warm welcome for his book *Carbon Democracy,*[39] even though some of his theses surprised his readers. Mitchell links the evolutions of democracy since the 19th century to the modes of production of energy and above all to the means of action of workmen. Thus the miners, strong in numbers and well organized, were able to lead decisive actions in sensitive places and weaken the most fragile production lines. However, the transition from coal to oil profoundly changed the situation. For oil is not a manpower industry, it is more scattered and transportation by boats or pipelines lends itself less to interventionism.[40] Consequently, the attempts at blockage or sabotage would be much more difficult with black gold, which has enabled large fortunes and trusts to develop, to conquer and monopolize power. But clearly it is around nuclear energy that the debate has become politicized in the most sensitive way. The decision to set up civil nuclear power plants was felt by many protesters in the 1970s to be non-democratic because it was imposed by a lobby made up of a few experts and heads of companies ("the

37 See for instance: Alain Beltran, Léonard Laborie, Pierre Lanthier et Stéphanie Le Gallic (ed.) *Electric Worlds/Mondes électriques. Creations, Circulations, Tensions, Transitions (19/21st C.)* (Bruxelles : PIE Lang, 2016). Several articles are devoted to Africa, China , South America...

38 For instance, Rodrigue Lekoulekissa, *Electrification en Afrique : le cas du Gabon (1935-1985)* (Paris: L'Harmattan, 2011).

39 Timothy Mitchell, *Carbon democracy. Le pouvoir politique à l'ère du pétrole* (Paris: La Découverte, 2013), preface by Michel CALLON and Bruno LATOUR. By the same author: *Petrocratia : la démocratie à l'âge du carbone* (Alfortville: Ère, 2011). And also, Frédéric *Denhez, La dictature du carbone* (Paris : Fayard, 2011).

40 Among the huge literature on oil, one can mention that the theme of the excessive power of oil companies is to be found very early in Ida Tarbell, *The History of the Standard Oil Company* (London: W. Heineman, 1905) as well as in Lenin (Imperialism, the Supreme Stage of Capitalism, 1916).

nucleocrats").[41] Nuclear energy[42] has become unwittingly the symbol of dangerous decisions imposed from above, disrespectful of the will of citizens and often motivated by "greatness"[43] and prestige. This criticism is one of the basics of political ecology which, from one European country to another, does not have the same characteristics. Nevertheless in Switzerland, Germany and France, the nuclear dimension in the protest against the major technical choices is often dominant.[44] The political front which demands more democracy is in fact quite heterogeneous: it gathers together left-wing activists hostile to profit (even in the case of public companies), NGOs which defend nature in all its forms, scientists who oppose engineers, certain media... The German *energiewende*[45] *(*energy watershed) acts in favour of giving up nuclear facilities following the conclusions of an Ethics commission headed by a clergyman. It would not be wrong to say that the struggle against nuclear energy is both the matrix of a certain dissent and the smallest common denominator between groups that are often seeking to unite. These different movements have had an echo in Germany and the Germanic world (Austria has no nuclear plant, Switzerland complains of those of its French neighbour). Nuclear energy in the vast array of means of production is not in reality a type of energy quite like others. Firstly on account of its military origin, giving man the power of self-destruction.[46] Born of "Big Science", nuclear energy requires important technical and financial means, a real policy tending in the best of cases towards more energy independence, in the worst towards proliferation. The first of these arguments has served in particular in France to justify a vast electronuclear program. The structure of development and the system which carries nuclear energy are denounced by a certain number of thinkers, in particular in Germany.[47] In a word, nuclear development would necessitate a powerful, centralised, technocratic state admitting no counter-politics in the name of science and progress. And so, in a symmetrical fashion, the opposition to nuclear energy puts forward renewable energies, decentralisation, local production, solidarity networks. To contest nuclear power means to combat the role played by the State as guarantor of security and of the continuity of public services. It is also to contest the omnipotence of technology that would lead the world to an impasse.[48] These notions can be found, condensed, in an important book, *Der Atom-Staat*[49] by Robert Jungk. The work followed on from many reflections by this former journalist on nuclear power. Jungk analyses the transformation of a state that chooses nuclear power (whether civil or military), as the convergence between Big Science, big capital and strong government. One of the main ideas of the book is that confronted with the permanent threat weighing upon nuclear power (accident, attack), the State must put in place a permanent state of emergency which by definition restricts liberties and modifies messages.

41 It is the title of a book of interviews by Philippe Simonnot (Grenoble : Presses Universitaires de Grenoble, 1978).

42 Amory B. Lovins, *Nuclear Power. Technical Bases for Ethical Concerns* (Friends of the Earth, 1975) and *The Energy Controversy* (Friends of the Earth, 1979), etc. Lovins was translated belatedly in France even if his first book in this language was published as early as 1975. (*Stratégies énergétiques planétaires*, Christian Bourgois pub.)

43 Stéphane Savard, Martin Pâquet (dir.), "Energie et citoyenneté", *Globe, Revue internationale d'études québécoises*, vol. 13, n°2, 2010. Gabrielle Hecht, *The Radiance of France. Nuclear Power and National Identity after World War II* (Cambridge: MIT Press, 1998).

44 For the Canadian example, see Ronald Babin, *L'option nucléaire : développement et contestation de l'énergie nucléaire au Canada et au Québec* (Montréal: Boréal Express, 1984).

45 Craig Morris, Arne Jungjohann, *Energy Democracy, Germany's Energiewende to Renewables* (London - New York: Palgrave Mac Millan, 2016).

46 See Martin Heidegger on *The Atomic Age*, in particular his 1955 lectures. More recently, Ulrich Beck with *La société du risque. Sur la voie d'une autre modernité* (Paris: Aubier, 2001), experienced an important success owing largely to the Tchernobyl catastrophe.

47 We base ourselves in particular on a very clear and well documented text: Andreas Folkers, "Nuclear States, renewable Democracies?", *LIMN*, n°7, 2016., (LIMM, http://limm.it//nuclear-states-renewable-democracies/?doing_wp_cron=1508318414.2110929489135742187500)

48 This criticism is not new: one can think of Lewis Mumford : *Technique et civilisation* (Paris: Parenthèses, 2016), published in the United States in 1934.

49 Robert Jungk, *Der Atom-Staat* published in French under the title *L'État atomique, les retombées politiques du développement nucléaire* (Robert Laffont, 1977).

18 With the arrival of NICT (new information and communication technologies) and the rise of renewable energies (essentially solar and wind power), the link was established between these new technical possibilities which free the citizen and the democratic aspirations which had been repressed for too long. Certain texts by Jeremy Rifkin[50] on the third industrial revolution highlight the disruption that should take place thanks to the technique of *smart grids, smart cities,* and exchanges between citizens. Consequently, if one follows Rifkin, the great companies of the energy sector are doomed to disappear. The author of the *Third Industrial Revolution* believes that a certain empowerment of territories is possible (which does not however mean self-sufficiency) thanks to the new technologies which make the sharing of data possible. A democratic and essential notion is put forward: the "collaborative commons", sustainability, cooperation and the intrinsic worth of objects replace consumerism, competition and selfishness. The allusion to "commons" harks back to the farming practices of the Ancien Régime where part of the land (crops or livestock) was used in common by villagers. The consumer who was alienated would henceforth become "prosumer", both *producer* and *consumer.* There would be the advent of a new society, more cohesive and more democratic. Finally, by both Mitchell and Rifkin, official experts are either denounced or disqualified. Indeed, according to these critical thinkers, the expert speaks "from somewhere" and is not objective. Expertise must be transferred to every citizen through a democratic and cohesive approach. Is not the speech of the engineer or of the representative of public powers the accomplice of the powerful?[51] Conversely, is not the speech of the committed activist citizen by definition truer, more sincere and more effective? Energy is not the only field in which these shifts are manifest. But these shifts are clearly symptoms of a society that—at least in part—no longer wants to reason as it did before.[52]

ADAPTING CONTEMPORARY NOTIONS TO PAST PROBLEMATICS: ON THE TOPICALITY OF HISTORY

19 Needless to say, since the 1970s, the *issue* of energy has come to the forefront of national preoccupations, European and above all worldwide.[53] On the one hand, oil prices have undergone sudden rises and counter-shocks whereas stable prices had long characterized black gold. This instability raised the acute question of energy dependency/independence, whether for oil or gas. But the least one can say is that European reactions in the 1970s were not in unison. Energy-saving, global warming, the development of renewable resources, the destiny of nuclear power and fossil fuels but also the question of pollution[54]...put energy issues at the heart of major preoccupations. The key word since the 1970s-1980s has become *sustainable.*[55] Certainly, the chronology of the raising of awareness and of environmental policies has recently given rise to perceptions that range from a scientific approach to (occasionally) a critical manifesto.[56] The very vocabulary takes

50 For example, Jeremy Rifkin, *The Third Industrial Revolution. How Lateral Power is Transforming Energy, the Economy and the World* (New York: Palgrave Mac Millan, 2011).

51 There are interesting remarks in James C. Scott, *Seeing like a State. How Certain Schemes to Improve the Human Condition have Failed* (New Haven: Yale University Press, 1999).

52 Benjamin Dessus, "L'énergie au défi de la démocratie", *Alternatives économiques*, N°24, 2004, pp90/105.

53 For example, David Howell, *Energy Empires in Collision. The Green Versus Black Struggle For Our Energy Future* (London: Gilgamesh Publishing, 2016).

54 Geneviève Massard-Guilbaud, *Histoire de la pollution industrielle, France 1789-1914* (Paris : Editions de l'EHESS, 2010). A recent work: François Jarrige et Thomas Le Roux, *La contamination du monde. Une histoire des pollutions à l'âge industriel* (Paris: Seuil, 2017).

55 Jose Goldemberg, Thomas B. Johansson, Amulya K.N. Reddy, Robert H. Williams, *Energy for a Sustainable World* (New Delhi: Wiley Eastern Ltd, 1988). A large share of the work deals with "developing countries".

56 As an example, Charles-François Mathis et Jean-François Mouhot (dir.), *Une protection de l'environnement à la française ? (19-20e s.)* (Paris: Champ Vallon, 2013). Céline Pessis, Sezin Topçu, Christophe Bonneuil (dir.), *Une autre histoire des trente Glorieuses. Modernisation, contestations et pollutions dans la France d'après-guerre* (Paris: La Découverte, 2013). Stefano Cavazza (a cura di), "Ambiente,

on a meaning: solar,[57] wind power and geothermal power have moved from the word "new" to the words "clean", "alternative" or "renewable". Laying aside the risk of anachronism, we must avail of this topicality to put a series of contemporary questions to the past, and to give the questions of today the long-term analyses which are essential. The past nourishes the present, the present gives meaning to past events. Today, certain notions such as energy efficiency and energy intensity are part of a common reflection. These themes, operating perfectly, can be translated into the near or distant past with all due methodological precautions. In this way we may sometimes reach counter-intuitive conclusions.

20 The term disruption, sifting through history, is doubtless well adapted to certain characteristics of our time. For example, energy growth is no longer closely correlated to economic growth, as was the case for a long time. The world—with one or two notable exceptions—has decided to enter into a new energy transition. This wish is accompanied by an upsurge of statistics and studies that take into account the situation since the beginning of the industrial era (with the affirmation of the notion of Anthropocene).[58] Despite this historical detour, it is not certain that every country interprets the notion of transition in the same way. Certain costed objectives were put forward (for example by the European Union, by COP21 or at the time of the Paris agreement). Can the ambition of these figures rely on comparable historical data? In particular, the question of the downturn in consumption, programs in favour of renewables and the slowing down of nuclear power (in spite of the fact that it is carbon-free) give rise to serious fighting over figures. In fact, nothing can be taken for granted and some fossil energies still have a future, be it oil, natural gas and even coal. Seeing how complex things are today, to rely on a few historical trends is probably not the solution, but only part of it. For technology, politics and consumption do not evolve at the same speed. To turn to the last two or three centuries enables us to illustrate this reality. Not forgetting that, yesterday as today, social considerations cannot be left aside: an energy policy also has its contradictions. The NIMBY or BANANA[59] syndromes are there to prove it. Certain notions must even be reconsidered: what do the words progress, comfort, solidarity mean today? The feeling of anxiety, of a race against time, some would say a race towards the abyss, must not at all prevent us from taking the time to find in the past a history of energy capable of identifying the right definitions and of asking the most relevant questions correctly.

21 These lines are neither a program nor a balance sheet. A conclusion mainly: a great number of journals on energy exist, but few touch upon historical issues: one can mention however *Energy Policy* and *Energy Research and Social Science*,[60] which regularly contain retrospective articles. Of course, all the great general history journals have at one time or another published articles about the field of energy. There lacked however a journal devoted entirely to the question. And to start this editorial adventure, it is worth stating that the theme which will be addressed in the years to come is an essential element to understand the evolutions of past, present and future societies. History, which tries to analyse man in society, his efforts to dominate Nature and his wish to exceed his destiny limited in time, must enrich itself with the many facets of our energy evolution. Let us remember the words of the great French historian Jules Michelet,[61] which can apply to the quest

Risorse energetiche e politica in prospettiva storica", *Ricerche di Storia Politica*, XXI, 1, 2018.

57 Denis Hayes, *Rays of Hope. The transition to a Post-Petroleum World* (New York: Norton, 1977).

58 See the recent dossier in the *Annales Histoire, Sciences sociales: "Anthropocène"*, (April-June 2017, 72/2, EHESS-Cambridge University Press).

59 "Not in My Backyard" ; "Build Absolutely Nothing Anywhere Near Anyone".

60 For example Roger Fouquet, "Lessons from Energy History for Climate Policy : Technological Change, Demand and Economic Development", *Energy Research and Social Science*, vol. 22, 2016. Or Robert F. Hirsch and Christopher F. Jones, "History's Contributions to Energy Research and Policy", *Energy Research and Social Science*, vol. 1, 2014, 106-111.

61 Jules Michelet, *Extract from Introduction à l'histoire universelle* (Paris: Calmann Lévy, 1879).

for energy: "With the world began a war which must finish with the world, and not before: that of Man against Nature, of mind over matter, of freedom against fatality. History is nothing more than the story of this endless struggle". The conquest of energy would thus be a concentration of the efforts to wrench man from the terrible limitations of his physical force. It can become the perfect symbol of *hubris,* like Prometheus seizing the fire—when the Gods would destroy us they make us believe there are no limits. It can equally be an object of pride since Humanity has been able to push back the limits and develop the strength necessary for its development. Today, doubt and fear certainly very often dominate. But if there are no *lessons* to be learnt from history, History can nonetheless give us sufficient knowledge and reflection for our contemporaries to be less disarmed and less arrogant. Consequently one can hope that the approach of the present journal will interest the curious, honest minds of the 21st century, and not only the "academic". An issue such as energy concerns us all. To avoid easy argument, it will be necessary to deepen knowledge, to listen and to understand. The subject of this journal is therefore broader than an academic discipline. It can be a place for knowledge and debate, to go beyond the controversies, to seek, firmly and modestly, a few historical facts to analyse and contextualize. History thus must be accessible, like an open book. Certainly it is the historian who writes, organises and chooses, but with the most critical mindset so as to reach the space in which a scientifically founded idea moves. Let us then leave the conclusion to a historian: "To understand is not to judge" (Marc Bloch), and to a philosopher: "We expect history to add a new province to the varied empire of objectivity"[62] (Paul Ricoeur).

62 Paul Ricoeur, *Histoire et vérité* (Paris: Seuil, 1955), 24.

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Energy consumers, a boundary concept for the history of energy

Abstract

The historical approach of energies consumers is based on several questions on the conceptual frameworks. In the dailylife anthropology framework, energy consumption disappears behind the use of the artefacts and becomes an infra-consumption. The category of "energy" itself presumes an integrated vision of energy sources. This vision is not rooted in the consumers practices and we suggest the concept of "energies consumers" to be closer to these behaviours. From this dialogue between empirical and theoretical approaches, the "energies consumers" is a concept fruitful for the contemporary historical works (gender, global history, transition...).

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1 In the endeavor of constructing an integrated history of energy—or more simply a history of energy—the demarcation of the field comes up against many boundary concepts.[1] These boundary concepts belong to a number of disciplines, and as such anchor historical methods both when facing and alongside the other social sciences. Energy consumption and consumers fall under this situation. The very definition of the category of "energy consumer" raises problems for the historian, with respect to both the first and second term. It is an unproductive assessment on the part of the historian to consider that the "energy consumer" will orient himself toward a history of consumption and energy, given the extent to which both are still emerging, and how neglected a subject the energy consumer is with respect to both. Moreover, while the discipline of history is just beginning to seize upon the subject, the large amount of research in other disciplines in the Humanities and social sciences evinces a dynamic that sometimes has a tendency to carry away the historian, instead of enabling him to better establish his disciplinary field. Historical reflection is nourished by the results and epistemological explorations[2] of fields such as the sociology of consumption and the sociology of energy, consumer law and energy law, consumption economics and energy economics, along with the geography of consumption and energy geography.

2 In the history of consumption, which has undergone a major renewal over the last decade in the work of Frank Trentmann,[3] Matthew Hilton, Marie-Emmanuelle Chessel,[4] Ruth Oldenziel and others, energy has long occupied a minor role. The contribution of these authors was to leave behind questions regarding the origins of consumer society, all while maintaining that "an initial increase in consumption"[5] during the eighteenth century, along with a transformation of distribution methods during the twentieth century, were both major shifts. By positioning the history of consumption within the circulation of objects, the material civilization of everyday life, and the organizational methods of consumers, this research definitively ascribed a singular role to consumers and users, especially in European history, by making them independent of productive structures.[6] Within this social and political history of consumption, which tempers cultural explanations for consumption and even more so political ones, energy remains largely ungraspable, in the sense that the marketing and distribution of energy seem to follow a logic that is different than that of objects, as a result of regulation and legislation constructed around the notion of "public service," as well as the disappearance of the purchased product in the act of consumption. For that matter, purchasing practices for energy leave little room for the symbolic dimension that serves as an explanatory linchpin for anthropological approaches. The "Material Cultures of Energy" project led by Frank Trentmann and Hiroki Shin, which was completed in 2017,[7] laid the groundwork for the history of energy consumption through four research focuses (space, forecasting, shortage, transition). Yet even in the most recent research, consumers have often been less studied than consumption and its staging, to the point of being called a "missing person"[8] in the history of

1 Boundary concepts are the pendants of boundary objects for the social sciences, that is to say categories that concern various disciplines. Pascale Trompette and Dominique Vinck, "Retour sur la notion d'objet-frontière," *Revue d'anthropologie des connaissances*, vol. 3, n° 1, 2009, 5-27.

2 Éric Rémy, Philippe Robert-Demontrond (eds), *Regards croisés sur la consommation* (Cormelles-le-Royal: Éditions EMS, 2014) ; Roberta Sassatelli, *Consumer Culture: History, Theory and Politics* (Los Angeles: Sage Publications, 2007).

3 Frank Trentmann, "Beyond Consumerism: New Historical Perspectives on Consumption," *Journal of Contemporary History*, vol. 39, n° 3, 2004, 373-401 ; Frank Trentmann, *Empire of Things. How We Became a World of Consumers, from the Fifteenth Century to the Twenty-first* (London: Allen Lane, 2016). The author evokes the domain of energy a number of times in this magisterial compendium.

4 Marie-Emmanuelle Chessel, *Histoire de la consommation* (Paris: La Découverte, 2012).

5 Daniel Roche, *Histoire des choses banales. Naissance de la consommation. XVIIe-XIXe siècle* (Paris: Fayard, 1997), 10.

6 Ruth Oldenziel and Mikael Hård, *Consumers, Tinkerers, Rebels. The People who Shaped Europe* (Basingstoke: Palgrave MacMillan, 2013).

7 http://www.bbk.ac.uk/mce

8 Frank Trentmann, "Knowing Consumers – Histories, Identities, Practices", *in* Frank Trentmann (ed.), *The Making of the Consumer. Knowledge, Power and Identity in the Modern World* (Oxford - New York: Berg, 2006), 1.

consumption, despite the paradoxical fact that the "consumer-citizen" has never been more present in discourses.

3 It is important to recognize that the history of energy does not truly exist today. Approaches focusing on an energy source have explored consumption and consumers, but have done so by giving preference to a particular source, and more rarely by examining the processes of choice, situations of competition, and mechanisms of substitution and replacement. Historical analyses of energy companies and their markets have drawn attention to marketing strategies, notably for gas and electricity. Uses and users have been presented in research that remains broadly incomplete despite having opened the way forward,[9] which is not the case for consumers of coal, oil (gasoline or heating oil), and alternative sources of energy. The book *Consuming Power* by David E. Nye marked one stage in this understanding of energy consumption, by emphasizing ordinary behavior within a complex process of the construction of energy systems.[10] However, this book—and this is not a criticism—remains on a high level of generality, one that is in keeping with a panorama stretching over multiple centuries, and based more on the cultural characteristics associated with each energy than on a history of practices.

4 Finally, with regard to methods, the historian is on shifting ground given the plethora of research on energy consumers in the fields of sociology, political science, law, economics, anthropology, and semiology. The contribution of history is not reducible to applying concepts from the other social sciences to the past, however heuristic they may be. The historiographical appraisal of studies of energy consumers is ultimately quite scant, perhaps due to a lack of clearly identified sources, although it is not entirely empty. This text, which is based on new approaches to the history of consumption, as well as current explorations that span the historical field, will sketch out a few areas of future research within a history of energy approach, as well as avenues to avoid. The objective of this text is not to develop a consensus-based and historicized definition of the "energy consumer" that seeks to serve as a reference for future research, nor is it to proceed with the preliminary deconstruction of a notion, an indispensable stage in analysis. It is instead the exploration of what the concept of "energy consumer" denotes for the historian.

FOR A SYSTEMIC APPROACH TO ENERGY CONSUMERS

Energy consumers nowhere to be found

5 The category of "energy consumer" is not an obvious one for the historian, as the singular makes it as mysterious as the "European voter," "French laborer," or "Eastern merchant." Because the historical approach is firstly based on concrete contextualized situations rather than the construction of an ideal-type, the plural imposes itself, and "energy consumers" subsequently replaces the imperfect "energy consumer." But are energy consumers any more graspable by historians? Nothing could be less certain. Energy is consumed in all human activity (cooking food, heating lodgings, lighting, transportation, producing goods), and this was true well before any notion of "consumer society" or of the commercial circulation of objects. Certain approaches emphasize the physical aspects of these energy productions, especially animals and humans, without giving consumers a role in this dynamic.[11] During the modern period, consumption increased considerably, corresponding of course to the increase in production by different energy sources, as well as the increase in uses.[12] The usual distinction between industrial

9 AHEF (Association pour l'histoire de l'électricité en France), *L'électricité et ses consommateurs, textes réunis et édités par Fabienne Cardot* (Paris: AHEF/PUF, 1987) ; Serge Paquier, Jean-Pierre Williot (dir.), *L'industrie du gaz en Europe aux XIXe et XXe siècles. L'innovation entre marchés privés et collectivités publiques* (Bruxelles: Peter Lang, 2005), especially ch. 2.

10 David E. Nye, *Consuming Power. A Social History of American Energies* (Cambridge: The MIT Press, 1998), 11.

11 Jean-Claude Debeir, Jean-Paul Deléage, Daniel Hemery, *Une histoire de l'énergie. Les servitudes de la puissance* (Paris: Flammarion, 2013).

12 David E. Nye, "Consumption of Energy", *in* Frank Trentmann (ed.), *The Oxford Handbook of The History of Consumption* (Oxford: Oxford University Press, 2012), 307-325.

and domestic consumers amounts to separating energy as a factor of production from energy as the satisfaction of non-productive needs. This is how statistics included the service and domestic sectors in gas and electricity consumption, since this consumption was "non-productive."

6 From a historical perspective, and following on the concept of "technological momentum,"[13] the first consumers of a given energy, often industrial actors, are crucial in the growth of an industry and the structuring of production capacities, whether it be for coal, electricity, or oil. According to Thomas P. Hughes, these first users were not simply purchasers of energy, but actually the designers of energy networks, which were constructed according to a process seeking to satisfy these initial demands. Since the phase of industrialization initiated in the mid-eighteenth century, factories, works, and mills were the first consumers of energy, thereby fashioning a new system of consumption.[14] This social construction of networks by energy consumption has strong inertia, framing the subsequent production and consumption that develop in enduring fashion. By defining the market, these industrial activities structured energy networks and marketing methods, and even became involved in the construction of production capacities for their own needs. Industrial consumers thus became producers according to a logic of vertical integration, in an effort to control costs and to not be entirely dependent on suppliers. Verified for gas, oil, and coal (steel industry), this logic reached its most developed expression with electricity during the first half of the twentieth century in Norway (Norsk Hydro), Germany, Switzerland (Aluminium Industrie AG, subsidiary of AEG), France (Ugine, Pechiney), and the United States (Alcoa).[15] The primary consumers of electricity remained the electro-intensive companies in the aluminum, chemistry, steel, and railroad industries.[16] Today other major firms, such as Google, which is acquiring wind and solar farms and has set the goal of 100% renewable energies for its purchases, are developing production capacities in order to control costs and free themselves of purchases that are dependent on fossil energies, notably in terms of public image. Historical studies are woefully lacking on these industrial energy consumers despite their role, whether it be through an approach focusing on an energy source, or through the set of scales ranging from a monograph on an industrial site to the European or even global space.

7 Unsurprisingly, the consumers that have drawn the most attention—even though they did not necessarily have a leading role in the energy system depending on the period or the energy source (domestic consumers represented less than 10% of coal consumption in the United Kingdom in 1900, as opposed to 38% around 1830)[17]—are indeed households, and hence domestic consumption. The first traces of an institutional definition of domestic consumers appeared in legal proceedings, for instance when British courts defined a "consumer interest" in contractual negotiations between a gas supplier and clients, offering recommendations as early as 1847 to avoid the commercial exploitation of consumers by gas companies.[18] The regulation of a local energy system by legal or political authorities was not necessarily in favor of

13 Thomas P. Hughes, *Networks of Power. Electrification in Western Society, 1880-1930* (Baltimore: The Johns Hopkins University Press, 1983) ; Richard F. Hirsh, « Power Struggle: Changing Momentum in the Restructured American Electric Utility System », *Annales historiques de l'électricité*, n° 2, 2004, 107-123.

14 Vaclav Smil, *Energy Transitions. History, Requirements, Prospects* (Santa Barbara: Praeger, 2010), 10.

15 William J. Hausman, Peter Hertner, Mira Wilkins, *Global Electrification. Multinational Enterprise and International Finance in the History of Light and Power, 1878-2007* (New York: Cambridge University Press, 2008), 90-91 ; Denis Varaschin, *La fée et la marmite. Electricité et électrométallurgie dans les Alpes du Nord* (Le Parnant: La Luiraz, 1996).

16 Christophe Bouneau, *Entre David et Goliath. La dynamique des réseaux régionaux. Réseaux ferroviaires, réseaux électriques et régionalisation économique en France du milieu du XIXe siècle au milieu du XXe siècle* (Pessac: MSHA, 2008).

17 Astrid Kander, Paolo Malanima, Paul Warde, *Power to the People. Energy in Europe over the Last Five Centuries* (Princeton: Princeton University Press, 2013), 189-190.

18 Martin Daunton, "The Material Politics of Natural Monopoly: Consuming Gas in Victorian Britain", *in* Martin Daunton, Matthew Hilton (ed.), *The politics of consumption. Material Culture and Citizenship in Europe and America* (Oxford, New York: Berg, 2001), 69-88.

consumers: the case of the local government in Manchester, which maintained a high price for gas in order to collect revenues and thereby reduce taxes, echoes that of Geneva, where the municipalization of energy networks in the late nineteenth century was in keeping with the same preoccupation on the part of local elites to ensure "good management," in an effort to avoid tax increases.[19] In these different examples, the emergence of the category of "energy consumers" proceeded from an institutionalization of regulation.

8 This institutional approach to the notion has hardly exhausted the subject. Reflection regarding the category of energy consumers has also drawn on an empirical process. Consumption is segmented socially and spatially, especially in an urban environment it helps to structure,[20] defining consumers based on their lifestyles, social belonging, and spaces. This segmentation of spaces in the characterization of energy consumers cannot be reduced to the city/country distinction, even if we are aware of the role of the countryside in the emergence of new uses through a behavior of resistance/appropriation in the United States,[21] and even within the definition of "consumption systems" through a hybridization of behavior combining self-sufficiency and commercial networks.[22] Once could mention for instance the continuation of self-supply for wood, even with homes being connected to a network providing electricity.

9 Finally, from a historical perspective, one of the primary difficulties is the identification of consumers at a given moment. Statistical aggregates over the *longue durée* outline trends,[23] although the result of these compilations is disappointing when they limit themselves to adding up energy sources. Disruptions, whether accidental or connected to an event, serve as revelatory moments for such consumption by disrupting consumer behavior.[24] This is especially true of blackouts[25] as well as geopolitical crises, such as the Suez crisis in 1956 or the OPEC decision in September 1973; even the shortage of coal during the world wars revealed consumption at the very moment it was disappearing. Energy consumers, who are difficult for the researcher to grasp, become partially visible in the sense that they must adapt to an abruptly new situation.

10 The first assertion therefore sounds obvious: there is not *a* consumer of energy, but rather *consumers* of energy. The diverse statuses between companies, administrations, and private individuals, along with the multitude of uses ranging from car transportation to apartment heating, make it difficult to be satisfied with aggregate statistics, whether on the national level or by energy type. How should the coal that still served in 1960 for locomotive propulsion be added to the buckets needed for a few old domestic stoves in the city center, or to a modern electricity production factory? Quite the contrary, it is through tracking the behavior behind consumption data that consumers can be found, thereby making energy a social relation[26] and not just a physical measurement.

19 Serge Paquier, "Développement internationale des industries de réseaux et construction d'une identité nationale : les cheminements technologiques et institutionnels des villes suisses vers un système stabilisé au XIXe siècle," *Flux*, n° 72/73, 2008, 13-26.

20 Jon Stobart, Andrew Hann, Victoria Morgan, *Spaces of Consumption. Leisure and Shopping in the English Town, c. 1680-1830* (Abingdon: Routledge, 2007), 18-19.

21 Richard Kline, "Resisting Consumer Technology in Rural America: The Telephone and Electrification", *in* Nelly Oudshoorn, Trevor Pinch (eds.), *How Users Matter. The Co-Construction of Users and Technology* (Cambridge: The MIT Press, 2003), 51-66.

22 Jean-Claude Daumas, "La consommation dans les campagnes françaises dans les années 1880-1914 : un régime de transition," *in* Nicolas Marty, Antonio Escudero (ed.), *Consommateurs & consommation. XVIIe-XXIe siècle. Regards franco-espagnols* (Perpignan: Presses universitaires de Perpignan, Publicacions Universitat d'Alacant, 2015), 221-248.

23 Astrid Kander, Paolo Malanima, Paul Warde, op.cit., 457 (cf. note 17).

24 Frank Trentmann, "Disruption is Normal. Blackouts, Breakdowns and the Electricity of Everyday Life," *in* Elizabeth Shove, Frank Trentmann, Richard Wilk (ed.), *Time, Consumption and Everyday Life. Practice, Materiality and Culture* (Oxford: Berg, 2009), 67-84.

25 David E. Nye, *When the Lights went out. A History of Blackouts in America* (Cambridge: The MIT Press, 2010).

26 Mathieu Arnoux, *Le temps des laboureurs. Travail, ordre social et croissance en Europe (XIe-XIVe siècle)* (Paris: Albin Michel, 2012).

In search of energy consumers

11 Have energy consumers previously consumed energy? There is nothing incongruous about the question, given how much the analysis of consumer behavior in modern societies is based on the premise that consumers had a capacity to choose. Some uses, especially those connected to public services (education, health), can be grasped outside of this framework. However, following on numerous studies of self-service stores and retailers,[27] the staging of choice and the conditioning of consumer behavior are considered as pillars of "consumer societies." The capacity to choose assumes a possibility of choice, in other words a kind of competition between different products. Contrary to a vision based on the monopolies of private or public companies, situations of competition were not absent from the field of energy, quite the contrary. Sometimes likened to public services, companies providing energy could compete with one another. Let us think, for instance, of retailers of the coal that provided the essential part of energy for heating and cooking for most European households until the 1960s. Not only were different qualities of coal distinguished in order to adapt to the retail market,[28] thereby creating competition between products, but different brands, sources, and distribution channels were also battling it out among themselves. Similarly, the act of purchasing gasoline for a car was clearly connected to a distinction between fuels (depending on the motorization, but also on additives), with different prices and communication processes (the most classic being the accumulation of points to ensure customer loyalty), competing brands, along with commercial and political considerations connected to the taxation of gasoline. Unlike stored energies, in the case of flow energies such as gas and electricity, competition between companies was less frequent until the recent period of deregulation. We will nevertheless mention the case of Barcelona and Marseille, where electrical companies contended with one another before the First World War.[29]

12 While this competition between providers of the same energy deserves attention, what is more interesting for a history of energy is actually competition between different sources of energy. Some uses were involved in confrontations over the *longue durée*. Cooking and heating are the best examples of a competition that does not necessarily include competition between companies. For cooking, it would be simplistic to consider the evolution of energy sources as a linear succession, transitioning from wood to coal, and then to gas and ultimately electricity. Not only were hybrid systems (coal-gas, gas-electricity) successfully developed, but different energies coexisted more than they succeeded one another, as manufacturers of gas stoves innovated to preserve their market share, often with the support of energy companies.[30] For heating as well, recompositions took place during the twentieth century, sometimes even within a few years. In the United States in 1950, the primary fuels were coal (35% of homes), gas (29%), and oil (23%). Wood was still the primary fuel in 11% of homes, while electricity was used in less than 2% of households. Two decades later, coal represented only 3% and wood 2%, while the share of gas had risen to 61%.[31] Lighting

27 Franck Cochoy, *Aux origines du libre-service. Progressive Grocer (1922-1959)* (Lormont: Le Bord de l'eau, 2014) ; Ralph Jessen, Lydia Langer (ed.), *Transformations of Retailing in Europe after 1945* (Farnham: Ashgate, 2012). We note the recent appearance of a journal, *History of Retailing and Consumption* (Taylor & Francis Online).

28 Nadège Sougy, *Les charbons de la Nièvre, La houillère de La Machine, ses produits et ses marchés (1838-1914)* (Grenoble: PUG, 2008).

29 Horacio Capel (dir.), *Las Tres Chimeneas. Implantación industrial, cambio tecnológico y transformación de un espacio urbano barcelonés* (Barcelon: FECSA, 1994) ; Yves Bouvier, *Connexions électriques. Technologies, hommes et marchés dans les relations entre la Compagnie générale d'électricité et l'Etat. 1898-1992* (Bruxelles: P.I.E. Peter Lang, 2014), 56-67 for the case of Marseille, and 115-121 for Barcelona.

30 Yves Bouvier and Léonard Laborie, "L'Europe comme civilisation matérielle en transition," *in* Yves Bouvier and Léonard Laborie, eds., with the collaboration of Reynald Abad and Arielle Haakenstad, *L'Europe en transitions. Énergie, mobilité, communication. XVIIIe-XXIe siècles* (Paris: Nouveau monde éditions, 2016), 9-21.

31 Stanley Lebergott, *Pursuing Happiness. American Consumers in the Twentieth Century* (Princeton: Princeton University Press, 1993), 107.

was also the subject of rivalry between gas and electricity for public spaces, and between the oil lamp and electrical bulb for private spaces.[32]

13 This competition between energies therefore entails a situation of choice for the consumer. Yet were consumers genuinely making a choice between energies when they chose an electrical refrigerator instead of a gas refrigerator in 1950? How was the choice of a new stove made: was it firstly a desire to modernize an interior, or to change energy source? At what moment and to what extent is energy a criterion in a consumer's purchasing decision for a capital good? The answer is not clear given how much purchasing logic, or at least what historians can perceive of them, differs from one use to another. The energy consumption of an appliance can have an impact on the choice depending on the price of the initial investment and consumption during use, introducing a sometimes summary economic calculus into the purchasing decision. Once again, reducing the analysis to individual choice risks obscuring the overall aspects of household appliances and energy infrastructures. The kitchen is also a technical and political construction, illustrated by the kitchen debate between Nixon and Khrushchev.[33] Similarly, likening an individual car to a new liberty no doubt confers a political meaning on this acquisition.[34]

14 What role should be ascribed to the choice of energy in consumption that combines political meaning, economic interests, and social aspirations? In a certain way this is a question that is no longer relevant, for the notions of choice and energy cannot be adopted without critical examination. By opting for one source of energy rather than another, do consumers think of themselves as energy consumers? Do they formulate an energy choice? By establishing the list of energy consumption for a suburban area during the 1980s, which more or less corresponds to a "social model" of Western societies, we find both charcoal for summer barbecues as well as fuel oil for the boiler, natural gas for the stove, gasoline for the car, and electricity from either a nuclear, hydraulic, or thermal source for lighting and practically all household appliances. Recent sociological studies[35] have challenged this approach of complete awareness on the part of consumers. What emerges is that energy consumers are in fact "consumers of energy," not only because behavior leads them to use different sources of energy, but especially because a global and uniform grasp of energy is not put in place at any point. In other words, the fragmentation between energy sources portrays a consumer broken into little pieces, running counter to a conception of *homo consumericus*[36] as *homo economicus*, or even as a rational social actor.

ENERGY CONSUMERS IN CURRENT HISTORICAL APPROACHES

15 By considering that "energy consumers" is more of an analytical category—even if this is sometimes the case in certain consumerist groups—we can examine current historical paradigms to determine what role this category should be given. A history of energy is therefore firstly inscribed in the dynamics of the historical field.

Energy consumers in globalizations

16 While consuming different sources of energy, did individuals from Western societies think of the implications of this consumption? The question of course applies today, although it merits being asked of earlier periods. Numerous consumerist groups have sought to make consumers more responsible, which is to say to unveil the mechanisms that enable this consumption in order to bring about a change in behavior, whether through the acceptance of a higher price (fair

32 Alain Beltran, "Lumières 'fin de siècle' en Europe (1880-1914)," *in* Y. Bouvier, L. Laborie (eds.), op.cit., 169-189 (cf. note 30).

33 Ruth Oldenziel and Karin Zachmann, ed., *Cold War Kitchen. Americanization, Technology and European Users* (Cambridge: The MIT Press, 2009).

34 Mathieu Flonneau, Léonard Laborie, and Arnaud Passalacqua, eds., *Les transports de la démocratie. Approche historique des enjeux politiques de la mobilité* (Rennes: Presses universitaires de Rennes, 2014).

35 Sophie Dubuisson-Quellier, ed., *Gouverner les conduites* (Paris: Les Presses de Sciences-Po, 2016).

36 Gilles Lipovetsky, *Le Bonheur paradoxal. Essai sur la société d'hyperconsommation* (Paris: Gallimard, 2006), 11.

trade), or the boycott of products for moral, political, or environmental reasons. Energy does not escape this rule.

17 With the global turn, the historian has the legitimate temptation to propose a global history of energy, although this has been much more attached to productions and their physical measurement[37] —not without lapsing into caricature[38] —than to consumers. Some historical studies of non-Western worlds have prepared the subject,[39] although it is raw materials in particular that can inscribe consumer behavior in this approach. Oil,[40] coal, and uranium[41] lend themselves well to this global history, which consists of the circulation of materials on the planetary level, along with economic interests, links between energy resources and political authorities that are rather easily seen as being inflammatory, and the deconstruction of consumer behavior by both consumerist movements and public authorities. It is hardly a revelation to affirm that the Berlin car driver in 1900 was inscribed in a global economy, since oil was primarily imported from the United States,[42] or that the user of a hairdryer in Paris in 1985 was connected to the uranium mines of Niger, or that the boy carrying a bucket of coal in a Neapolitan building in the 1870s was connected to British imperial power.[43] Perhaps more so than in other domains—although this remains to be proven for food and leisure—energy consumers are globalized consumers, in the sense that energy sources circulate on a global level. Explorations of global history, which focus on phenomena of global dimensions as well as connections/circulations and processes of integration,[44] are absent from this research, leaving the task of periodizing the globalization of the energy consumer entirely open.

18 Economic and diplomatic considerations, much more so than environmental ones, have marked out the institutionalization of the global scale in the field of history.[45] The circulation of raw materials first and foremost had a political connotation that imposed itself in the very conception of the consumer. Until the mid twentieth century, the import of British or German coal by France, Switzerland, and Italy created a dependence of which the political authorities were aware, but which remained relatively removed from consumers given how much the promotion of this energy was based on the commercial dynamism of private actors. For instance, for French households before the First World War, the promotion of British or German anthracite for heating had supplanted the coke from national steel and gas industries. Similarly, in Europe during the 1970s and 1980s, the origins of oil imports (Middle East, Africa, Soviet Union) were familiar in public opinion, even if only through the oil crises and contracts signed with the Soviet Union. Yet it seems that no consumer movement was able to organize by emphasizing the political aspects of this supply of provisions.

19 The environmental consequences of energy consumption are evident today on two levels: within the consumption itself, and within the production of energy that is made available. Whether evoking the pollution connected to combustion engines, diesel or not, or the waste from

37 Vaclav Smil, *Energy in World History* (Boulder: Westview Press, 1994) ; Alfred W. Crosby, *Children of the Sun. A History of Humanity's Unappeasable Appetite for Energy* (New York: W.W. Norton & Cy, 2006).

38 Bruce Podobnik, *Global Energy Shifts. Fostering Sustainability in a Turbulent Age* (Philadelphia: Temple University Press, 2005) ; Timothy Mitchell, *Carbon democracy. Political Power in the Age of Oil* (New York: Verso, 2011).

39 Pierre Lanthier, "Appropriating modernity : electricity in Mumbai's slums before the financial crisis of 2008," *Entreprises et Histoire*, n°70, 2013, 92-105.

40 Brian C. Black, *Crude Reality. Petroleum in World History* (Lanham: Rowman & Littlefield Publishers, 2012).

41 Gabrielle Hecht, *Being Nuclear, Africans and the global Uranium Trade* (Cambridge: The MIT Press, 2012).

42 Helmut Mejcher, "Banking and the Germano oil industry, 1890-1939," *in* R.W. Ferrier, Alexander Fursenko, *Oil in the World Economy* (Abingdon: Routledge, 2016 [1989]), 95-96.

43 Giovanni Federico, Sandra Natoli, Giuseppe Tattara, and Michelangelo Vasta, *Il commercio estero italiano. 1862-1950* (Bari: Editori Laterza, 2011), 37.

44 Sebastian Conrad, *What Is Global History?* (Princeton: Princeton University Press, 2016), 6-11.

45 A number of histories of international organizations connected to energy have been completed. See especially Rebecca Wright, Hiroki Shin, and Frank Trentmann, *From World Energy Conference to World Energy Council. 90 years of cooperation, 1923-2013* (London: WEC, 2013).

nuclear power plants, environmental considerations have become a structural part of industrial societies. Against a backdrop of global warming, it is indeed fossil energies that have primarily been blacklisted. But has consumer behavior integrated this awareness in everyday gestures? Have consumers made the connection between their consumption and the environmental aspects of production? The historian is not in a position to provide an answer, only to seek out in the past the expression of an energy boycott, or of a public opinion campaign on the subject. The identification of environmental consequences does not date from recent decades.[46] Well before the dramatic episode of 1952, London fog was identified as a consequence of mass coal use. In similar fashion, the effects of the overconsumption of wood gave rise to increasingly political debates during the eighteenth century.[47] The construction of the Cusset factory-dam in the heart of Lyon during the 1890s was based on both a discourse of maintaining small-time jobs and on a local hygienism that boasted of the disappearance of smoke resulting from the use of hydroelectricity.[48] The health effects of the pollution generated by leaded gasoline were identified and fought in the United States beginning in the 1970s. At the time, 98% of motorized vehicles used this type of gasoline, and 80% of the lead in the air was due to automobiles.[49] Yet these environmental arguments were situated in and associated with local configurations, with the occasional assertions applying a global scale being much more rhetorical than argumentative. In the end, it was during the 1980s, with the emergence of the notion of a global environment, that this new idea was introduced: energy consumption has effects on global warming and the pollution of the planet.

20 In this globalization of energy consumption, the tendency to ascribe guilt to the consumer is more in keeping with a moral injunction than a historical observation of consumer practices. It would be useful in this respect to retrace how the moralization of energy consumption emerged in discourses, especially to see how stigmatization, denunciation, and discernment appeared.[50] Of course political movements in the past relied on consumer awareness to fight against slavery and political situations (boycott in Ireland, or more recently against Apartheid in Sought Africa, or against the occupation of Palestinian territories). Yet there are no studies for consumer movements linking coal consumption with working conditions in mines—whose health aspects were well-known even though history began exploring the subject only recently[51]—or for movements that succeeded in mobilizing motorists against oil spills or military conflicts linked to oil interests. We can naturally analyze the current situation, as Jean-François Mouhot has done, as one of an emerging awareness of environmental considerations resulting from the least consumption of everyday energy.[52] Nevertheless, no such movements were structured for energy in the past. The antinuclear movement itself, powerful albeit not very structured, only marginally focused its activities on electricity consumers, preferring instead to politicize the subjects of its risks and waste instead of a boycott of electricity consumption.

21 Energy consumers were thus firmly inserted in this global circulation of raw materials, particularly with the rise of coal and oil. While the

46 Jean-Baptiste Fressoz, *L'apocalypse joyeuse. Une histoire du risque technologique* (Paris: Seuil, 2012).

47 Reynald Abad, "L'Ancien Régime à la recherche d'une transition énergétique ? La France du XVIIIe siècle face au bois," *in* Y. Bouvier, L. Laborie (eds.), op. cit., 23-84 (cf. note 30).

48 Stéphane Frioux, *Les batailles de l'hygiène. Villes et environnement, de Pasteur aux Trente Glorieuses* (Paris: PUF, 2013) ; Denis Varaschin, *La Société Lyonnaise des Forces Motrices du Rhône (1892-1946). Du service public à la nationalisation* (Le Parnant: La Luiraz, 1996).

49 Peter Dauvergne, *The Shadows of Consumption. Consequences for the Global Environment* (Cambridge: The MIT Press, 2008), 80.

50 Mathieu Brugidou, "Faire preuve de discernement à propos des économies d'énergie : un nouvel énoncé des ménages/citoyens," *in* Isabelle Garabuau-Moussaoui, Magali Pierre (dir.), *Pratiques sociales et usages de l'énergie* (Paris: Lavoisier, 2016), 227-239.

51 Judith Rainhorn, ed., *Santé et travail à la mine. XIXe-XXIe siècle* (Villeneuve d'Ascq: Presses universitaires du Septentrion, 2014).

52 Jean-François Mouhot, *Des esclaves énergétiques. Réflexions sur le changement climatique* (Seyssel: Champ Vallon, 2011).

prism of globalization is useful for the historian to grasp consumer practices, it does not appear to be very relevant to understanding the motivations of individual consumers, which are more inscribed in local social configurations with multiple dimensions, and which Jérôme Cihuelo and Arthur Jobert have called "interface situations."[53]

Social history of an infra-consumption

22 The consumer has been studied as the purchaser of objects, in accordance with a logic of comfort, equipment, and social signs.[54] The transfer of the North American "consumption system," with its political implications, to Europe has been the subject of numerous publications on a possible "Americanization" of Europe through lifestyles. Yet this "American mirror" is not so much that of energy, but of objects.[55] The purchasers of goods are never considered as energy consumers, even if these laundry machines, cars, and game consoles require energy. The energy consumer disappears behind the uses of goods,[56] making energy consumption an "infra-consumption."

23 Taking an interest in energy consumers entails abandoning entire sections of the social sciences devoted to consumption. How is it possible to conceive of a fetishization of the kilowatt-hour? What sacralization is there for the natural gas burning beneath a pan? Does an emotion as a consumer of energy take hold when a coffee maker is plugged in? Semiology and semiotics, which are sometimes included in studies, are not on solid ground when the subject is energy instead of a technical object. The economic approach itself is not always relevant in understanding consumer behavior: are we thinking of an electricity bill when we are in front of the television? The answer is of course no. As a result, the process of making energy consumption invisible can itself become a subject of exploration. Conversely, filling a stove with coal or turning the dial on a radiator can be associated with the expense generated. When consumers flipped the switch to turn on an electric bulb during the 1890s, they potentially had the cost per hour of lighting in mind, all the more so if they had just dropped a coin in the meter installed inside their home.

24 However, in the end it was the object that consumed energy much more than its user. And if we need to calculate the energy consumption of an object, what should be counted? The trips made for the purchase? The energy incorporated in the object for its manufacture, which can be calculated using life cycle analyses? And how to reconstruct the life cycle of objects from earlier periods? Consumption connected to use seems the most obvious, although it is not necessarily the most important; for instance for a cellular phone, the energy consumption connected to its manufacture represents approximately 75% of the total, as opposed to less than 20% for usage. Can one include the production of waste and possible recycling, and even the production of energy that is obtained in this phase? When the energy consumption of a device is mentioned, it is the consumption relating to its use. The European classification of household appliances is based on an energy label introduced in 1992, which presents the energy consumed during the appliance's use. This informs the consumer regarding an estimated bill, but not regarding the complete energy assessment of the purchased product. The question of the energy consumption of household appliances should also be resituated in historical perspective in order to understand when this information appeared, as well as for what type of object

53 Jérôme Cihuelo and Arthur Jobert, "Énergie et situations d'interface," *in* Jérôme Cihuelo, Arthur Jobert and Catherine Grandclément, eds., *Énergie et transformations sociales. Enquêtes sur les interfaces énergétiques* (Paris: Lavoisier, 2015), 217-236.

54 Mary Douglas and Baron Isherwood, *The World of Goods. Towards an Anthropology of Consumption* (New York: Basic Books, 1979).

55 Richard Kuisel, *Seducing the French. The Dilemma of Americanization* (Berkeley: University of California Press, 1993); Victoria de Grazia, *Irresistible Empire. America's Advance through Twentieth-Century Europe* (Cambridge: The Belknap Press of Harvard University Press, 2005).

56 Regina Lee Blaszczyk, *American Consumer Society, 1865-2005. From Hearth to HDTV* (Wheeling: Harlan Davidson, 2009). For the electric twenties in particular, p. 139-140 and p. 152-153. See also chapters 8 to 10 of Peter Scott, *The Market Makers. Creating Mass Markets for Consumer Durables in Inter-War Britain* (Oxford: Oxford University Press, 2017).

and energy source. The impact of certain contexts of shortage (war, economic crisis, embargo, increasing scarcity, etc.), along with strong competition between industrial actors in a period of prosperity, have played a decisive role in the introduction of this information.

25 This assessment of the partial invisibility of energy consumption agrees with the nuances provided by the notion of agency, which is to say the consumer's capacity to act on his or her environment. In the case of energy, it is actually the consumer's inability to act that is given priority, even if it is not synonymous with absolute passivity. Agreeing with Frank Trentmann's more general reflections on the new orthodoxy of the active consumer, which calls for a consensus-based discourse seeking to break with the pattern of mass consumption, one can consider that the figure of the consumer proceeded from a unification of behavior and demands in the late nineteenth century and especially during the interwar period, by virtue of the dual role of public authorities (legislation) and associations.[57] The consumer, and energy illustrates this assertion well, cannot be reduced to a simple marketing construction. A social history of consumers emphasizes the decisive nature of the years between 1910-1940 in the emergence of this new figure, especially through children's consumption.[58] The historical examination of the socialization of energy consumers has yet to be completed, although illustrated magazines and school programs contributed to "educating" consumers by promoting uses and elementary security rules.

26 Cultural approaches to energy, whether the study of utopic or dystopic representations or studies on gender, can also be questioned. Does a gendered history have meaning on the level of consumers? Responding in the affirmative may seem obvious, given how much the division of household tasks or the relation to certain goods—automobile, vacuum, washing machine, etc.—illustrate gender relations in Western societies. Yet here once again, energy disappears behind the object. The research of Kristin Ross,[59] Karin Zachmann and Ruth Oldenziel,[60] and Quynh Delaunay[61] avoids energy consumption. We should recognize that the abundance of advertising, along with the power of slogans (the inevitable "Moulinex liberates the woman" from 1962) and the consistent denunciations by feminist movements, have displaced analysis from a social history to the socio-cultural relations of gender. Social stereotypes have sometimes been associated with energy, as in this a 1967 study conducted by an applied sociology firm, which states that "gas is considered more feminine, and electricity more masculine. Gas is highly associated with household chores and the practice of everyday tasks. Electricity is associated with rigor, precision, knowledge, and progress. It entails industrial clarity and appears more rational, whereas gas is the symbol of pragmatism."[62] Only systematic academic studies of gender relations with respect to different energy sources and energy in general can provide a way out of conventional discourses. The most structured research began to appear in the United Kingdom.[63] A gendered history of energy probably deserves to be explored, although the connection to energy consumption could be minor, with the research that has already been conducted for energy leading to a rediscovery of obvious facts that are otherwise familiar.

27 The social relations that are inherent to consumption naturally concern the field of energy. In general, social norms do not conceive of

57 Frank Trentmann, ed., op.cit., 11 (cf. note 8).

58 Lisa Jacobson, *Raising Consumers. Children and the American Mass Market in the Early Twentieth Century* (New York: Columbia University Press, 2004), 4-5.

59 Kristin Ross, *Aller plus vite, laver plus blanc. La culture française au tournant des années soixante* (Paris: Editions Abbeville, 1997).

60 Ruth Oldenziel and Karin Zachmann, eds., op.cit. (cf. note 33).

61 Quynh Delaunay, *La machine à laver en France. Un objet technique qui parle des femmes* (Paris: L'Harmattan, 2003).

62 Opinion poll conducted by Cofremca and commissioned by Gaz de France. Archives nationales du monde du travail, 2011 020-8064.

63 Anne Clendinning, *Demons of Domesticity. Women and the English Gas Industry, 1889-1939* (Farnham: Ashgate Publishing, 2004) ; Graeme Gooday, *Domesticating Electricity: Technology, Uncertainty and Gender, 1880-1914* (London: Pickering & Chatto, 2008).

consumption in the same way depending on the social category: the moral of thrift for the poor, whereas the consumption of the rich is encouraged because it is good for prosperity.[64] Whether it is for wood during the eighteenth century or for the uses of coal by the working classes in cities during the nineteenth century, the search to limit consumption was inscribed in a discourse combining social economy and aspirations of social mobility. The "energy insecurity" that is observable was of course transformed when the notion of public service gradually took hold, initially through local regulations, although it involved only certain energies (electricity and gas, but not oil). It took until the turning point of the 2000s for legislation to recognize a "right to energy," under pressure from both unions and consumer organizations as well as through European regulations.[65] Unlike most capital goods, energy does not come under financing conditions based on credit. Except for the most underprivileged households, energy is considered as both a vital good and a commercial good, with the implementation of cut-offs for outstanding bills. Specific behaviors subsequently set in, as do strategies of access to energy for individuals in precarious situations,[66] combining social assistance, deferred cashing of bills, brief service interruptions, and possible violations through unmetered connections. We will simply note that the Soviet Union made universal access to energy—especially for heating—a pillar of its social model by implemented free energy supply, which could lead to waste as well as tensions in collective housing.

Unlike the shortage for the poorest consumers, 28
the behavior of the most well-to-do social categories was marked by abundance and even conspicuous consumption, in the sense of Thorstein Veblen. The strong blaze in the fireplace of a dwelling in Normandy, the increase of Christmas decorations, the gasoline consumption of certain 4x4s are so many signs of social affluence. Such behavior has been denounced since the mid-1970s, and in a kind of anthropomorphism energy waste is associated with social portliness[67] and the excesses of a society of energy abundance. Still, such behavior has not disappeared, although the most excessive manifestations are less visible. For all that, economic affluence still leads to considerable energy consumption, despite discourses encouraging greater control.[68]

Energy consumerism: organization, demands, and environmental turning point

While considering that energy consumers in the 29
past did not undergo strong structuring in the social domain, it is nevertheless useful to take interest in forms of mobilization and the role played by energy in these movements. There was an attempt to establish a "buyer's internationale" in 1908 during the international conference of the Ligues sociales d'acheteurs.[69] While advocacy movements were organized on a local basis, some movements had a larger scope, such as the creation of the *National Consumers League* in the United States in 1899, or the Ligue sociale d'acheteurs in France in 1902. Energy took its place within this emerging consumerism, which was both structured by elites and led by local social movements, as demonstrated by protests against gas rates in France before

64 Martin Daunton and Matthew Hilton, "Material Politics," *in* M. Daunton and M. Hilton, eds., *The politics of consumption. Material Culture and Citizenship in Europe and America* (Oxford, New York: Berg, 2001), 4.

65 François Bafoil, Ferenc Fodor, and Dominique Le Roux, eds., *Accès à l'énergie en Europe. Les précaires invisibles* (Paris: Les Presses de Sciences-Po, 2014).

66 These strategies, which are beyond the field of energy, are the focus of Anaïs Albert's work, Consommation de masse et consommation de classe. Une histoire sociale et culturelle du cycle de vie des objets dans les classes populaires parisiennes (des années 1880 aux années 1920) (Ph. D., université Paris 1 Panthéon-Sorbonne, 2014); Sophie Béroud, *Les Robins des bois de l'énergie* (Paris: Le Cherche Midi, 2005).

67 Benjamin Dessus, *Pas de gabegie pour l'énergie* (La Tour d'Aigues: éditions de l'Aube, 1994).

68 Anne Dujin and Bruno Maresca, "La température du logement ne dépend pas de la sensibilité écologique," *Crédoc. Consommation et modes de vie*, n° 227, 2010; Marie-Christine Zélem, *Politiques de maîtrise de la demande d'énergie et résistances au changement. Une approche socio-anthropologique* (Paris: L'Harmattan, 2010).

69 Marie-Emmanuelle Chessel, "Consommation et réforme sociale à la Belle Epoque. Le congrès international des Ligues sociales d'acheteurs (1908)," *Sciences de la société*, n° 62, 2004, 45-67.

the First World War.[70] Furthermore, as shown by Marie-Emmanuelle Chessel, modes of organization, discourse, and range of actions circulated on the scale of industrial societies fairly early, with internationalization being driven by the decisive role of Catholic circles engaged in social activities.[71] The organization of consumer movements took place in connection with industrial actors, while in the United States and Europe energy providers and equipment manufacturers supported associations or publications for the promotion of energy uses. The *Electrical Association for Women*, which was created in the United Kingdom in 1924 and existed until 1986, or the *Women's Gas Federation*, had equivalents in other countries, such as the Australian association founded in 1934 by Florence McKenzie, or Paulette Bernège's publications in France on the role of electricity in housekeeping. The transnational dimension of a political consumerism took other forms during the last quarter of the twentieth century with the diffusion of labels and certifications.[72] While present in the demands made by the consumer movements that developed and became institutionalized during the second half of the twentieth century, energy was rarely emphasized until recent years, when deregulation created situations of choosing between different providers. In the defense of consumers and in the practice of a state that regulates conflicts connected to consumption,[73] energy was likened to a public service, with subjects such as low prices, installation security, and generalized access. At the Salon des consommateurs, held for the first time in Paris in October 1972, energy companies organized their stands around three subjects: hygiene, health, and security. The intense debates regarding consumer society are indicative of the political dimension ascribed to consumers.[74]

30 In addition to structured movements, whose expression in the public sphere can be retraced, an infra-political interpretation emerged, particularly in the work of Lizabeth Cohen,[75] which combines the political system with consumer practices. A "Consumers' Republic" and even a "democracy of consumers" was apparently exported from the United States to Europe through advertising, cinema, productivity, discourses, and public relations.[76] This "new American hegemony" during the Cold War, which combined NATO protection, Marshall Plan assistance, and the adoption of American products, naturally came from the productivity of American industry, as did the "incredible consumption of energy during the manufacturing process."[77] Western democracies were thus consolidated and rooted in the liberal bloc by applying the slogan "the consumer is king." This perspective is of course somewhat simplistic, if only because it sets aside infrastructures, whose role in the integration of different blocs have been shown by other historians,[78] although it raises a real question in the political meaning to be given to consumers. While objects that use energy have been studied, such as the Miracle Kitchen by RCA-Whirlpool and its tour in Europe in 1957,[79] the same is not true of the political

70 Dominique Pinsolle, "Les grèves des abonnés du gaz en France (1892–1914): des grèves de consommateurs parmi d'autres ?," *Transportes, Servicios y Telecomunicaniones*, n° 25, 2013, 130-148.

71 Marie-Emmanuelle Chessel, *Consommateurs engagés à la Belle Époque. La Ligue sociale d'acheteurs* (Paris: Les Presses de Sciences-Po, 2012).

72 Michele Micheletti, "Le consumérisme politique. Une nouvelle forme de gouvernance transnationale ?," *in* Marie-Emmanuelle Chessel and Franck Cochoy, eds., "Marché et politique. Autour de la consommation engagée," *Sciences de la société*, n° 62, 2004, 119-142.

73 Alain Chatriot, "Qui défend le consommateur ? Associations, institutions et politiques publiques en France (1972-2003)," *in* A. Chatriot, ME. Chessel, and M. Hilton, eds., *Au nom du consommateur. Consommation et politique en Europe et aux États-Unis au XXe siècle* (Paris: La Découverte, 2004), 165-181.

74 Sheryl Kroen, "A political history of the consumer," *The Historical Journal*, vol. 47, n° 3, 2004, 709-736.

75 Lizabeth Cohen, *A Consumers' Republic. The Politics of Mass Consumption in Postwar America* (New York: Alfred A. Knopf, 2003).

76 Sheryl Kroen, "La magie des objets, le plan Marshall et l'instauration d'une démocratie de consommateurs," *in* A. Chatriot, ME Chessel, and M. Hilton, eds., op.cit., 80-97 (cf. note 73).

77 Richard Kuisel, op.cit., 150 (cf. note 55).

78 Per Högselius, Arne Kaijser, and Erik van der Vleuten, *Europe's Infrastructure Transition. Economy, War, Nature* (Basingstoke: Palgrave MacMillan, 2016).

79 Ruth Oldenziel and Karin Zachmann, "Kitchens as Technology and Politics," *in* R. Oldenziel and K. Zachmann, eds., op.cit., 1-10 (cf. note 33).

analysis of energy consumers, despite the fact that at least in Europe providers were generally public companies or even administrations, and political authorities developed recurring discourses on energy access. Energy was sometimes an electoral campaign theme, both on the local level by challenging concession-based municipal management in France at the turn of the nineteenth century, and on the national level when the British conservative party added requests from British households to its platform in the early 1950s, including those regarding gas and electricity.[80]

31 In energy as in other domains, critical consumerism was also a normative pattern that took concrete form through the implementation of labels, production of a discourse, and involvement in some consumption related issues, leading to the identification of consumer rights and responsibilities. By calling on the "responsibility" of consumers, these movements advocated for an aware, politicized, and involved consumer, who would jointly fashion his or her own behavior.[81] These discourses sought to increase the reflexivity of actors in everyday practices, but also assumed that consumers were active. The movement promoted green consumption as an "alternative," but came up against energy companies who promoted their own definitions of the green and responsible consumer. Finally, these movements put more emphasis on the (moral) responsibilities of the consumer rather than on his or her rights, thereby connecting with the origins of consumerism.

Energy consumers in technical and economic systems in transition

32 Energy consumers are grasped by the social sciences through different statuses: users, clients, consumers, etc. These statuses are partly linked to the nature of the relation established with the providers of this energy. The insertion of consumers within techno-economic systems gives rise to questions regarding temporalities. Consumers are placed in a situation of dependence with regard to providers by virtue of their connection to a technical network, as well as purchasing practices and the connection with companies. The question that arises is to know what role these energy consumers have in the dynamics of techno-economic systems.[82] Without returning to the role of pioneering consumers in the emergence of a system, the mass adoption of a new energy source creates a kind of energy dependence in the same way as "path dependence," all the more so as companies seeking to promote a new energy contend with consumers who consider these new energies to be "expensive, useless, and difficult to use," requiring entrepreneurs to build demand.[83] All while seeking to adopt the perspective of consumers in energy transitions, Christopher F. Jones must admit that despite boosters for demand, "providers of new energy developed in advance of consumer demand."[84] In other words, techno-economic systems for energy were built as systems of supply rather than demand, although certain uses, such as those linked to industry, played a structuring role.

33 Once again, sociological and anthropological studies of energy have demonstrated the complexity of current situations by studying consumer practices. Elizabeth Shove in particular combines the establishment of a social norm for domestic comforts with the technical and industrial considerations of appliances such as the washing machine, air conditioner, and hot water for showers.[85] The transitions at work are naturally the result of public policies, but also of

80 Matthew Hilton, *Consumerism in 20th-Century Britain. The Search of a Historical Movement* (Cambridge: Cambridge University Press, 2003), 179.

81 Roberta Sassatelli, "Virtue, Responsibility and Consumer Choice. Framing Critical Consumerism," *in* John Brewer and Frank Trentmann, *Consuming Cultures, Global Perspectives. Historical Trajectories, Transnational Exchanges* (Oxford New York: Berg, 2006), 219-250.

82 François Caron, *La dynamique de l'innovation. Changement technique et changement social (XVIe-XXe siècle)* (Paris: Gallimard, 2010).

83 Christopher F. Jones, *Routes of Power. Energy and Modern America* (Cambridge: Harvard University Press, 2014), 5.

84 *Ibid*., 232.

85 Elizabeth Shove, *Comfort, Cleanliness and Convenience. The Social Organization of Normality* (Oxford, New York : Berg, 2003). See also the highly informative site http://www.demand.ac.uk/.

a rapid transformation of consumer behavior, a behavior that should be historicized.[86]

34 The transition from the passive consumer to the consumer-producer is therefore interesting to study, for one could interpret it as a way of finding an active role for these energy consumers. However, in the past the industrial nature of production made it so that consumers could themselves produce their own coal, oil, or hydraulic energy, with this exploration of the consumer-producer rooting itself in reality during the period that began with the 1980s. The Danish movement against the Swedish nuclear reactor at Barsebäck promoted the development of wind energy in Denmark. While noting the participation of students in the construction of the famous Tvind wind turbine, interpreting the success of the Danish wind industry as a movement of users launching a new decentralized energy policy is excessive to say the least.[87] The same remark can be made for photovoltaic solar energy. In this declared transition toward renewable sources of energy—one championed by Jeremy Rifkin[88]—a new revolution involves consumers taking ownership of the energy system. The question of national models cannot for all that be set aside so easily, and the role of companies, promoted by a competitive vision of the energy market, can lead the historian only to a certain prudence with regard to these declared upheavals of energy systems.

35 In addition to the initial exploration that prompted us to believe that "energy consumers" have rarely behaved as conscious consumers, or with an integrated conception of energy, I sought to provide an overview of the paths available to the historian of energy. The historical subject emerges in all contemporary approaches, whether they involve diversity of behavior, social segmentation, the impact of cultural patterns, the inclusion of raw materials within international circulations, the production of discourses by organized movements, and the emergence of technical and moral norms. Listing the most stimulating historical examinations for a history of energy consumers cannot be done without first pointing out that they have a minor presence in sources. In a history of energy, research could thus focus on the history of measuring consumption (meters, bills, social relations), discourses regarding energy in organized consumer movements, competition between providers to attract clients and ensure their loyalty (advertising, marketing, social studies), the "production" of the consumer by educational institutions (teaching the security of using gas and electricity) and media tools (children's publications, cartoons, public campaigns, etc.), how unions experienced difficulty in including consumers in their forms of action and demands, international normalizations of products and services, and the circulation of products and practices on a planetary scale, among others. In the end, the history of energy consumers must lead to an identification of temporalities that do not fully overlap with those of technical macro-systems of energy production, and even more so with regulations and political institutions. It is through the implementation of these explorations on different scales that the history of energy—and not just the history of consumption—can in turn nourish boundary concepts and enter into dialogue with other disciplines.

86 Frank Trentmann and Anna Carlsson-Hyslop, "The Evolution of Energy Demand in Britain: Politics, Daily Life, and Public Housing, 1920s-1970s," *The Historical Journal*, 2017, 1-33.

87 Ruth Oldenziel and Mikael Hård, op.cit, 262-271 (cf. note 6); Matthias Heymann, *Die Geschichte der Windenergienutzung, 1890-1990* (Frankurt-am-Main: Campus Verlag, 1995).

88 Jeremy Rifkin, *The Third Industrial Revolution: How Lateral Power is Transforming Energy, the Economy, and the World* (Basingstoke: Palgrave Macmillan, 2011).

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From the history of sources and sectors to the history of systems and transitions: how the history of energy has been written in France and beyond*

Abstract
This historiographical essay shows how historians have dealt with energy since the beginning of the 20th c. and until today. During the two first third of the 20th c., only a handful of authors have tried to give an overview of humans made use of the energy existing all around them over centuries. Historians of the last decades of the 20th centuries were interested in specific energy *sources* as well as in energy *sectors*. More recently, tendency has come back to considering energy as a whole, studying energetic *systems* and the *transitions* between them. There has been so far no consensus on the nature and the stakes involved in the past transitions.

Plan of the article

* An expanded French version of this article will appear in Mathis Charles-François, Massard-Guilbaud Geneviève (dir.), *Systèmes et transitions énergétiques. Les hommes et l'énergie du Moyen Âge à nos jours*, Histoire environnementale 3 (Paris: Éditions de la Sorbonne, 2019). I would like to thank the Editions de la Sorbonne for authorizing this translation.

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1 The IPCC[1] (which is not a neutral institution, and whose history should be written one day, although for now its research remains the most reliable available) has long considered it *extremely likely* that the anthropogenic portion is the greatest cause of global warming.[2] While fossil energies, which represent 80% of the energy we put into use,[3] are not solely responsible for the entire anthropogenic portion, they are by far the major cause.[4] As a result, it is no longer possible today to write the history of energy as we (or our predecessors) did 15 years ago, by speaking of "king carbon" or "the electricity fairy," as though we were unaware of how we have all mobilized and continue to mobilize energy that now has an impact on our planet's climate[5]; as though we were unaware that the climate upheaval underway has already led and will continue to lead—if we persist in proceeding on the same course—to a considerable degradation of the conditions of life on Earth, with the most fragile humans being the ones most brutally affected. It is no longer time to quibble over the share of a particular activity's responsibility in the emission of greenhouse gases, or to continue studying energy as the driver of an economy that must proceed along the same path, as though nothing were wrong. The time has come for historians to study the relations that societies have maintained with the energy available around them, which is to say how these societies have reflected on this energy (or not), how they mobilized it (or not), and how we have come to the energy system we have today, one that we must urgently leave behind.

2 Historians, who generally share this point of view, do not agree on how to go about writing this history, or on how it unfolded. It is therefore important for me to specify a few of my convictions on this subject. The first is that in order to understand the relations that our societies have maintained and continue to maintain with the energy dispensed to us by the sun, it is vital to consider things in as long a term as possible. During the course of this *temps long*, the forms for mobilizing energy have changed, and there have been transitions between different energy systems. By transition I mean the change, more or less extended in time, from one *energy system* to another (not from one energy to another, and even less from carbon-based energy to "clean" energy).[6] Just as demographic transitions shifted our Western societies from one demographic system to another, and continue to do so in other parts of the world, energy transitions have on many occasions shifted them from a system with one set of energies to a system with another. Yet unlike demographic transitions, which shifted our societies—according to different processes depending on the location—from a particular demographic system (high birth and death rates) to another particular system (low birth and death rates), energy transitions lead

1 Intergovernmental Panel on Climate Change

2 "The effects [of Anthropogenic greenhouse gas emissions, together with those of other anthropogenic drivers] have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th c.." IPCC (Intergovernmental Panel on Climate Change), *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Geneva: IPCC, 2014), 4. For more details, see the IPCC's "Summary for policymakers" (Group I), which notably mentions: "Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes." http://ar5-syr.ipcc.ch/topic_summary.php accessed 30 August 2017.

3 Enerdata, "Global Energy Trends - 2017 report", https://www.enerdata.net/publications/reports-presentations/global-ener..., 2017, accessed 12 July 2017. Historical data on energy that was reconstructed and gathered by historians is included in Etemad Bouda *et al*. (dir.), *World Energy Production, Production mondiale d'énergie, 1900-1985* (Genève: Droz, 1991).

4 IPCC, *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Geneva: IPCC, 2014), 3.

5 Contrary to what the usual terminology may lead one to believe, we never produce energy, we simply mobilize it. We could also say retrieve.

6 A reflection on the use of this term can be found in Di Manno Sylvain, "La transition énergétique, entre histoire politique et politique de l'histoire", *Communication, école thématique d'automne 2014 de l'IFRIS : La transition comme question politique et objet de recherche pour les SHS* (Florence: 26/09 2014), https://dimannosylvain.wordpress.com/communications/la-transition-energ..., accessed 8 May 2018.

from dissimilar initial systems[7] to final systems that are not necessarily similar either.[8] They also proceed at varying speeds, and use methods that are different depending on each case. The concept of energy transition consequently does not at all have the same meaning today in Europe as it does in Africa, where certain populations still do not have access to electricity.[9] As a result, there is not *an* energy transition, but so many transitions, in time and space, from one energy system to another.

3 These transitions have not involved the substitution or simple addition of one or more energy sources to those already in use, but rather a gradual replacement of one *energy system* by another. The notion of energy system—used (in German) by Rolph Peter Sieferle, and later in French by Jean-Claude Debeir, Jean-Paul Deléage, and Daniel Heméry in works I will discuss in greater detail in the third part of this essay[10]—brings to mind the term "technical system" proposed by Bertrand Gille, which refers to the series of relations that connect the available techniques with the correlated social system at a particular point in time.[11] It can be usefully transposed to the domain of energy, as each energy system includes a series of elements relating to the economic, social, political, geopolitical, and cultural conditions of the time, as well as and perhaps especially to the choices made by humans—choice of primary energy sources put into use, choice of converters—with little room remaining for fatality. As it happens, the substitution of one system for another has rarely meant the disappearance of earlier energy sources. Often a new hierarchy of energy sources emerged, with some intensifying and other seeing their role reduced, but without disappearing altogether.

4 While the role of energy is crucial to the economy, the latter should not be the exclusive focus of our attention. The questions that arise regarding transitions are therefore not just "what sources of energy were used before and after the transition?", or "how efficient were the previous and new systems?", but also "who decided on these changes—if a decision was made—and to what ends?", "who possessed (the energy sources, the converters, the power to impose them on others)?", "how did the new forms spread?", "who benefited (or suffered) from these changes?", "what changes did they make to social organization?", etc. Transitions have never been linear or identical, and have sometimes included abandoned and even sabotaged experimentations, and have sometimes taken the form of cycles. Nothing was "scripted," as different choices could generally have been made. In fact, they were not called "transitions," as this term has apparently been used in connection with energy only recently. People spoke instead of energies of "substitution," "replacement," or "alternatives," or used paraphrase.

5 Focusing on these questions hardly entails, in my opinion, digging through observations of past transitions for formulas to reproduce for the present, as is believed by those who expect historians to provide "ready to use" models for managing the future—wars are never won with the weapons of the preceding war. What matters is to understand how and why the past choices were made, choices that have brought us to where we are today, in a system that we must

7 See for example, in the former European energy system, the importance of peat or coal for certain regions, sources that elsewhere played a small role, or no role at all.

8 For example, countries that today have "modern" energy systems comparable in many respects, such as Norway and Sweden, have very different energy mixes.

9 Pokam Kamden Moïse Williams, "Le thermique et l'hydraulique dans la production d'électricité au Cameroun (1931-2013) : enjeux de substitution et de combinaison", *in* Mathis, Massard-Guilbaud (dir.), *Systèmes et transitions énergétiques* (cf. note *).

10 Sieferle Rolf Peter, *Der unterirdische Wald, Energiekrise und industrielle Revolution* (München: Beck, 1982). English translation: *The Subterranean Forest: Energy Systems and the Industrial Revolution* (Cambridge: White Horse Press, 2001). Debeir Jean-Claude, Deléage Jean-Paul, Hémery Daniel, *Les servitudes de la puissance. Une histoire de l'énergie* (Paris: Flammarion, 1986). New revised edition in 2013 under the title *Une histoire de l'énergie*. English translation, *In the Servitude of Power: Energy and Civilization through the Ages* (London: Palgrave MacMillan, 1991).

11 Gille Bertrand (dir.), *Histoire des techniques. Technique et civilisations, technique et sciences* (Paris: Gallimard, 1978). See also Idem, "La notion de 'système technique' (essai d'épistémologie technique)", *Technique et Culture*, vol. 1, 1979.

abandon if we do not want to leave future generations an increasingly unmanageable legacy. It is precisely because these past choices weigh on the present and the future that we believe it is crucial to define them. This task falls to historians, who are the best equipped to carry it out. The work has just begun, and as we shall see, there is no consensus today among historians on how we entered our current energy system, or on the value of studying it, for some believe that the research has already been conducted, while others believe that transitions do not and have never existed.

6 Writing the history of energy is hardly something new, and this historiographical essay aims to show the forms this writing has taken over the last century. The objective is not to praise or stigmatize a particular approach to the subject, but rather to evaluate what we have at our disposal, to understand the nature of the views taken until present, and to better identify the direction in which we must now move.

7 I will first discuss the initial research conducted in the history of energy, which was written during the 19th c. and the first two thirds of the 20th, and then the considerable quantity of published research over the past three decades leading up to the present. During this last period, historians have generally focused on a particular energy source or sector. This is why I will also present them in this way. The scope of this historiography is such that it is impossible to include in this second part works outside the French bibliography, aside from exceptions justified by the particular interest of a specific work. This choice naturally raises problems, for there is no subject more global than energy, and as the historiography advances through both national and international exchange, it is difficult to isolate individual works from those that respond to and complement one another. It is easily comprehensible why I had to make choices, given that the library created by the Forest History Society—to cite just one example—alone includes 45,000 references, a collection that, for the most part, naturally involves the energy uses of wood.[12] This panorama will essentially be historical in nature. This is not out of ignorance of the aspects that other disciplines (physics as well as philosophy, economics, ecology, etc.) have explored within the history of energy, but once again out of necessity.

Finally, in the third part I will show that other 8
ways of conceiving and writing the history of energy gradually emerged, along with the types of questions they raise. Contrary to the preceding section, this part will make room for foreign research, as well as research from other disciplines. We will see that the writing of the history of energy has tended to become more comprehensive, and recently the most stimulating ideas have not come from France, or always from historians.

HISTORIANS AND ENERGY, INITIAL RESEARCH

Beginning in the 18th c. and throughout the 9
19th c., economists such as Adam Smith, David Ricardo, Thomas Malthus and later Karl Marx, W. Stanley Jevons and others took a close interest in the *longue durée* of energy questions. I will not linger on this research, although we will see that the historians of energy about whom I will speak in the third part of this text were all interested in the perspective of classical, neoclassical, or Marxist economists. In *Les Économistes et la fin des énergies fossiles (1865-1931)* [Economists and the End of Fossil Energies],[13] the historian of economic ideas Antoine Missemer analysed how the perspective of economists evolved, notably that of Jevons, who in 1865 published his famous *The Coal Question*.[14] With regard to historians, numerous scholars in the 19th c. studied

12 The bibliography created by the FHS is available at http://prestohost26.inmagic.com/Presto/home/home.aspx The figure of 45,000 references refers only to written documents, and does not include images or audio archives. FHS management itself recognizes that despite its size, the collection is hardly exhaustive for publications in languages other than English.

13 Paris, Classiques Garnier, 2017.

14 Jevons William S., *The Coal Question, An Inquiry concerning the Progress of our Nation and the Probable exhaustion of our Coal Mines* (London: Macmillan, 1865).

the general problem of energy; while they did not do so in the same way as economists, they as least explored the history of wood and coal, whose massive use was disrupting the economy at the time.[15]

10 During the first decades of the 20th c., historians set to work on the history of animal power, hydraulics, firewood, and coal, producing works that still serve as references today. A few examples in very different genres are the books or articles of Richard Lefebvre des Noëttes, John Nef, and Marc Bloch.[16] Their interpretations have not always stood up against later studies, although this is entirely normal for pioneering research. For instance, Nef's argument that the exhaustion of forest resources caused the spread of coal use in England was reconsidered during the 1950s by G. Hammersley and Michael W. Flinn,and more recently by Robert C. Allen and others,[17] while Bloch's chronology on the industrial use of water mills was reconsidered by archaeologists specializing in Antiquity.[18]

11 The interwar period also produced an important text in *Technics and Civilization* by Lewis Mumford, a philosopher and historian of sciences who is today considered one of the precursors of the theory of degrowth.[19] The American academic was not, strictly speaking, offering a history of energy, but rather a history of technics in which the different phases that he identified were determined by the nature of the energy used. Emphasizing how energy was the basis of all human activity, Mumford recommended using it economically, and limiting the use of mechanical energy, subsistence crops, and raw material extraction. His reflections on transitions, which concern us today, remain worthy of interest.

12 In this digression beyond strictly historical confines, I would also like to mention the original thought of the geographer Jean Brunhes. In his *Géographie Humaine* [Human Geography], originally published in 1910 and with many subsequent editions, Brunhes classified extractive industries in the category of "acts of destructive

15 We will cite the famous *La Vie souterraine. Les mines et les mineurs*, by Louis Simonin (Paris: Hachette et cie., 1867), republished in 1993 by Champ Vallon, and in 2012 by General Books. For Great Britain, see Holland John, *The History and Description of Fossil Fuel, the Collieries, and Coal Trade of Great Britain* (London: Whittaker, 1835). There are numerous references of this type in the footnotes of Benoit Paul, Verna Catherine, *Le charbon de terre en Europe occidentale avant l'usage industriel du coke* (Turnhout: Brepols, 1999).

16 Lefebvre des Noëttes Richard, *La Force motrice animale à travers les âges* (Nancy: Berger Levrault, 1924). Nef John U., *The Rise of the British Coal Industry* (London: Routledge, 1932). [for Great Britain, the work of reference is now *History of the British Coal Industry: Hatcher John, Vol. 1 : Before 1700: Towards the Age of Coal* (Oxford: Oxford University Press, 1993). Flinn Michael W., *Vol. 2 : 1700-1830: The Industrial Revolution* (Oxford: Clarendon Press, 1984). Hall Alan, Church Roy A., Kaneksky John, *Vol. 3 : 1830-1913: Victorian Pre-Eminence* (Oxford: Clarendon Press, 1986). Supple Barry, *Vol. 4: 1914-1946: The Political Economy of Decline* (Oxford: Oxford University Press, 1987).] Bloch Marc, "Avènement et conquête du moulin à eau", *Annales d'histoire économique et sociale*, vol. 7, 1935. See also, in the same issue, regarding human and animal energy: Bloch Marc, "Les 'inventions' médiévales". The thesis by M. Rouff also bears mentioning, *Les Mines de charbon en France au XVIIIe siècle, 1744-1791, étude d'histoire économique et sociale* (Paris: F. Rieder et Cie, 1922). Dion Roger, "Usines et forêts. Conséquences de l'ancien emploi du bois comme combustible pour les forêts", *Revue des Eaux et Forêts*, vol. 76, 1938.

17 Hammersley George, "The Crown Woods and their Exploitation in the 16th and 17th c.", Historical Research, vol. 30/82, 1957. Flinn Michael W., "Timber and the advance of technology: A Reconsideration", *Annals of Science*, vol. 15/2, 1959. Warde Paul, "Fear of Wood Shortage and the Reality of the Woodland in Europe, c. 1450-1850", *History Workshop Journal*, vol. 62, 2006. Allen Robert C., *The British Industrial Revolution in Global Perspective* (Cambridge: Cambridge University Press, 2009). Idem, "Was there a timber crisis in early modern Europe?", *in* Simonetta Cavaciocchi (ed.), *Economia e Energia, Secc. XIII-XVIII, Atta de la "Trentaquattresima Settimana di Studi", 15-19 aprile 2002, Istituto Internazionale di storia economica "E Datini"* (Prato: Le Monnier, 2003).

18 Amouretti Marie-Claire, Le *pain et l'huile dans la Grèce antique, Évolution des techniques agraires d'Hésiode à Théophraste, Annales littéraires de l'Université de Besançon, Centre de Recherches d'histoire ancienne 67* (Paris: Les Belles Lettres, 1986). Wikander Örjan, *Handbook of Ancient Water Technology* (Leyden: Brill, 2000). Brun Jean-Pierre, "Les moulins hydrauliques en Italie romaine" et Leveau Philippe, "Les moulins de Barbegal. 1986-2006", *in* Jean-Pierre Brun, Jean-Louis Fiches (dir.), *Énergie hydraulique et machines élévatrices d'eau dans l'Antiquité* (Naples: Centre J. Bérard, 2007).

19 Mumford Lewis, *Technics and Civilization* (London: Routledge and Kegan, 1934). French translation: *Technique et civilisation* (Paris: Le Seuil, 1950). New edition with a new translation: Marseille: Parenthèses, 2016.

occupation."[20] The passage he devoted to the use of coal and petroleum was original to say the least—coming at a time when the climate didn't pose a problem for anyone—and prompted reflection on what we are doing when we use fossil resources.[21]

13 In 1961, the Italian economic historian Carlo Maria Cipolla published, in the "Débats et Combats" [Debates and Battles] section of *Annales ESC,* an article entitled "Sources d'énergie et histoire de l'humanité" ["Energy Sources and the History of Humanity"].[22] It was only an outline, but it offered a correct presentation of the problem.

14 Six years later, in the first volume of *Civilisation matérielle et capitalisme* [*The Structures of Everyday Life: Civilization and Capitalism, 15th-18th c.,* Vol. 1], Fernand Braudel devoted a large part of the fifth chapter to the history of energy during the centuries of the Ancien Régime.[23] While the work generally drew praise when it was published, it was also criticized, notably for the reliability of the quantitative data used.[24] While subsequent research once again clarified certain points, this chapter has the merit of being one of the first to attempt an overview of the energy question on a practically global scale—and not solely a picture of a particular source of energy, often in a single country, as most of his predecessors had done, or as many of his successors still do.[25] Nearly ten years before Gille proposed the notion of technical systems, thereby emphasizing the links between techniques and society, Braudel was drawing the economic and social conclusions of how all types of energy had been mobilized by humans up to that point. These conclusions were limited in number, and can be summarized as follows: the small quantities of energy put into use during the centuries of the Ancien Régime, coupled with this energy's lack of flexibility, prevented the development of machinism until the late 18th c., and with it economic growth. We will see that this theory was revived and developed both 20 years later as well as today, although it is now the subject of criticism.

STUDIES BY ENERGY SOURCE AND SECTOR

15 Research began to increase during the 1980s. Various aspects of the economic, political, and intellectual context most certainly explain this historiographical shift: oil crises, coal crisis, appearance of the history of companies... The French historiography of the time took the form of studies focusing on primary energy sources or sectors. The panorama that I will present here will therefore be classified in this way. It is with regret that I had to neglect the energy source of food, a very important aspect of the energy question, one that for a long time was approached in terms of subsistence capacity rather than in strictly energy terms. The birth of agriculture, a new human know-how that enabled the recovery—much more efficiently than gathering—of the energy produced by photosynthesis, was undeniably a major energy transition. The

20 Brunhes took inspiration from the German geography of Raubwirtschaft (economy of rapine or devastation). On this subject see Massard-Guilbaud Geneviève, "Historiens et géographes français et relation de l'homme au milieu, de Vidal de la Blache aux programmes de recherche interdisciplinaires de la fin du XXe siècle", *in* Robert Chenorkian, Samuel Robert (dir.), *Les Interactions hommes-milieux. Questions et pratiques de la recherche en environnement* (Versailles: éditions Quæ, 2014).

21 Brunhes Jean, *Géographie Humaine* (Paris: PUF, 1942), 215 et seq.

22 Cipolla Carlo M., "Sources d'énergie et histoire de l'humanité", *Annales. Économies, sociétés, civilisations*, vol. 3, 1961.

23 Braudel Fernand, *Civilisation matérielle, économie et capitalisme, XVe-XVIIIe siècles* (Paris: Armand Colin, 1967), 251-283.

24 Morineau Michel, "Un grand dessein : Civilisation matérielle, économie et capitalisme, XVe-XVIIIe siècles, de Fernand Braudel", *Revue d'Histoire Moderne & Contemporaine*, vol. 28/4, 1981.

25 One of the first, but not the first. With no pretention of being exhaustive, we will cite among earlier works the synoptic viewpoint of Wilhelm Schultz-Bodmer's (1797-1860) Menschenkraft, Tierkraft, Windenkraft, Dampfkraft, concerning Prussia, France, and England, which was mentioned by Morineau in his critique of Civilisation matérielle (cf. note 24), and the conference given by R.-J. Forbes, Professor at the University of Amsterdam, at the Palais de la Découverte in June 1956, published under the title *La Technique et l'énergie au cours des siècles, Les Conférences du Palais de la découverte 42* (Paris: Université de Paris), in which the author attempted a synoptic panorama from Antiquity to the mid-12th c.

capacity to produce food in quantity was also one of the important aspects of the transition that took place starting in the late 18th c. Taking food production into account would nevertheless have led me to consider the entire history of agriculture and land use, which was quite simply impossible given the space available here.

16 I will now mention, once and for all, an invaluable collection that has played a role across all sections of this article, for it involves diverse sources of energy: the proceedings of the study week held in Prato in 2002, published under the title *Economia e Energia, Sec. XIII-XVIII* [Economy and Energy, 13th-18th c.].[26] This volume of over a thousand pages brings together a remarkable series of contributions regarding all aspects of the history of energy from the Middle Ages to the 18th c.

Wood, water, and wind

17 The energy uses of wood in France under the previous economic system have been the subject of many conferences and books in France, generally published by researchers from the Groupe d'histoire des forêts françaises [Group for the History of French Forests]. The research of Denis Woronoff and the works he edited evoke the relation between wood and the steel industry,[27] while the book that Jérôme Buridant drew from his thesis explores the impact that another wood-hungry industry, glassmaking, had on forests.[28] The geographer Jean-Paul Métailié edited the proceedings of a conference on the relations between protoindustry and forests.[29] The handbook *Le Bois, source d'énergie* [Wood, A Source of Energy], edited by Andrée Corvol,[30] pertains more to domestic heating, as does Jean Boissière's thesis.[31] On heating there is also the fine recent book by Stéphane Castelluccio, *L'éclairage, le chauffage et l'eau* [Lighting, Heating, and Water], which notably examines—with regard to what interests us here—oil lamps, tallow candles, candles, and various other fuels used for heating.[32] Serge Benoit has shown the importance of the role played by traditional energy sources, wood and water, in industrialization *à la française*.[33]

18 Very recent research has come from other countries regarding wood and the key question of a possible "wood crisis" during the 18th c., and its role in the Industrial Revolution. This initially took place in Germany with the work of Joachim Radkau, a senior environmental historian, whose book *Holz, Wie ein Naturstoff Geschichte schreibt* [Wood: A History] is especially

26 Cavaciocchi Simonetta (ed.), *Economia e Energia, Secc. XIII-XVIII, Atta de la "Trentaquattresima Settimana di Studi", 15-19 aprile 2002, Istituto Internazionale di storia economica "E Datini"* (Prato: Le Monnier, 2003). The work includes articles in four languages (Italian, French, English, and German).

27 Woronoff Denis, *L'industrie sidérurgique en France pendant la Révolution et l'Empire* (Paris: Éditions de l'EHESS, 1984). Woronoff Denis (dir.), *Révolutions et espaces forestiers*, (Paris: L'Harmattan, 1989). Woronoff Denis (dir.), *Forges et forêts: recherches sur la consommation proto-industrielle de bois* (Paris: Éditions de l'EHESS, 1990).

28 Buridant Jérôme, *Espaces forestiers et industrie verrière XVIIe-XIXe siècle* (Paris: l'Harmattan, 2005). Buridant Jérôme, "Le premier choc énergétique. La crise forestière dans le nord du bassin parisien (début 18e-début 19e siècle)" (HDR (research-director thesis), Université Paris 4, 2008). See also Palaude Stéphane, "Verreries noires d'Avesnois-Thiérache, XIXe-XXe siècles" (Ph.D. diss., Université de Lille 3, 2009). On Colbert's forest reform, see the Ph.D. diss. publication of Devèze Michel, *Une admirable réforme administrative. La grande réformation des forêts sous Colbert (1661-1683)* (Nancy: impr. G. Thomas, 1962). A synthetic work on the history of forests: Chalvet Martine, *Une histoire de la forêt* (Paris: Le Seuil, 2011).

29 Métailié Jean-Pierre (dir.), *Protoindustries et histoire des forêts : actes du colloque tenu à la Maison de la forêt, Loubières, Ariège, les 10-13 octobre 1990* (Toulouse: GDR ISARD 881 - CNRS, 1992).

30 Corvol Andrée (dir.), "Le Bois, source d'énergie : naguère et aujourd'hui". *Journée d'Études de l'IHMC, janvier 1999 - Environnement, Forêt et Société, XVIe-XXe siècle. La Ville, troisième partie, IHMC-CNR, Cahier d'Études n° 10* (Paris: École normale supérieure, 2000).

31 Boissière Jean, "Populations et économies du bois dans la France moderne : contribution à l'étude des milieux forestiers entre Paris et le Morvan au dernier siècle de l'Ancien régime (vers 1685-vers 1790)" (Ph.D. diss., Université Paris 1, 1993).

32 Castelluccio Stéphane, *L'éclairage, le chauffage et l'eau aux XVIIe et XVIIIe siècles* (Montreuil: Éditions Gourcuff Gredingo, 2016).

33 Benoit Serge, "La modernité de la tradition: les énergies renouvelables classiques : l'eau et le bois dans la voie française de l'industrialisation, c.1750-c.1880" (Ph.D. diss., Université d'Evry-Val d'Essonne, 2006).

remarkable,[34] along with Rolf P. Sieferle, whose work I will discuss below.[35] It later emerged in Great Britain with the economic historians Tony Wrigley, Robert C. Allen, and Paul Warde, whose role in changing the historiography I will also discuss below.[36]

19 In an indication of its vitality, the history of water (in all its uses, not just as a source of energy) has been the sole object of study of the International Water History Association since 1999, while "non-specialized" societies of environmental history have also devoted numerous conference sessions to the subject.[37] Since 2009, the history of water has been the subject of both the journal *Water History,* as well as the academic social network (H-Water).[38] This substantial institutionalization of the research field reflects the considerable attention given to the subject by researchers.[39]

20 Most publications exploring watermills are naturally the work of archaeologists or historians of Antiquity and the Middle Ages. The former challenged the idea that watermills only spread during the Middle Ages despite dating back to Roman Antiquity,[40] while medievalists published broadly on the question of hydraulic energy and its role in medieval social organization, changing our perspective of the latter.[41] For instance, in a series of articles that were later reworked in his *Le Temps des laboureurs* [The Time of Labourers], Mathieu Arnoux defended a new reading of the links between the spread of mills, the development of seigniorial structures, and

34 Radkau Joachim, Holz, *Wie ein Naturstoff Geschichte schreibt* (München: Oekom Verlag, 2007). English translation *Wood: A History* (Cambridge: Polity Press, 2012).

35 Sieferle, *Der unterirdische Wald* (cf. note 10).

36 Wrigley E. Anthony, "The Supply of Raw Materials in the Industrial Revolution", *The Economic History Review, New Series*, vol. 15/1, 1962. Idem, *Continuity, Chance and Change. The character of the industrial revolution in England* (Cambridge: Cambridge University Press, 1988). Idem, *Energy and the English Industrial Revolution in England* (Cambridge: Cambridge University Press, 2010). Allen Robert C., *The British Industrial Revolution* (cf. note 17). Warde Paul, "Fear of Wood Shortage" (cf. note 17). Idem, *Energy Consumption in England & Wales, 1560-2000* (Naples: CNR, 2007). Idem, "Early Modern 'Resource Crisis': the Wood Shortage Debates in Europe", *in* A. T. Brown, Andy Burn, Rob Doherty (eds.), *Crisis in Economic and Social History* (Woodbridge: Boydell & Brewer, 2015, 137–160).

37 *European Society for Environmental History* http://eseh.org; *American Society for Environmental History* https://aseh.net; *la Sociedad Latinoamericana y Caribeña de Historia Ambiental* https://solcha.uniandes.edu.co/index/

38 https://link.springer.com/journal/12685, https://networks.h-net.org/h-water *H-Net* also includes the *H-Energy network*: https://networks.h-net.org/h-energy

39 We will cite only a single "international" title: *A History of Water: Vol. 1.* Tvedt Terje, Jakobsson Eva (ed.), *Water Control and River Biographies; vol. 2.* Coopey Richard, Tvedt Terje (ed.), *The Political Economy of Water; Vol. 3.* Tvedt Terje, Oestigaard Terje (ed.), *The Political Economy of Water* (London: I. B. Tauris, 2006).

40 Amouretti Marie-Claire, *Le pain et l'huile* (cf. note 18). Wikander Örjan, *Handbook of Ancient Water Technology* (cf. note 18). Leveau Philippe, "Les moulins de Barbegal" (cf. note 18). Viollet Pierre-Louis, *Histoire de l'énergie hydraulique: Moulins, pompes, roues et turbines de l'Antiquité au XXe siècle* (Paris: Presses de l'école nationale des Ponts et Chaussées, 2006). Brun Jean-Pierre, Fiches Jean-Louis (dir.), *Énergie hydraulique* (cf. note 18). A strictly technical work: Bonnin Jacques, *L'eau dans l'Antiquité : l'hydraulique avant notre ère* (Paris: Eyrolles, 1984).

41 Chauvin Benoît, "Réalités et évolution de l'économie cistercienne dans les duché et comté de Bourgogne au Moyen-Age. Essai de synthèse", *in* Flaran 3. *L'économie cistercienne, géographie, mutations du Moyen Age aux Temps Modernes, [Actes des] Troisièmes journées internationales d'histoire, Abbaye de Flaran, 16-18 septembre 1981* (Auch: Comité départemental du tourisme du Gers, 1983). Lohrmann Dietrich, "Le moulin à eau dans l'économie de la Neustrie, VIIe-XIXe siècles", *in* Hartmut Atsma (dir.), *Les pays du Nord de la Loire de 650 à 850, Beihefte der Francia 16, vol. 1* (Ostfildern - Sigmaringen: Jan Thorbecke Verlag, 1989). Crouzet-Pavan Élisabeth, Maire-Vigueur Jean-Claude (ed.), *Water Control in Western Europe 12th-16th c., 11th International Economic History Congress* (Milano: Université Bocconi, 1994). Benoit Paul, Berthier Karine, "L'innovation dans l'exploitation de l'énergie hydraulique d'après le cas des monastères cisterciens de Bourgogne, Champagne et Franche-Comté", *Actes des congrès de la Société d'archéologie médiévale*, vol. 6/1, 1998, 58-66. Rivals Claude, *Le Moulin et le meunier. Mille ans de meunerie en France et en Europe Vol. 1 : Une technique et un métier, Vol. 2 : Une symbolique sociale* (Portet-sur-Garonne: Empreinte, 2000). Mousnier Mireille (dir.), *Moulins et meuniers dans les campagnes européennes (IXe-XVIIIe siècle), Actes des XXIe Journées internationales d'histoire de l'Abbaye de Flaran, 3-5 septembre 1999* (Toulouse: Presses Universitaires du Mirail, 2002). Durand Aline, *Jeux d'eau. Moulins, meuniers et machines hydrauliques, XI-XXe siècles. Études offertes à Georges Comet, Cahiers d'histoire des techniques 7* (Aix-en-Provence: Publications de l'Université de Provence, 2008). We also note the existence of the doctoral thesis by Philippe Robert, "L'Énergie au Moyen-Âge" (Ph.D. diss., Université Paris 4, 1980), for which I have been unable to locate a copy.

the constitution of a regulated hydraulic market, inviting us to rethink the role of peasants in their implementation and operation.[42]

21 Modern historians often devoted their research on water to river management (deepening, straightening, diking up) and the conflicts these works led to, rather than energy production.[43] Some works, such as *Archives, objets et images des constructions de l'eau du Moyen Âge à l'ère industrielle* [Archives, Objects, and Images of Water from the Middle Ages to the Industrial Era], explore both aspects.[44] The role played by mills in the Industrial Revolution, studied by Serge Benoit in his previously cited thesis, was challenged in 1984 by Louis Bergeron, who wrote very cogently in a ground-breaking article: "The history of watermills puts historians on the path of re-examining the general interpretation of French industrialization during the 18th and 19th c. in light of the energy choices made by entrepreneurs."[45]

22 Floating, a mode of transport that played a major role because water power could transport the highly important fuel (and raw material) of wood over long distances, was also the subject of research.[46] Modern historians of course have tended to focus on hydroelectric dams, which I will discuss further in the paragraph devoted to electricity.

23 Most likely because the wind energy that powered them was intermittent, windmills never had more than a relatively secondary economic role, and have garnered less research attention than watermills.[47] The work by Claude Rivals, *Le Moulin à vent et le meunier dans la société française traditionnelle* [The Windmill and the Miller in Traditional French Society], also bears mentioning.[48] While wind-driven boats played an essential role in both commerce and European endeavours for overseas extension, and also maintained their primacy in maritime transport until the late 19th c., wind energy does not seem to have interested historians of sailing ships either, despite greatly lowering operating costs (unlike draft animals, sailing ships did not eat). Jean Rougé, the historian of Mediterranean

42 Arnoux Mathieu, *Le Temps des laboureurs. Travail, ordre social et croissance en Europe, XIe-XIVe siècle* (Paris: Albin Michel, 2012).

43 Fournier Patrick, Lavaud Sandrine (dir.), *Eaux et conflits dans l'Europe médiévale et moderne actes des XXXIIes Journées internationales d'histoire de l'abbaye de Flaran, 8 et 9 octobre 2010, Flaran 32* (Toulouse: Presses universitaires du Mirail, 2012). Ballut Christèle, Fournier Patrick (dir.), *Au fil de l'eau ressources, risques et gestion du néolithique à nos jours* (Clermont-Ferrand: Presses universitaires Blaise-Pascal, 2013). Serna Virginie, Gallicé Alain (dir.), *La rivière aménagée entre héritages et modernité formes, techniques et mise en oeuvre actes du colloque international, Muséum des sciences naturelles d'Orléans, 15-16 octobre 2004, Aesturia cultures et développement durable 7* (Cordemais: Estuarium, 2005).

44 Hilaire-Pérez Liliane, Massounie Dominique, Serna Virginie (dir.), *Archives, objets et images des constructions de l'eau du Moyen Âge à l'ère industrielle, Cahiers d'histoire et de philosophie des sciences n° 51* (Lyon: ENS Éditions, 2002).

45 Bergeron Louis, "'Le cœur de la vallée, c'est son moulin...' Les moteurs hydrauliques et leurs applications industrielles en France (XVIIIe-XXe siècle)", *Terrain - anthropologie & sciences humaines*, vol. 2, 1984, http://journals.openedition.org/terrain/2796.

46 Guillot-Chêne Gérard, *Le Flottage en Morvan, du bois pour Paris* (Paris: Garnier, 1979). Martinet Jean-Claude, *Clamecy et ses flotteurs de la monarchie de juillet à l'insurrection des "Marianne", 1830-1851* (Précy-sous-Thil: Ed. de l'Armançon, 1995). Boissière Jean, *Populations et économies du bois* (cf. note 31). Kleine Roland, *Le flottage du bois sur la Sarre aux XVIIIe et XIXe siècles* (Sarrebourg: Société d'Histoire et d'Archéologie de Lorraine, 2003).

47 Things have proceeded differently elsewhere. See for example Kealey Edward Joseph, *Harvesting the Air: Windmill Pioneers in twelfth-century England* (Berkeley: University of California Press, 1987). Hills Richard L., *Power from Wind, a History of Windmill Technology* (Cambridge: Cambridge University Press, 1994); Lohrmann Dietrich, "Von der östlichen zur westlichen Windmühle", *Archiv für Kulturgeschichte*, vol. 77/1, 1995; Righter Robert W., *Wind Energy in America: A History* (Norman: University of Oklahoma Press, 1996). Lucas Adam, *Wind, water, work ancient and medieval milling technology, Technology and Change in History 8* (Leiden Boston: Brill, 2006). See also chapters 3 and 4 of Cottrell William F., *Energy & Society (Revised): The Relation Between Energy, Social Change, and Economic Development* (New York: AuthorHouse, 2009).

48 Rivals Claude, *Le Moulin à vent et le meunier dans la société française traditionnelle* (Boulogne-Billancourt: Berger Levrault, 1995). See also Philippe Robert, "Les premiers moulins à vent", *Annales de Normandie*, vol. 32/2, 1982. Leguay Jean-Pierre, *L'air & le vent au Moyen Âge* (Rennes: Presses universitaires de Rennes, 2011).

commerce during the Roman Empire, nevertheless took some interest in the subject.[49]

Fossil energies

24 The various kinds of fossil energies have not prompted as many studies in proportion to their genuine importance in history. First, with regard to peat, whose use had a particularly important impact on the environment, and which the early modernist Paul Allard believes played a very uneven role in Europe depending on the region—but one that is more important than generally believed (for its many uses and not just as a fuel)—was the subject of a conference held by the Groupe d'histoire des zones humides [Wetlands History Group], published by the journal *Aestuaria*.[50] Its collected articles concern France as well as Scotland, Ireland, Holland, and Flanders. Jérôme Buridant explores forest crises and peat use side by side, calling the fuel an "energy of transition." Aside from this collective work, there are numerous local monographs on peat bogs, but no work of synthesis.[51]

25 The historian of technology Paul Benoit made a major contribution to our understanding of mines, coalmines in particular.[52] The most interesting work for our subject is the one he edited with Catherine Verna on coal before the industrial use of coke.[53] This work brings together contributions from different European countries, and covers the period from the Middle Ages to the 18th c.. It notably informs us that the Romans, whose country did not have mineral coal, nevertheless used it where it was available in their empire.[54] While coal use is not attested in Europe during the High Middle Ages, it was vigorously rekindled during the 13th c. in Belgium and England, with increasingly deep mines that required the raising of considerable capital and the creation of large companies. Its use and consumption expanded during the 16th and 17th c.. Outside of England, where it was used for heating and caused considerable health and environmental damage, as William Cavert has shown in a recent book,[55] coal was used essentially by industry, and the properties specific to the different types of carbon were well known. The social and environmental impact of its use was, like that of peat, considerable. During the 18th c., French production increased seven- or eightfold, and industrial uses became even more diversified. However, as pointed out by the many works on the Industrial Revolution, it was only during the second half of the 19th c. that it took on a major role in France. The leading branch of industrialization, textiles, initially developed thanks to animal[56], human, or hydraulic power, with the latter playing an important role for a

49 Rougé Jean, *Recherches sur l'organisation du commerce maritime en Méditerranée sous l'empire romain* (Paris: SEVPEN, 1966), 47-81. See also Cucari Attilio, *Les Grands voiliers du Moyen âge à nos jours* (Paris – Bruxelles: Elsevier Séquoia, 1978). Masson Philippe, *Histoire de la marine* (Paris: C. Lavauzelle, 1981, 2 vol.). is in the tradition of "battle-history." Charliat Pierre-Jacques, *Le temps des grands voiliers, Histoire Universelle des explorations 3* (Paris: Nouvelle librairie de France : F. Sant'Andrea, 1955) does not take an interest in wind power, despite being prefaced by Lucien Febvre.

50 Derex Jean-Michel, Grégoire Fabrice (dir.), *Histoire économique et sociale de la tourbe et des tourbières, actes du deuxième colloque international du groupe d'histoire des zones humides (GHZH), naturAgora, Laon, 18, 19, 20 octobre 2007, Aestuaria Histoire et terres humides* (Cordemais: Estuarium, 2009).

51 The work cited in the preceding footnote includes numerous references for peat bogs. See also http://pole-tourbieresdoc.org/dyn/portal/index.seam?page=home&fonds=2 (accessed 1 August 2018).

52 Benoit Paul, Braunstein Philippe (dir.), *Mines, carrières et métallurgie dans la France médiévale, actes du colloque de Paris, 19, 20, 21 juin 1980* (Paris: Éditions du CNRS, 1983). Benoit Paul, Fluck Pierre (dir.), *Les techniques minières de l'Antiquité au XVIIIe siècle actes du colloque international sur les ressources minières et l'histoire de leur exploitation de l'Antiquité à la fin du XVIIIe siècle réuni dans le cadre du 113e Congrès national des sociétés savantes* (Strasbourg, 5-9 avril 1988), *Actes des congrès nationaux des sociétés savantes Comité des travaux historiques et scientifiques 113* (Paris: Éditions du CTHS, 1992).

53 Benoit Paul, Verna Catherine, *Le charbon de terre en Europe occidentale avant l'usage industriel du coke, Proceedings of the 20th International congress of history of sciences* (Turnhout: Brepols, 1999).

54 On this subject see also Dearne Martin J., Branigan Keith, "The Use of Coal in Roman Britain", The Antiquaries Journal, vol. 75, 1995, 71–105.

55 Cavert William M., *The Smoke of London: Energy and Environment in the Early Modern City* (Cambridge: Cambridge University Press, 2016).

56 Little attention has been granted to animal energy. On this topic, see however Roche Daniel, *La culture équestre de l'Occident, XVIe-XIXe siècles. L'ombre du cheval, Tome 1, Le cheval moteur, essai sur l'utilité équestre* (Paris: Fayard, 2008).

long time thanks to the substitution of turbines, whose energy efficiency was greatly superior to waterwheels.

26 While the Jeanneney Plan (1960) had just announced the start of the French coal industry's rollback in France, and at the very moment that a general strike of miners (March-April 1963) forced Georges Pompidou's government to yield, a conference under the direction of Louis Trénard was held in Lille on the subject of coal mines and miners, which would be published under the title *Charbon et Sciences Humaines* [Coal and the Humanities].[57] With regard to energy, the conference essentially focused on the role of coal in the Industrial Revolution. In the Spring of 1963, *Le Mouvement social* devoted a very substantial special issue to miners[58]: it included three research articles, with two on the historical sources for mining, along with a record and a dozen or so reviews, including a review of Pierre Guillaume's *La Compagnie des mines de la Loire, 1846-1854* [The Loire Mining Company, 1846-1854].[59] Rolande Trempé contributed a bibliography, while foreign researchers provided reviews of the state of research in their respective regions. The bulk of studies on coal were still to come, but a generation of young historians had clearly seized upon the subject.

27 Beginning in the 1970s, a number of orientations can schematically be distinguished in the history of coal and coalmines.[60] The first is an economic history primarily interested in the appearance of the industrial branch and its evolution, the companies that comprise it, industrial strategies, and products and markets. In addition to Pierre Guillaume's previously cited thesis, this group of research also includes Marcel Gillet's thesis on the coalfields of the Nord and Pas-de-Calais departments between 1815 and 1914,[61] Reed G. Geiger's study on the Compagnie d'Anzin,[62] Jean-Michel Gaillard's study of the mining company and city of la Grand-Combe, and Nadège Sougy's book on La Machine.[63] The coal market has more recently been the subject of two theses, one covering the years 1945-1958, and the other the First World War.[64]

28 A second orientation is in line with the history of the labour movement, and later that of the miners themselves. It was initially personified by Rolande Trempé, who devoted her doctoral thesis to miners and the formation of their "political class conscience."[65] In her *Les Trois batailles du Charbon* [The Three Battles of Coal], published 20 years after her thesis, Trempé returned to

57 Trénard Louis (dir.), *Charbon et sciences humaines actes du colloque, actes du colloque organisé par la Faculté des lettres de l'Université de Lille en mai 1963, Industrie et artisanat 2* (Paris - La Haye: Mouton and co., 1966).

58 Le Mouvement Social, n°43: *La Mine et les mineurs*, 1963.

59 The review does not indicate the nature of the text analysed. It was most likely P. Guillaume's doctoral thesis, which would be published in 1966 under the same title (Guillaume Pierre, *La Compagnie des mines de la Loire (1846-1854). Essai sur l'apparition de la grande industrie capitaliste en France, Publications de la Faculté des Lettres de Clermont-Ferrand, 2ème série n° 24* (Paris: PUF, 1966)).

60 These orientations did not succeed one another chronologically, and are of course not hermetic.

61 Thesis published under the title of *Les Charbonnages du Nord de la France au XIXe siècle, Industrie et artisanat 8* (Paris - La Haye: Mouton, 1973). Marcel Gillet had already explored the economy of coalmines in a book he published with J. Bouvier and F. Furet: Bouvier Jean, Furet François, Gillet Marcel, *Le mouvement du profit en France au XIXe siècle matériaux et études, Industrie et artisanat 1* (Paris: Éditions de l'EHESS, 1965), 23-163. See also Gillet Marcel, *Histoire sociale du Nord et de l'Europe du Nord-Ouest, Recherches sur les XIXe et XXe siècles* (Lille: Presses Universitaires de Lille, 1984), a collection of articles whose entire first section is about coal mines.

62 Geiger Reed G., *The Anzin Coal Company 1800-1833: Big Business in the early Stages of the French Industrial Revolution* (Newark: University of Delaware press, 1971). Also see Mastin Jean-Luc, "Concentration dans l'industrie minière et construction de l'espace régional : le cas du Nord-Pas-de-Calais de 1850 à 1914", *Revue du Nord*, vol. 387/4, 2010.

63 Gaillard Jean-Michel, "Un exemple français de 'ville-usine' la Grand-Combe, Gard et sa 'compagnie des mines', 1836-1921" (Ph.D. diss., Université de Paris-Nanterre, 1974). Sougy Nadège, *Les charbons de la Nièvre la houillère de La Machine, ses produits et ses marchés, 1838-1914* (Grenoble: Presses universitaires de Grenoble, 2008).

64 Perron Régine, *Le marché du charbon, un enjeu entre l'Europe et les États-Unis de 1945 à 1958, Publications de la Sorbonne. Série internationale 51* (Paris: Publications de la Sorbonne, 1996). Chancerel Pierre, "Le marché du charbon en France pendant la Première Guerre mondiale (1914-1921)" (Ph.D. diss., Université Paris X - Nanterre, 2012).

65 Trempé Rolande, *Les mineurs de Carmaux, 1848-1914* (Paris: Éditions ouvrières, 1971).

miners by studying their role in coal crises from the Front Populaire to the Liberation.[66] During the same period, the American labour historian Donald Reid also devoted a study to the miners of Decazeville, which had the distinctive feature of stretching from the end of the Ancien Régime to the Fifth Republic, while the Terre Humaine collection published the account of the miner Augustin Viseux.[67] This vein also includes theses on unionism, the labour movement among miners, and the miners of the Cévennes,[68] as well as Jean-Louis Tornatore's thesis on the peasant mines and miners of the Briançonnais.[69] More recently, Diana Cooper-Richet has returned to the subject of her early research with a work on the *longue durée* entitled *Le Peuple de la nuit. Mines et mineurs en France (xixe-xxie siècle)* [The People of the Night: Mines and Miners in France (19th-21st c.)].[70] The series of works published on the occasion of the centenary of the Courrières catastrophe[71] could also be classified in this group, as could the interesting work by Marion Fontaine on the Liévin catastrophe (1974) and the "elimination" of the figure of the miner.[72]

A third category of publications, generally more recent and focusing on longer periods, has presented the temporary nature of coal extraction, and revisits the history of coal mines by emphasizing new aspects: relation to the land, the myth of the Gueules noires [Black faces], the end of coal-producing activity, and strategies of reconversion.[73] The research emerging from studies of plans, international relations, and the ECSC (European Coal and Steel Community) also bear mentioning.[74]

66 The battle for coal was also explored in Desbois Évelyne, Jeanneau Yves, Mattéi Bruno, *La Foi des charbonniers les mineurs dans la bataille du charbon 1945-1947, Ethnologie de la France 5* (Paris: Éditions de la Maison des sciences de l'Homme, 1986).

67 Reid Donald, *The Miners of Decazeville a genealogy of deindustrialization* (Cambridge Mass.: Harvard University Press, 1985). Viseux Augustin, *Mineur de fond fosses de Lens, soixante ans de combat et de solidarité, Terre humaine* (Paris: Plon, 1991).

68 Cooper-Richet Diana, "La fédération nationale des mineurs, contribution à l'histoire du syndicalisme français avant 1914" (Ph.D. diss., Université Paris 4 Sorbonne, 1976). Michel Joël, "Le Mouvement ouvrier chez les mineurs d'Europe occidentale (Grande-Bretagne, Belgique, France, Allemagne)" (Ph.D. diss., Université Lumière - Lyon 2, 1987). Sugier Fabrice, "La Classe ouvrière et le mouvement ouvrier dans les mines de charbon du Bassin du Gard : 1914-1922" (Ph.D. diss., Université Paris 8, 1990).

69 Tornatore Jean-Louis, "Le charbon et ses hommes : Tensions, coordination et compromis dans le réseau sociotechnique de l'exploitation du charbon des Alpes briançonnaises, XVIIIe - XXe siècles" (Ph.D. diss., Université de Metz, 2000).

70 Cooper-Richet Diana, *Le peuple de la nuit. Mines et mineurs en France (XIXe - XXe)* (Paris: Perrin, 2002).

71 Conus Marie-France *et al.*, *10 mars 1906, Compagnie de Courrières, enquête sur la plus grande catastrophe minière d'Europe, Mémoires de Gaillette 9* (Lewarde: Centre historique minier du Nord-Pas-de-Calais, 2006). Varaschin Denis, Laloux Ludovic (dir.), *10 mars 1906, Courrières, aux risques de l'histoire* (Vincennes: Groupe de recherche sur l'histoire de l'énergie, 2006).

72 Fontaine Marion, *Fin d'un monde ouvrier. Liévin, 1974* (Paris: Éditions de l'EHESS, 2014).

73 Leboutte René, *Vie et mort des bassins industriels en Europe, 1750-2000* (Paris: l'Harmattan, 2000). Rabier Jean-Claude (dir.), *La remonte. Le bassin minier du Nord-Pas-de-Calais entre passé et avenir* (Villeneuve d'Ascq: Presses universitaires du Septentrion, 20002). Varaschin Denis, *Travailler à la mine, une veine inépuisée* (Arras: Artois Presses Université, 2003). Daumalin Xavier *et al.*, "Le bassin minier des Bouches-du-Rhône", *Industries en Provence, dynamiques d'hier et d'aujourd'hui*, n°11, 2003. Daumalin Xavier *et al.*, *Gueules noires de Provence. Le bassin minier des Bouches-du-Rhône (1744-2003)* (Marseille: Jeanne Lafitte, 2005). Autran Jacques, Lochard Thierry, Monteau Raymond, *L'exploitation dans le bassin minier de Provence, quartiers, puits et galeries* (Aix-en-Provence: CNRS – Travaux de l'Observatoire Hommes-Milieux du Bassin minier de Provence, 2014). Daumalin Xavier, Daviet Sylvie, Mioche Philippe (dir.), *Territoires européens du charbon : des origines aux reconversions* (Aix-en-Provence: Publications de l'Université de Provence, 2016). Eck Jean-François, Friedemann Peter, Lauschke Karl (dir.), *La reconversion des bassins charbonniers. Une comparaison interrégionale entre la Ruhr et le Nord-Pas-de-Calais, Revue du Nord, Hors-Série 21* (Lille: Université Charles de Gaulle - Lille 3, 2006). Eck Jean-François, Terrier Didier (dir.), *Aux marges de la mine. Représentations, stratégies, comportements autour du charbon en Nord-Pas-de-Calais, XVIIIe-XXe siècles* (Valenciennes: Presses Universitaires de Valenciennes, 2007). Martin-Amouroux Jean-Marie, *Charbon, les métamorphoses d'une industrie* (Paris: Technip, 2008). Godard Michel, "Enjeux et impacts de l'exploitation minière du bassin houiller de Ronchamp" (Ph.D. diss., Université de technologie de Belfort-Montbéliard & Université de Franche-Comté, 2012). Aprile Sylvie *et al.* (dir.), *Les Houillères entre l'État, le marché et la société les territoires de la résilience XVIIIe - XXIe siècles* (Villeneuve d'Ascq: Presses Universitaires du Septentrion, 2015).

74 Thuillier Jean-Paul, "Les Charbonnages de France et le Plan Marshall", *in* René Girault, Maurice Lévy-Leboyer (dir.), *Le Plan Marshall et le relèvement économique de l'Europe*

30 A final research category renews the history of mines through its focus on the health and environmental impact of the extractive industry. This category includes Paul-André Rosental's research on silicosis,[75] as well as the works recently edited by the historian Judith Rainhorn and the law expert Hervé Pujol.[76] In the same vein, two theses show the considerable damage and conflicts caused by coalmining in the France-Belgium and France-Saarland cross-border coalfields.[77]

(s.l.: Comité pour l'histoire économique de la France / IGPDE, 1993). Thuillier Jean-Paul, "De Monnet à Massé. Enjeux politiques et objectifs économiques dans le cadre des quatre premiers plans (1946-1965)", in Henry Rousso (dir.), *De Monnet à Massé. Enjeux politiques et objectifs économiques dans le cadre des quatre premiers plans (1946-1965)* (Paris: Éditions du CNRS, 1986). Lucas Nigel J. D., *Energy in France : Planning, Politics and Policy* (London: Europa Publications for the David Memorial Institute of International Studies, 1979). Carbonnel Mauve, "La politique charbonnière de la CECA 1952-2002", *in* Xavier Daumalin, Sylvie Daviet, Philippe Mioche (dir.), *Territoires européens du charbon* (cf. note 73). Berger Françoise, "La CECA et la question de l'énergie", *in* Alain Beltran *et al.* (dir.), *État et énergie XIXe-XXe siècle* (Paris: Comité pour l'histoire économique et financière de la France, IGPDE, 2009).

75 Rosental Paul-André (dir.), *Silicosis, A World History* (Baltimore: John Hopkins University Press, 2017). Rosental Paul-André, Devinck Jean-Claude, "Statistique et mort industrielle. La fabrication du nombre de victimes de la silicose dans les houillères en France de 1946 à nos jours", *Vingtième Siècle, Revue d'histoire*, vol. 95/3, 2007. Idem, "La silicose comme maladie professionnelle transnationale", *Revue française des Affaires Sociales*, vol. 2-3, 2008. Rosental Paul-André, Devinck Jean-Claude, "'Une maladie sociale avec des aspects médicaux' : la difficile reconnaissance de la silicose comme maladie professionnelle dans la France du premier XXe siècle", *Revue d'histoire moderne et contemporaine*, vol. 56/1, 2009. Idem, "De la silicose et des ambiguïtés de la notion de 'maladie professionnelle", *Revue d'histoire moderne et contemporaine*, vol. 56/1, 2009.

76 Pujol Hervé (dir.), *Tristes mines. Impacts environnementaux et sanitaires de l'industrie extractive* (Bordeaux: Les études hospitalières, 2014). Rainhorn Judith (dir.), *Santé et travail à la mine (XIXe-XXIe siècle)* (Villeneuve d'Ascq: Presses Universitaires du Septentrion, 2014). For the United States, see Andrews Thomas G., *Killing For Coal. America's Deadliest Labor War* (Boston: Harvard University Press, 2008). One of its chapters has been translated into French: "Militants des profondeurs de la terre. Luttes des mineurs du Colorado au tournant du XXe siècle", *Écologie & Politique*, vol. 50, 2015.

77 The Ph.D. diss. by Troch Kévin, "'Ne pas grever l'avenir au bénéfice du présent.' Une histoire environnementale de l'extraction du charbon, de la fin du XVIIIe siècle jusqu'à l'Entre-deux-guerres : un développement non soutenable. L'exemple du Couchant de Mons et du Valenciennois" (Université de Lille 3), defended in January 2018, explores the environmental aspect of coal extraction in Belgium and France from the 1870s to the 1950s. Jonas Kaesler's Ph.D. diss (dir. G. Massard-Guilbaud and Ch. Cornelißen), whose defence is scheduled for 2019, examines the cross-border conflicts sparked by the Lorraine coalfields from 1945 to the 1970s. See also Troch Kévin, "Une vulnérabilité délibérément acceptée par les pouvoirs publics ? Extraction du charbon et inondations dans la vallée de la Haine, 1880-1940", *Vertigo : la revue électronique en sciences de l'environnement*, vol. 16/3, 2016. Kaesler Jonas, "'Ein vordringlich europäisches Problem?' Industrielle Verschmutzung und die Entstehung saarländischer Umweltproteste im deutsch-französischen Grenzgebiet, 1957-1959", *in* Olivier Hanse, Annette Lensing, Birgit Metzger (dir.), *Mission écologie. Tensions entre conservatisme et progressisme dans une perspective franco-allemande // Auftrag Ökologie. Konservativ-progressive Ambivalenzen in deutsch-französischer Perspektive* (Bruxelles: Peter Lang, 2018).

31 While in the case of hydraulic power historians generally evoke the "improvements" made to a river to capture energy, the traditional converter for the power of flowing water (the mill), and finally the miller as well as his work and position in society as a whole, the same is not true of coal: its historiography always separates what falls under mineral extraction (coal mining companies, manpower, along with health, social, and environmental impact) from the conversion phase of the potential energy contained in the mineral, which is connected to the history of industrial technology. From the standpoint of the history of energy that I espouse, the implementation of this potential coal energy should also be added to this historiography of coalmining. For the 19th c., this essentially involves the history of the steam engine (stationary and mobile), the boiler, and coal gas. I will not provide an exhaustive list of the existing works on these subjects, however I will simply note the existence of major research works, such as those by Jacques Payen on the steam engine,[78] and Jean-Pierre Williot, Lenart R. Berlanstein, and Jean-Baptiste Fressoz on gas lighting.[79] The

78 Payen Jacques, *Technologie de l'énergie vapeur* (Paris: Éditions du CTHS, 1985). Idem, *Capital et machine à vapeur au XVIIIe siècle : les frères Périer et l'introduction en France de la machine à vapeur de Watt* (Paris: Mouton and co., 1969). Idem, *La machine locomotive en France : des origines au milieu du XIXe siècle* (Lyon: Presses Universitaires de Lyon - Éditions du CNRS, 1988).

79 Williot Jean-Pierre, *L'Industrie du gaz à Paris au XIXe siècle* (Paris: Rive-Droite, 2010). Berlanstein Lenard R., *Big business and Industrial Conflict in 19th c. France: A Social*

work co-edited by Serge Paquier and Jean-Pierre Williot, *L'industrie du gaz en Europe* [The Gas Industry in Europe], covers two centuries in various European countries, and includes both coal gas and natural gas.[80]

32 Most likely because its role in our societies, which albeit important did not truly become so until the second half of the 20th c., the historiography of petroleum was for a long time limited to the work of André Nouschi, who approached it from the perspective of the history of international relations.[81] It has developed recently, notably under the impetus given by Alain Beltran, who edited a number of works opening new perspectives on oil companies, oil routes, and oil and war.[82]

Electricity

33 Electricity, an energy whose industrial production still relies on the use of another energy source, has a prominent place in the historiography. The initial impetus came, in our country, from l'Association pour l'histoire de l'électricité en France [The Association for the History of Electricity in France]. This association, which was created in 1982 by EDF President Marcel Boiteux, EDF Inspector General Maurice Magnien, and the economic historian François Caron, was behind the monumental *Histoire générale de l'électricité en France* [General History of Electricity in France], published between 1991 and 1996.[83] Growing out of Boiteux's desire for the history of the company he presided over to be written, in the eyes of François Caron and the other historians engaged with him in the undertaking, Maurice Lévy-Leboyer and Henri Morsel,[84] this history was in fact an opportunity to work with the executives of a major nationalized company, in an effort to both retrace its history and to record their point of view regarding its construction.

34 This compendium, which mobilized dozens of authors, and whose volumes and chapters are fairly different in tone from one another, sought to cover electricity's scientific, technical, economic, industrial, social, and cultural aspects. It took its place within a tradition of a liberal history of companies, and prized innovation and technological progress. It contributed a great deal to our knowledge, but in my eyes poses a major epistemological problem.

35 Could the decision to allow three senior EDF executives to write 80% of the third volume actually produce anything but a *pro domo* appeal, defence and illustration of the company so dear to them? For instance, the authors took as certitudes ideas that had already been broadly debated and even outmoded at the time the volume was written, such as the unavoidable nature of the permanent rise in the consumption of electricity, and the indisputability of the choices made to provide it—or to prompt it. Ten years after Chernobyl, opposition to civilian nuclear programs was referred to as "fear of the year 2000," "psychological obstacles" that had

History of the Parisian Gas Company (Berkeley: University of California Press, 1991). On the risks of gas lighting, see chapter 5 in Jean-Baptiste Fressoz, *L'apocalypse joyeuse. Une histoire du risque technologique* (Paris: Seuil, 2012). On the imaginary of lighting, see also Schivelbusch Wolfgang, (trad. Weber Anne), *La nuit désenchantée: À propos de l'histoire de l'éclairage artificiel au XIXe siècle* (Paris: Gallimard, 1993).

80 Paquier Serge, Williot Jean-Pierre (dir.), *L'industrie du gaz en Europe au XIXe et XXe siècles. L'innovation entre marchés privés et collectivités publiques* (Bruxelles: Peter Lang, 2005).

81 Nouschi André, *Pétrole et relations internationales depuis 1945* (Paris: Armand Colin, 1999). Idem, *La France et le pétrole : de 1924 à nos jours* (Paris: Picard, 2001).

82 Beltran Alain (dir.), *A Comparative History of National Oil Companies* (Bruxelles: Peter Lang, 2010). Idem (dir.), *Le Pétrole et la Guerre / Oil and War* (Bruxelles: Peter Lang, 2011). Idem (dir.), *Les routes du pétrole. Oil routes* (Bruxelles: Peter Lang, 2016). See also Malti Hocine, *Histoire secrète du pétrole algérien* (Paris: La Découverte, 2010). Bouguen Jean-Marie, *Le Pétrole en France. Genèse et stratégies d'influence* (Paris: l'Harmattan, 2013).

83 *Histoire générale de l'électricité en France*, Volume 1: Caron François, Cardot Fabienne (dir.), introduction by Marcel Boiteux, *Espoirs et conquêtes (1881-1918)*; Volume 2: Lévy-Leboyer Maurice, Morsel Henri (dir.), *L'interconnexion et le marché (1919-1946)*; Volume 3: Morsel Henri (dir.), *Une oeuvre nationale : l'équipement, la croissance de la demande, le nucléaire (1946-1987)* (Paris: Fayard, 1991, 1994 and 1996).

84 F. Cardot represented EDF for the editing of the first volume.

to be "overcome."[85] As a result, instead of the history of electricity announced by the title, we have, at least with the third volume, something of a collection of accounts made by the actors. What is required to make it into history is to connect this source with others and to provide a critique of it, as historical method requires.

36 Beginning in 2001, when the great work was complete,[86] the association most probably no longer had a reason to exist. It gave way to a Comité d'histoire de l'électricité [Committee for the History of Electricity], which in 2013 added energy to its name. This committee, presided over by Alain Beltran and financed by the Fondation EDF, has published *Annales historiques de l'électricité* from 2003 to the present, and in 2011 launched the "Histoire de l'énergie" [History of Energy] collection with the publisher Peter Lang.

37 The historians who are committee members, along with their students (and a few others), have published such a large number of works that it is impossible to provide a summary here, or even a complete list. Their publications have explored all domains relating to electrical energy: companies, production (especially hydroelectric),[87] the national and international market,[88] transportation and distribution networks,[89] the role of state and public policy,[90] the organization of research,[91] and sometimes even the social and cultural history of electricity, as in the book *La Fée et la Servante. La société française face à l'électricité (XIX-XXe siècle)* [The Fairy and the Servant: French Society in the Face of Electricity (19th-20th c.)], for which a broadly revised and expanded new edition was just published under the title *La Vie électrique. Histoire*

85 Volume 3, 776 (cf. note 83).

86 The association also published other works, such as Lamiral Georges, *Chronique de trente années d'équipement nucléaire à Électricité de France* (Paris: Association pour l'histoire de l'électricité en France, 1988), or the proceedings of its conferences, including Trédé-Boulmer Monique (dir.), *Électricité et électrification dans le monde 1880-1980, Actes du deuxième colloque international d'histoire de l'électricité, organisé par l'Association pour l'histoire de l'électricité en France* (Paris: Presses Universitaires de France, 1992), and Grelon André, Ramunni Girolamo, Badel Laurence (dir.), *La naissance de l'ingénieur-électricien. Origines et développement des formations nationales électrotechniques, Actes du troisième colloque international d'histoire de l'électricité* (Paris: PUF, 1997).

87 Varaschin Denis, "La Société lyonnaise des forces motrices du Rhône, 1892-1946. Du service public à la nationalisation" (Ph.D. diss., Université Pierre Mendès-France - Grenoble, 1996). Giandou Alexandre, "Histoire d'un partenaire régional de l'État : la Compagnie nationale du Rhône (1933-1974)" (Ph.D. diss., Université Lyon 2). Bertrand-Camitaud (Dalmasso) Anne, "Nationalisation et exploitation de la production hydroélectrique dans les Alpes de Savoie des années 1930 aux années 1970" (Ph.D. diss., Université Lyon 2, 1993). Varaschin Denis, *La Fée et la marmite : électricité et électrométallurgie dans les Alpes du Nord* (Paris: La Luiraz, 1996). Varaschin Denis, Tignes, la naissance d'un géant (Arras: Artois Presses Université, 2001). Gouy-Gilbert Cécile, Bertrand-Camitaud (Dalmasso) Anne, Jakob Michael (dir.), *Alpes électriques : paysages de la houille blanche* (Renage: Dire l'entreprise, 2011). Bouvier Yves, Varaschin Denis (dir.), *Le patrimoine industriel de l'électricité et de l'hydroélectricité, actes du colloque international de Divonne-les-Bains et de Genève (7 et 8 juin 2007)* (Chambéry: Université de Savoie, 2009). Varaschin Denis, *Les Entreprises du secteur de l'énergie sous l'Occupation* (Arras: Artois Presses Université, 2006). Bouneau Christophe, *The History of CIGRE (International Council on Large Electric Systems). A key player in the development of electric power systems since 1921* (Paris: Conformes, 2011). Varaschin Denis, *Mémoires de l'électricité* [DVD] (Paris: Éditions de la Maison des Sciences de l'Homme, 2007); Bouneau Christophe *et al.* (dir.), *Les Paysages de l'électricité : perspectives historiques et enjeux contemporains (XIXe - XXIe siècles)* (Bruxelles: Peter Lang, 2012). See also Frost Robert L., *Alternating Currents. Nationalized Power in France, 1946-1970*, (Ithaca - London: Cornell University Press: 1991). Barjot Dominique (dir.), *Annuaire statistique de l'économie française, vol. 2 : L'Énergie au XIXe et XXe siècles* (Paris: Presses de l'ENS, 1991).

88 Beltran Alain, Morsel Henri (ed.), *Electricity generation and supply : regulation, market, competition. International comparisons. Proceedings of the eleventh International Economic Congress (B15 Session)* (Milan: Università Bocconi, 1994); Beltran Alain, Couvreux Jean Paul (collab.), *Électricité de France, Cinquante ans d'histoire(s) à l'international* (Paris: Le Cherche-Midi, 1996).

89 Bouneau Christophe, Derdevet Michel, Percebois Jacques, *Les réseaux électriques au cœur de la civilisation industrielle* (Boulogne: Timée Éditions, 2007). Arzul Jean-Yves *et al.*, *Le système nerveux du réseau français de transport d'électricité : 1946 à 2006, 60 années de contrôle électrique, EDF R&D* (Paris: Tec & Doc-Lavoisier, 2012).

90 Picard Jean-François, Beltran Alain, Bungener Martine, *Histoire(s) de l'EDF. Comment se sont prises les décisions de 1946 à nos jours* (Paris: Dunod, 1985). Varaschin Denis, "États et électricité en Europe occidentale" (HDR (research-director thesis), Université Pierre Mendès-France - Grenoble, 1997).

91 Bouvier Yves *et al.* (dir.), *De l'atelier au laboratoire. Recherche et innovation dans l'industrie électrique. XIXe-XXe siècles* (Bruxelles: Peter Lang, 2011).

et imaginaire (XVIII-XXe siècles) [Electric Life: History and Imaginary (18th-20th c.)].[92] Some of the publications by committee members also involve energy in general,[93] such as the seminar on the state and energy co-edited by Alain Beltran, Christophe Bouneau, Yves Bouvier, Denis Varaschin, and Jean-Pierre Williot.[94] Aside from two exceptions relating to the energy policy of the state, the contributions in this group all focus on one specific energy sector.

38 During the 2000s, large dams were the subject of research seeking to show the decision-making behind them, the communication policy of the EDF, the reaction of communities affected by their construction, and the consequences of massive expropriations.[95] Even more recently, a new generation of studies have appeared that are more distant from the institutions concerned, critical of the policies pursued, and attentive to the environmental aspects of development.[96]

39 The French electronuclear sector has until now prompted only a limited amount of historical research, which is most probably due to the accessibility of sources.[97] The most interesting academic work, recently expanded and revised, is the one by the anthropologist Françoise Zonabend, in which she shows how we inhabit, think, and defend a peninsula dedicated to nuclear power.[98]Among historians, the most stimulating reflections on the subject have come from across the Atlantic, in the work of Gabrielle Hecht. The rich documentation assembled by this historian has enabled her to discuss the French nuclear exception with great cogency, as well as to examine the relations between the nuclear industry and national identity, engineers and politicians, and unions and local populations.[99] More recently, Hecht has published a second book focusing on the market, labour and workers connected to African uranium (the source of an energy that is supposed to embody out "national" energy independence).[100] The sociologist Yannick Barthe has analysed public policies with regard to nuclear waste,[101] Cyrille Foasso the debates that have

92 Beltran Alain and Carré Patrice, *La Fée et la Servante. La société française face à l'électricité (XIX-XXe siècle), Paris, Belin, 1991. New edition under the title La Vie électrique. Histoire et imaginaire (XVIII-XXIe siècles)* (Paris: Belin, 2016).

93 Beltran Alain, "La question de l'énergie en Europe occidentale", *Histoire, Économie et Sociétés*, vol. 18/2, 1999. Beltran Alain, "La question énergétique en France de 1960 à 1974 : dépendance, crise et rôle de l'État", *in* Éric Bussière (dir.), *Georges Pompidou face à la mutation économique de l'Occident : 1969-1974 : actes du colloque des 15 et 16 novembre 2001 au Conseil économique et social* (Paris: PUF, 2003). For a comparative viewpoint see Chick Martin, *Electricity and Energy policy in Britain, France and the United States since 1945* (Cheltenham: Elgar, 2007).

94 Beltran, *État et énergie XIXe-XXe siècle* (cf. note 74).

95 Bodon Virginie, *La modernité au village : Tignes, Savines, Ubaye. La submersion de communes rurales au nom de l'intérêt général, 1920-1970* (Grenoble: Presses universitaires de Grenoble, 2003). Blanc Nathalie, Bonin Sophie (dir.), *Grands barrages et habitants, Les risques sociaux du développement (Versailles - Paris: Quae Editions - Maisons des sciences de l'Homme, 2008). Nougarède Olivier, Naussac-en-Margeride : L'histoire économique et sociale d'une vallée noyée* (Ardon: INRA, Laboratoire d'économie et de sociologie rurales, 1980).

96 Pritchard Sara B., *Confluence. The Nature of Technology and the Remaking of the Rhône* (Cambridge (Mass.): Harvard University Press, 2011). Bernhardt Christoph, *Im Spiegel des Wassers. Eine transnationale Umweltgeschichte des Oberrheins (1800-2000)* (Köln: Böhlau Verlag, 2016).

97 See nevertheless chapters 8, 9, and 10 of a book that we will discuss later, Debeir, Deléage, Hémery, *Les servitudes de la puissance* (cf. note 10). Investigative journalists, along with pro- and anti-nuclear militants, have nevertheless published largely on the subject.

98 Zonabend Françoise, *La Presqu'île au nucléaire* (Paris: Odile Jacob - Le Seuil, 1989), republished under the title *La Presqu'île au nucléaire : Three Mile Island, Tchernobyl, Fukushima... et après ?* (Paris: Odile Jacob, 2014).

99 Hecht Gabrielle, *The Radiance of France, Nuclear Power and National Identity after World War II* (Cambridge (Mass.): MIT Press, 1998). French translation *Le Rayonnement de la France. Énergie nucléaire et identité nationale après la seconde guerre mondiale* (Paris: La Découverte, 2004).

100 Being Nuclear, *Africans and the global Uranium Trade* (Cambridge (Mass.): MIT Press, 2012). French translation *Uranium africain, une histoire globale* (Paris: Seuil, 2016). Two American journalists have discussed the role of engineers from the Mines school of mining engineers at the head of the CEA: Pringles Peter, Spigelman James, (trad. Vierne Béatrice), *Les barons de l'atome* (Paris: Seuil, 1982). For a diametrically opposed perspective, see Belot Robert, *L'atome et la France. Aux origines de la technoscience française* (Paris: Odile Jacob, 2015). See also Soutou Georges-Henri, "La logique d'un choix : le CEA et le problème des filières électro-nucléaires, 1953-1969", vol. 68, *Relations Internationales*, 1991. Soutou Georges-Henri, Beltran Alain (dir.), *Pierre Guillaumat. La passion des grands projets industriels* (Paris: Éditions Rive Droite, 1995).

101 Barthe Yannick, *Le pouvoir d'indécision. La mise en politique des déchets nucléaires* (Paris: Economica, 2006).

marked the community of engineers in this sector and the process of expertise and decision-making that have enabled assessments of this energy source's acceptability,[102] and Sezin Topçu how this strongly contested industry is governed.[103]

40 This group of research on electricity finally includes the annual issue of the *Annales de l'Électricité* [Annals of Electricity], which explores subjects as varied as social movements and electricity, electricity and the environment, the human body and electricity, public policy and solar energy, etc.

STUDIES OF ENERGY SYSTEMS AND TRANSITIONS

41 These sector-based studies were necessary. Others will come as well, if only because territorial anchoring is necessary for the writing of history, and works of synthesis require more targeted works in order to be written. However, as abundant and useful as these works may be, they cannot replace a reflection on the relations humans have had at different periods with the energy available around them, a history that I believe, as previously stated, takes the form of a study of systems and transitions. This history, which emerged slowly, is what I would like to speak about presently, by once again pointing out that it is impossible to be exhaustive in the space available here. My objective is therefore not to cite *all* of the works that discuss energy systems and the transitions between them. I have instead tried to show the terms in which the debate has been framed since the emergence of this type of study, using a few of the works I believe to be the most significant. I will begin by one of the rare French-language works, if not the only one, that can be included in this category of studies taking a global approach to the energy question, before discussing an essentially English-language historiography.

42 The first edition of a book entitled *Les Servitudes de la puissance. Une histoire de l'énergie* [In the Servitude of Power: Energy and Civilization through the Ages] appeared in 1986.[104] In their introduction, the authors Jean-Claude Debeir, Jean-Paul Deléage, and Daniel Hémery affirm: "Historians have not granted any attention to energy so far,"[105] "it does not exist in the social sciences as a specific object of knowledge."[106] The 2013 edition adds: "It is evoked only from the standpoint of economic growth."[107]

43 This statement may seem paradoxical in view of the preceding historiographical panorama, but the paradox is only apparent, with the remark regarding energy as a totally neglected subject being essentially justified. Let us consider, as an illustration of this assertion, the example of a collection of texts on contemporary economic history published by Michel Margairaz in 1992, six years after the publication of *Servitudes de la puissance*.[108] This well-conceived work brings together a few dozen of the best pieces by economic historians of modern France from the preceding decades. One looks in vain for energy, both in the twelve sections into which the texts are divided, or within the texts themselves. While energy is the necessary condition for all economic activity to be possible, modern economic historians were still ignoring it as recently as the last decades of the 20th c., or at least were not putting it at the heart of their reflections. They conceived of it only as a condition—of course a *sine qua non*—of what for most of them was central to their reflection: economic growth. The author of the anthology was not the cause, as he could not include what did not exist: his collection presents the areas of interest of economic historians as they stood at the time.

102 Foasso Cyrille, *Atomes Sous Surveillance: Une Histoire de la sûreté nucléaire en France* (Bruxelles: Peter Lang, 2012).
103 Topçu Sezin, *La France nucléaire. L'art de gouverner une technologie contestée* (Paris: Seuil, 2013).
104 Debeir, Deléage, Hémery, *Les servitudes de la puissance* (cf. note 10).
105 *Ibid*., 10 of the 1986 edition.
106 *Ibid*., 11 (1986, p. XII English translation).
107 *Ibid*., 9 (2013). This addition, which was entirely relevant in 1986, is not entirely in keeping with the present reality.
108 Margairaz Michel (dir.), *Histoire économique, XVIIIe-XXe siècles* (Paris: Larousse, 1992).

44 Of course many works on the Industrial Revolution had discussed coal at length, while the ones focusing on the 20th c. explored electricity and its networks, works that I mentioned earlier. Yet this historiography was missing a global view of the energy question as I defined it in my introduction: a vision of how societies reflected on (or didn't) and organized (or didn't) energy use; a global vision that also shows the consequences (not always desired) of how they mobilized, converted, divided, and spent it; a history that considers humans for what they are, living beings who are an integral part of nature, and subject to its balance and limits—in matters of energy as with everything else.

45 The authors of *Servitudes de la puissance* were thus correct on this point, for in 1986 energy essentially remained a neglected historical subject, although the reason they saw for this is not a convincing one for me:

46 Not least among these [the limits of history] is the proliferation of empirical research, ever more fragmented and obedient to the current dominant trend in research—the infinite accumulation of findings—with its refusal to look at the totality, to place the energy crisis in historical perspective. Such a perspective, however, is the only methodological choice that can provide a solid foundation for the analysis of society's relation to energy.[109]

47 Here we have the old reproach that historians of science direct toward historians "as such," who submerge themselves in empirical and monographic research, and prove unable to assemble generalities, or even worse *refuse* to do so. Yet while it is indeed necessary to "solidly base analysis of the relations societies maintain toward energy," it is also true that at least until a certain level of research, empirical studies (whatever their sources, which in the case of history includes archives that are written, oral, visual, archaeological, etc.) are the best way, if not the only way, of doing so. For a historian, the search for *totality,* however necessary it may be, is built through the synthesis of information contained in primary sources that are constructed, problematized, analysed, and cross-referenced. The rest of *Servitudes de la puissance* was in fact based on empirical research, without which the writing of this book would not have been possible. As a result, the question of energy's neglect is not framed in terms of a refusal to consider totality, but instead calls for a genuine reflection on the reasons why global studies of energy proved so rare for such a long time.

48 The fact that historians have been so slow in seizing upon the subject is another illustration, as though one were necessary, of the fact that they ask of the past only questions of their time (and in this case their future). But they manage to do so only in the best cases, and can be late in seizing upon key questions, or can simply not see them or even want to not see them—neglected subjects are nothing new in history, and various historians have shown how certain disturbing questions have taken a while to be raised. Neither the writing of intellectuals on both the right and the left—who for decades have laid the foundations for a critical reflection on the relation between humans and their environment—nor the environmentalist movement of the 1970s, nor anti-nuclear protests, nor "oil crises" have been enough to trigger a fundamental historical reflection on the relations our societies have with energy. It took the discovery of global warming and the role that human activity has played and continues to play in its arrival for it to emerge, and for us to begin to worry. The revelation that human activity is responsible for a change in climate served as an (still insufficient) incentive to explore a new aspect of history. This is why in the preceding sections I emphasized the existence of works that had already begun to reflect on the relation between society and energy, pioneering works that were "ahead of their time."

49 The German historian Rolph Peter Sieferle, whose contribution I will discuss below and who noted the importance of energy in the Industrial Revolution, also wondered why it was so slow in

109 Debeir, Deléage, Hémery, *In the Servitude of Power* (cf note 10), 15 (page XV of English translation).

coming to centre stage. He believed this blind spot goes back to classical economists, who understood questions of natural resources only as agricultural questions.[110] Marx placed the textile industry at the heart of his analysis. Yet this sector, which brought spectacular changes to work organization, was initially not based on the use of fossil energy (but on hydraulic and human power). Sieferle believes that this prevented Marx from assessing the problem.

50 To understand the slowness of historians in exploring the energy question, one must also explore how the vocabulary integrated the scientific meaning of the word "energy." For while the notion of energy as a "force that can create work" indeed appeared during the 19th c., with the formulation of the first laws of thermodynamics, it was not until 1932 that the *Dictionnaire de l'Académie française* [Dictionary of the Académie française] mentioned this meaning as a complement to its earlier one of "vigour of soul" or "vigour of speech." Even if, as indicated by *Le Robert*, the word began to be used in its scientific sense starting in 1868, or in a vaguer sense even as early as 1807, it took over a century for it to be adopted by l'Académie. The latter is certainly not known for its propensity to swiftly adopt novelty, but this slowness is surely also the reflection of society's difficulty (reticence?) in taking a global view of energy. The question calls for further exploration.

51 Whatever the reasons for this difficulty, it is necessary to give the authors of *Servitudes de la puissance* credit: theirs was the first French-language book to stress that the history of energy had not received necessary attention, and to propose an approach. Beyond the global outline it endeavoured to sketch out, some aspects of which can be debated, and the fact that the 2013 republication hardly took into account the evolution of the historiography since the 1980s, it drew attention to a number of important elements.

52 The first is that relations between human societies and nature are not limited to their economic and social aspects.[111] Human history cannot be written effectively without including biological aspects. Regardless of how it is formulated, this is the credo of environmental history[112]: as an integral part of nature, humans and the societies they form cannot be understood without their relation to the environment being taken into consideration.

53 Debeir, Deléage, and Hémery made another important remark directly connected to energy: the quantity of energy provided by the sun being infinitely superior to human needs,[113] the true question for them is not the existence of energy, but rather putting it into use, and therefore a question of converters. This remark has not lost any of its relevance.

54 A third essential point is the notion that the history of the relations between societies and the energy surrounding them takes place via the study of energy *systems*.[114] The authors' definition of an energy system included supply zones and techniques used for primary energy, methods for collection, extraction, transportation, and storage, types of converters, final forms of energy, competitive relations between various sectors, and finally forms of appropriation, which controlled the arrangement of energy converters and modes of energy.[115] This also leads to questions of free access to energy sources and

110 Sieferle, *Der unterirdische Wald* (cf. note 10). E. A. Wrigley also developed this point in the first part of *Energy and the English Industrial Revolution* (cf. note 36).

111 Debeir, Deléage, Hémery, *Les servitudes de la puissance* (cf. note 10), 17.

112 It was in an effort to support this idea that the author of this essay co-organised a conference with S. Mosley in Paris in 2008, partially published (under the same title): Massard-Guilbaud Geneviève, Mosley Stephen (ed.), *Common Ground. Integrating Social and Environmental in History* (Newcastle: Cambridge Scholars Publishing, 2011).

113 The authors refer on this subject to the article by Michel Bosquet (alias André Gorz), "Sources d'énergie et humanité", *Le Sauvage*, Spring 1980, 55-58.

114 The authors claim to have introduced this concept of energy system, but it had already been used by Rolph Sieferle four years earlier in Der unterirdische Wald, for which see below.

115 Debeir, Deléage, Hémery, *Les servitudes de la puissance* (cf. note 10), 17.

the appropriation of surplus, both of which also deserve particular attention.

55 The German historian Rolph Peter Sieferle, who died prematurely in 2016, had proposed a new vision of energy questions four years before the appearance of *Servitudes de la puissance*.[116] His work *Der unterirdische Wald. Energiekrise und industrielle Revolution*[117] [The Subterranean Forest: Energy Systems and the Industrial Revolution], which was published in 1982, did not appear among the bibliographical references of *Servitudes de la puissance*. Probably because its original version was in German and its English translation came late, before finally being republished in paperback nearly thirty years after the first edition, the work was little-known for a long time, with the original ideas developed by Sieferle sometimes being attributed to others, who in reality only repeated or reinterpreted them.

56 *Der unterirdische Wald* is not, strictly speaking, a general history of energy. Consisting of five relatively independent sections, the book offers a series of avenues for reflection that are both pioneering and stimulating. The first section sketches out a panorama of successive energy systems since the Neolithic; two others discuss questions connected to German forests during the early modern period; and a final section explores perceptions of energy. I will summarize here only one or two arguments developed in the third section, which pertain to coal and the Industrial Revolution in Britain. Sieferle argued that the use of coal as a replacement for wood had enabled the export of British textiles by freeing up land (that no longer had to be reserved for forests). In other words, the use of fossil energy allowed Great Britain to gain space. The use of fossil energy also meant that the country could transition to the stage of both territorial expansion (use of natural resources outside its territory) and temporal expansion (use of fossil resources accumulated underground during the Palaeozoic era). In changing from direct solar energy (through photosynthesis) to fossil energy,[118] Sieferle believed that the British economy shattered earlier territorial limitations. This was undeniably a new and stimulating way of considering things.

57 In an article from 1962, the English historian Tony Wrigley, a pioneer of historical demographics along with Peter Laslett, formulated a general interpretation of the change that had taken place with the Industrial Revolution. He introduced the notions of an advanced organic economy to refer to the pre-Industrial Revolution economy, and the mineral economy for the one that succeeded it.[119] He returned to these notions in *Continuity, Chance and Change,* a work in which he analysed why he believed Malthus' theory was inaccurate (evoking in this case the energy transition rather than the demographic transition).[120] In 2010 Wrigley finally returned to the question in *Energy and the English Industrial Revolution*,[121] in which he organized his entire interpretation of the Industrial Revolution around the question of energy. While recognizing that it is always difficult in the social sciences to identify *the* determining factor in a change, he again argued that the transition from the old economy (and therefore, in his mind, the end of poverty and misery for many) would not have been possible without access to a form of energy that was not subject to the limitations of the annual cycle of sunshine and photosynthesis.

58 This analysis, which brings to mind Braudel's conclusion when he presented the former economic system as being essentially restrained by nature in its energy system, raised the question of the relation to energy, economic growth, and the well-being of populations, and subsequently that of knowing whether the former economy

116 Tony Wrigley had already introduced the notion of organic/mineral economies, and discussed questions of energy in articles that can also be considered as being the first on their subject. However, it was not until 1988 and 2010 that he synthesized his body of ideas in two works that we will discuss below.

117 Sieferle, *Der unterirdische Wald* (cf. note 10).

118 Fossil energy of course also comes from solar energy, but on an entirely different time scale!

119 Wrigley, "The Supply" (cf. note 36), 1-16.

120 Wrigley, *Continuity, Chance and Change* (cf. note 36).

121 Wrigley, *Energy and the English Industrial Revolution* (cf. note 36).

had not in its course come to a breaking point, one in which a change of energy system had become necessary, and massive use of fossil energy *inevitable*. While the question is clearly an important one during a time of inventing "low-carbon" economies, there is no consensus today on this subject among historians.

59 The American historian Robert C. Allen has sought to show why Great Britain during the Elizabethan period developed an economy that was at least partially based on coal. The existence of coal underground is not reason enough to undertake its use: Germany and China also had large reserves of coal, but only began to extract it much later.[122] The traditional explanation for the early use of coal in Britain was the lack of wood (Nef's timber crisis): Great Britain deforested its territory well before France or Germany, and therefore ran short of wood much sooner than other countries. A wood shortage should have led to a price rise, yet Allen shows that the rising price of wood was neither clear nor uniform. The price varied from one British region to another, and from one period to another. The respective prices of wood and coal were of course not the only criterion in play. The respective properties of these two sources of energy also came under consideration: coal was greatly superior for lime kilns and forges, while wood or charcoal were in principle favoured for other uses. The price of fuels was nevertheless a key argument, as in London wood had become exceptionally expensive compared to the coal imported from the north of the country by waterway.

59 According to Allen, coal gradually became a backstop technology, that is to say an energy source that could provide very large quantities of energy at a low price, with this price becoming the price of reference. Yet important transformations had to take place for this to be possible, and not just with industry and among artisans. During the 17th c., over half of the energy consumed was for domestic heating. Yet it was impossible to heat homes with coal without completely transforming how they were built. The use of coal required them to be equipped with a chimney (which was not the case before that period), a stone wall to support it, a firebox lined with metal that could accommodate a fire with sufficient draft, etc. The British capital, whose centre had partly been destroyed by the Great Fire of London in 1666, and which was experiencing growth that was not present in the country's other cities, consequently (re)built, and transitioned to coal more quickly than the others. Whether or not Allen's overall theory is correct, this is a simple but particularly clear example of the important role played by a converter, and how a change in fuel could lead to social change that can only unfold over a relatively long period of time (but fostered here by the catastrophe of 1666—catastrophes having the property of accelerating change.)[123]

60 The book *Power to the People,* by Astrid Kander, Paolo Malanima, and Paul Warde, three European historians who have greatly contributed to this field of research in their previous publications, appeared in 2014.[124] Aside from the possible

122 Allen, *The British Industrial Revolution in Global Perspective* (cf. note 17). See also by the same author "Backward into the Future. The Shift to Coal and its Implications for the next Energy Transition", *Energy Policy*, vol. 50, 2012.

123 Massard-Guilbaud Geneviève, "The urban catastrophe, challenge to the social, economic and cultural order of the city", *in* Geneviève Massard-Guilbaud, Dieter Schott, Harold L. Platt (eds.), *Cities and Catastrophes : Coping with Emergency in European History. Villes et catastrophes. Réactions face à l'urgence dans l'histoire européenne* (Frankfurt am Main: Peter Lang Verlag, 2002, 9–42).

124 Kander Astrid, Malanima Paolo, Warde Paul, *Power to the People: Energy in Europe over the Last Five Centuries* (Princeton: Princeton University Press, 2013). Previous publications by these authors (among others): Stern David I., Kander Astrid, "The role of Energy in the Industrial Revolution and Modern Economic Growth", *The Energy Journal*, vol. 33/3, 2012. Kander Astrid, Warde Paul, "Energy Availability from Livestock and Agricultural Productivity in Europe, 1815-1913: a New Comparison", *The Economic History Review, New Series*, vol. 64/1, 2011. Gales Ben *et al.*, "North versus South: Energy Transition and Energy Intensity in Europe over 200 years", *European Review of Economic History*, vol. 11/2, 2007. Malanima Paolo, *Le energie degli italiani. Due secoli di storia* (Milano: B. Mondadori, 2013). Idem, *Energy Consumption in Italy in the 19th and 20th Centuries* (Napoli: Issm-Cnr, 2006). Idem, *Energia e crescita nell'Europa preindustriale* (Roma: La Nuova Italia Scientifica, 1996). Warde, "Fear of Wood Shortage" (cf. note 17). Idem, *Energy Consumption in England & Wales* (cf. note 36). Idem, "Early Modern 'Resource Crisis' " (cf. note 36).

nod to John Lennon's cult song, the authors lay claim to the dual meaning of the word *power*, affirming that control over energy is indeed a source of power, an idea that enjoys consensus. They present their work as a history of the European economy seen through the question of energy. They briefly discuss the various theories that have succeeded one another to explain why the Industrial Revolution initially took place in England (arguments that are economic and energy-based but also institutional, cultural, etc.), but deem this debate to be partly artificial, as they do not see the disagreements as being fundamental. They nevertheless point out that one of the central arguments that emerged from this debate was the existence in Great Britain of an abundant and relatively affordable fuel. Firmly convinced of this fact, they aim for the first time to provide as reliable of figures as possible for European energy consumption (or at least for a part of Europe) over a *longue durée*. The data they have constructed shows the succession, since the late Middle Ages, of three phases of consumption: three centuries of stagnation in energy consumption (1500-1800) were followed by an explosion in consumption (1800-1970), interrupted by the two world wars, with the period between 1970-2008 (date at which their data breaks off) being one of stabilization. The authors' objective is clearly to also provide meaning for this curve, and to explore the relations between economic growth and energy consumption. The study of elements driving energy transitions and the respective efficiency of various systems are also among the book's objectives.

61 Kander, Malanima, and Warde conclude that Europe before the Industrial Revolution indeed suffered from energy restrictions of two kinds: the lack of productivity of its lands (compared for instance to certain parts of Asia), and the low energy efficiency of its converters. These restrictions were obstacles to economic growth. The use of fossil energies was both the condition and the determining factor of the growth it subsequently experienced. The prosperity of Great Britain and the Netherlands during the Ancien Régime was also apparently due to their early use of fossil resources (coal for the former, peat for the latter), as well as their intensive use of wind (for their merchant marines). The transition seemingly took place during the 19th c. with the development of large-scale coal use. The latter created the conditions for developing steam engine use (which they consider to be one of the most important inventions in the history of humanity), which was itself at the origin of modern growth. Low coal prices and high salaries combined to make Great Britain the origin of the revolution instead of elsewhere. The authors also insist on the fact that they believe the energy factor to be more important for economic growth than economist generally think. In order to show how this transition took place, they also set out the functioning of what they call development blocks (for example the steam-coal-steel block).

While emphasizing that concern over energy 62
was an age-old and recurring phenomenon in Europe,[125] and that projections on this subject have always proven inaccurate, the authors attempt, while offering many precautions, to evaluate the implications of their study for the future. These implications can be summarized thus: returning to an organic economy would be both expensive and an obstacle to economic growth and the well-being of populations; today there is no macro-innovation of the type that drove the transition toward coal; the future is based on better energy efficiency ("Negawatt is the best watt"), although the rebound effect should not be neglected; and technological innovations often develop in niches and networks. Kander, Malanima, and Warde's book therefore provides a mass of new numerical "data," whose

125 On this point, see for example Brüggemeier Franz-Josef, "Le dépérissement de la forêt. Construction et déconstruction d'un problème d'environnement", *in* Christoph Bernhardt, Geneviève Massard-Guilbaud (dir.), *Le Démon moderne / The Modern Demon. La pollution dans les sociétés urbaines et industrielles d'Europe. Pollution in Urban and Industrial Societies* (Clermont-Ferrand: Presses universitaires Blaise-Pascal, 2002). See also Jonsson Fredrik A., "Abundance and Scarcity in Geological Time 1784–1844", *in* Forrester Katrina, Smith Sophie (eds.), *Nature, Action and the Future: Political Thought and the Environment* (Cambridge: University of Cambridge Press, 2018).

construction will surely be the subject of criticism, although in terms of interpretation it is in keeping with the sketch drawn out at another time by Braudel, and later developed by Wrigley.

63 Other authors, such as Kenneth Pomeranz, have developed arguments that do not differ enough from the ones I've mentioned for me to present them here as well.[126] However, I would like to briefly mention the research conducted in environmental history, and notably the history of energy, through the study of flows and the social metabolism. This research initially emanated from the Institut für Soziale Ökologie Alpen-Adria-Universität Klagenfurt (Austria), a research centre founded and for a long time directed by the sociologist Marina Fischer-Kowalski, who developed this concept.[127] A good overview of this approach can be found in the chapter by Richard Unger that will appear in *Systèmes et transitions énergétiques* [Energy Systems and Transitions].[128] The method has, to a certain extent, been echoed in France by specialists of the urban environment, such as Sabine Barles.[129]

64 Some researchers either do not appear to share the notion that we must renounce fossil energy, speaking of transitions but without appearing convinced of their value, or believe that taking pains to study them denotes the "triumph of a cultural history of energy."[130] Others mention transitions only as a warning. For instance in the degrowth journal *Entropia*, Jean-Baptiste Fressoz considers the concept of transition a "dangerous lure with no historical referent," and any attempt to understand how they function a kind of "managerial ambition."[131] François Jarrige and Jean-Louis Tornatore wonder "whether the concept of 'ecological transition' is not in fact the final avatar and consummate form of denial [of climate change]."[132]

65 Researchers who use the concept of the "anthropocene," which they define as a new geological era marked by the fact that humans have become a geological agent,[133] base their theory on series of charts that present the radical changes that have taken place during the last two centuries (changes that are familiar to historians, whose research has helped construct these charts), although they do not discuss its causes, the ways in which the presented changes took place, or the actors who sought them or initiated them. For example Alfred W. Crosby, in his synthetic history of human energy use entitled *Children of the Sun*,[134] offers an elegant description of phenomena that he never actually explains. In their recent book *The Great*

126 Pomeranz Kenneth, *The Great Divergence: China, Europe, and the Making of the Modern World Economy* (Princeton: Princeton University Press, 2000). French translation *Une grande divergence. La Chine, l'Europe et la construction de l'économie mondiale* (Paris: Albin Michel, 2010).

127 See especially Krausmann Fridolin, Habert Helmut, "The Process of Industrialization from the Perspective of Energetic Metabolism. Socioeconomic Energy Flows in Austria. 1830-1995", *Ecological Economics*, vol. 41, 2002.

128 Mathis, Massard-Guilbaud, *Systèmes et transitions énergétiques* (cf. note *), chapter 9. Other references on the energy metabolism are included in this article.

129 Kim Eunhye, Barles Sabine, "The Energy Consumption of Paris and its Supply Areas from the 18th c. to the Present", *Regional Environmental Change*, vol. 12, 2012. Barles Sabine, "The Seine and Parisian Metabolism: Growth of Capital Dependencies in the 19th and 20th Centuries", *in* Stéphane Castonguay, Matthew Evenden (eds.), *Urban Waters: Rivers, Cities and the Production of Space in Europe and North America* (Pittsburgh: Pittsburgh University Press, 2012). Barles Sabine, "A Metabolic Approach to the City: 19th and 20th C. Paris", *in* Dieter Schott, Bill Luckin, Geneviève Massard-Guilbaud (eds.), *Resources of the City: Contributions to an Environmental History of Modern Europe* (Aldershot: Ashgate, 2005).

130 Bouvier Yves (dir.), *Les défis énergétiques du XXIe siècle. Transition, concurrence et efficacité* (Bruxelles: Peter Lang, 2012). Cultural history is nevertheless not my orientation, as my chair at l'EHESS is entitled "Environmental, economic, and social history of the modern world."

131 Fressoz Jean-Baptiste, "Pour une histoire désorientée de l'énergie", *Entropia, Revue d'étude théorique et politique de la décroissance*, vol. 15, 2013.

132 Jarrige François, Tornatore Jean-Louis, "Un ministère pour la transition", *Sciences critiques*, https://sciences-critiques.fr/un-ministere-pour-la-transition, 2017.

133 See the seminal article for the concept of the anthropocene: Crutzen Paul J., "Geology of Mankind", *Nature*, vol. 415/23, 2002. French translation "La géologie de l'Humanité", *Écologie et Politique*, vol. 34, 2007. A more developed version co-authored by Steffen Will, Crutzen Paul J., McNeill John R., "The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?", *Ambio*, vol. 36/8, 2007.

134 Crosby Alfred W., *Children of the Sun. A History of Humanity's Unappeasable Appetite for Energy* (New York: W.W. Norton, 2006).

Acceleration,[135] John McNeill and Peter Engelke devote a 60-page chapter to energy, yet they also describe situations without ever saying how they were implemented, and evolutions without specifying what brought them about.

66 Marxist historians, who are critical of the concept of the anthropocene, which they believe obscures the responsibility of the capitalist bourgeoisie in a hypothetical *anthropos*, propose giving the former its due by replacing the term anthropocene with that of capitalocene. Let us note in passing that the term anthropocene raises many other (fully real) problems than the identity of the *anthropos* in question, notably knowing how and according to what time and spatial scales history is written, as well as the relation between the Earth and nature sciences on the one hand, and the Humanities and social sciences on the other. Developing this point is beyond the scope of my objective here, although not considering the anthropocene a useful framework for my reflection is an assumed choice.

67 Marxist historians therefore do not deny the existence of transitions, but endeavour to show how the most remarked of these transitions took place, namely the introduction of the mass use of coal. This is how *Capital Fossil* proceeds, a book published in 2016 and based on the doctoral thesis of Andreas Malm, a human ecology teacher at Lund University in Sweden.[136] The author directly opposes the conclusions of *Power to the People* and those he refers to as "Ricardo-Malthusians," with this term including Kander, Malanima, and Warde as well as Wrigley, Allen, and others such as Pomeranz. I will only discuss Malm's argument regarding the Industrial Revolution in Great Britain, the only one that is based on the study of original sources. Malm's demonstration aims to show that what led industrial actors in key sectors of the factory system to renounce hydraulic power in favour of coal was neither technological advances, nor the price of the different energies available or their converters, nor the need for economic growth, but rather the "logic of capital," especially the need for a large concentration of manpower, and the desire to control it more effectively and at lower cost, as well as to benefit from urban commercial infrastructure. While some of these "demonstrations" are in fact only theories, as the author recognizes himself a number of times,[137] the first part of this book provides a certain number of elements that deserve attention. The passages on industry's independence from firewood, the untapped capacities of hydraulic power, and the price of setting up steam power, for instance, could certainly fuel the current debate.[138] The conclusion Malm arrives at on the question of the Industrial Revolution is clearly diametrically opposed to that of the works I mentioned previously, and that can easily be sketched out as the following: the use of fossil energy was in no way necessary, but was simply the reflection of, or what made possible, the implementation of capitalist relations of production.[139]

68 This idea that the transition to fossil energy use was hardly inevitable or unequivocal as has been stated—an idea that has already been strongly emphasized by researchers who, without framing the problem in the same terms, were interested in wood or hydraulic power in recent decades (I am referring to the previously cited

135 McNeill John R., Engelke Peter, *The Great Acceleration. An Environmental History of the Anthropocene since 1945* (Cambridge (Mass.): The Belknap Press of Harvard University, 2014).

136 Malm Andreas, *Fossil Capital, The Rise of Steam Power and the Roots of Global Warming* (London: Verso, 2016), 38. *The book L'Anthropocène contre l'histoire* (Paris: La Fabrique, 2017), is not a translation of the aforementioned book, but a compilation of four articles.

137 Notably on page 264 of the English edition, where he writes, "But these are merely contours of a theory, waiting to be filled in."

138 If it is, for all that, possible to debate with an author who speaks with such a condescending tone of historians whose views he does not share!

139 It supplements in this sense the theories of Timothy Mitchell, who in his *Carbon Democracy. Political Power in the Age of Oil* (London: Verso, 2011), raised the strictly political aspects of energy systems by affirming that the transition from coal to oil was sought out in order to weaken miners' capacity to cause blockage, which was itself behind democratic advances. This is an appealing theory, but contradicted by many other works, and one that lacks support in my opinion.

works by Denis Woronoff and Serge Benoit)—is today reinforced by those who question the fact that the energy mix of the Ancien Régime, which experienced different transitions itself, was the cause of the economy's blockage. For instance, in an article published in the journal *Alternatives économiques,* Mathieu Arnoux stresses the fact that the renewable resources of the Ancien Régime were in fact the very ones that provided the margins of growth that made the Industrial Revolution possible.[140] Some authors, such as Grégory Clarks and David Jacks, go even further by affirming, contrary to Malm's theory, that coal did not play the role we have ascribed it under the Industrial Revolution, and that it only made negligible contributions to the profits in England earned during this period.[141]

CONCLUSION: WRITING THE HISTORY OF ENERGY DURING A TIME OF GLOBAL WARMING

69 I would like to conclude with a few brief remarks about the nature of the contributions and debate in the field of the history of energy.

70 The first is that the debate over the interpretation of transitions is not complete. To move forward, we need new contributions based on studies that are both territorialized *and* reflected on according to a global perspective.

71 The second is that to date, the debate surrounding the causes and processes of transitions focuses essentially on what Vaclav Smil has called "the Great Transition," which took place in the West during the 19th c. and led us (by stages, if truth be told) to our current energy system.[142] This is regrettable, for more perspectives on other transitions would contribute to a better understanding of the complex processes that we are seeking to grasp.

72 Finally, it is important to note that while French historians have contributed a great deal to research on various energy sectors, to date they have not made major contributions to the history of energy systems and transitions. Various signs nevertheless suggest that a shift is underway.

73 With regard to historians from the comité d'histoire de l'électricité [Committee for the History of Energy], a number of signs seem to indicate a desire to take a different approach to the history of energy: in 2013 the committee changed its name to the comité d'histoire de l'électricité *et de l'énergie*. Its journal transformed in 2018 into the *Journal of Energy History / Revue d'histoire de l'énergie,* whose first issue publishes this historiographical essay. Energy transitions were the subject of a conference in December 2017 under the leadership of these historians, a conference whose communications will serve as the material for a future issue of the same journal.[143] As indicated earlier, in 2011 this committee created a collection entitled "*Histoire de l'énergie*/History of Energy," which already includes ten titles. We can only offer praise for the creation of such a collection, although practically all of the works that make it up are devoted to the history of electricity. The Fondation EDF has also co-financed the doctoral allocation for Sophie

140 Arnoux Mathieu, "Les transitions énergétiques d'hier", *Alternatives Économiques*, no352, 2015.

141 Clarks Gregory, Jacks David, "Coal and the Industrial Revolution, 1700-1869", *European Review of Economic History*, vol. 11/1, 2007, 39–72.

142 In this text I could have discussed the contribution of Vaclav Smil, Professor Emeritus of Environmental Science and the author of many books on energy, its history and transitions. In my view his historical analyses do not always ascribe the appropriate role to the social aspects of the energy question. However, he has a remarkable capacity to explain the physical aspects to an audience whose initial education does not predispose it to understanding the question. See among others Smil Vaclav, *Energy in World History* (Boulder: Westview Press, 1994). Idem, *Energy and Civilization, a History* (Cambridge (Mass.): MIT Press, 2017). Idem, *Prime Movers of Globalization: The History and Impact of Diesel Engines and Gas Turbines* (Cambridge (Mass.): MIT Press, 2010). Idem, *Energy in Nature and Society. General Energetics of Complex Systems* (Cambridge (Mass.): MIT Press, 2007). Idem, *Energy Transitions. History, Requirements, Prospects* (Santa Barbara: Praeger, 2010). Idem, *Energy in China's Modernization* (New York: M.E. Sharpe, 1988).

143 https://calenda.org/404295 http://www.museoscienza.org/news/dettaglio.asp?idnotizia=1090 I did not attend this conference held in Italy, and therefore do not have anything to say in its regard.

Pehlivanian, who in 2014 defended a doctoral thesis on the history of solar energy in France.[144]

74 At l'Université Paris-Diderot, the LIED (Laboratoire interdisciplinaire des énergies de demain, UMR 8236) [Interdisciplinary Laboratory for the Energies of the Future] multidisciplinary research unit that was created in 2013 has placed research on "past, current, and future energy transitions" at the heart of its work. The Humanities and social sciences are represented within the unit in the same way as biology and physics, and one may believe that multidisciplinarity is not just a facade, because the research unit is directed by the historian Mathieu Arnoux. It is not common for a research centre to associate the natural and social sciences, and it is even less common for it to be directed by a researcher from the latter group.

75 At CIRED (Centre international de recherche sur l'environnement et le développement, UMR 8568) [International Research Centre for the Environment and Development], economists, historians, and sociologists have come together to offer master's students from both the social and environmental sciences multidisciplinary instruction on the history of past and current energy transitions.[145]

76 In September 2016 RUCHE (Réseau universitaire de chercheurs en histoire environnementale) [Network of University Researchers in Environmental History] organized a conference on the history of energy, which it had prepared by organizing a series of one-day workshops.[146] One of these was on transitions, and was entitled "Énergies renouvelables, énergies carbonées: transitions énergétiques à double sens" ["Renewable Energies, Carbon-Based Energies: Two-Way Energy Transitions], suggesting by its title alone that the history of transitions has nothing finalistic or linear about it. RUCHE also supported the conference held in March 2018 at l'Université de Bourgogne, organized by François Jarrige and Alexis Vrignon, on the history of renewable or alternative energies during the Industrial Age. During this conference, various interventions showed the abundance of cases in which the energy trajectory did not follow the model often presented as universal and inevitable,[147] in which traditional forms of energy use endured, or were readapted by new economic and social configurations. The publication of these communications will be of great interest.

77 Beyond the places and institutions that take a specific interest in the question of energy, we can see the emergence among some economic historians of an intention to rethink their knowledge in light of new environmental questions. This research is sometimes still in gestation, although that fact that it is rooted in a deep knowledge of a specific area makes it particularly interesting. One example is the ongoing research of Xavier Daumalin and Olivier Raveux on how the energy transition of the first half of the 19th c. took place for industry and the merchant marine in Marseilles. This transition is a good example of non-linearity, of a transition that did not include the addition of a previously unknown energy source, one marked instead by the adoption of a new converter (steam engine), and consequently by a new hierarchy within the existing energy mix. In Marseille, steam engines were slow to replace

144 Pehlivanian Sophie, "Histoire de l'énergie solaire en France : science, technologies et patrimoine d'une filière d'avenir" (Ph.D. diss., Université de Grenoble, 2014).

145 "Socio-histoire des transitions énergétiques, XVIIIe-XXe siècles," seminar coordinated in 2016-2017 by G. Massard-Guilbaud, and in 2017-2018 by A. Nadaï. Additional details at https://www.ehess.fr G. Massard-Guilbaud has already devoted three years (2013-2016) to seminars on the history of both energy and energy transitions. In 2018-2019 she and R. Bécot will offer a seminar entitled "Qu'avons-nous fait du soleil ? Histoire environnementale de l'énergie et des nuisances industrielles."

146 "L'animal source d'énergie: enquêtes dans l'Europe d'avant la Révolution industrielle" (Université de Valenciennes et du Hainaut-Cambrésis), "Énergies renouvelables, énergies carbonées: transitions énergétiques à double sens" (EHESS), "Anticiper la pénurie énergétique" (Université Bordeaux-Montaigne), "Le moteur hydraulique" (Université Clermont-Auvergne).

147 This is notably the theory of the sociologist Gras Alain, *Le Choix du feu. Aux origines de la crise climatique* (Paris: Fayard, 2007).

78 watermills not because they were unknown or inefficient, but because those who made their living from hydraulic power represented a powerful social group, and delayed its adoption, and also because their use required adapting the entire production and merchant system in order to be profitable. When it occurred, the transition to steam was brutal, but it hardly put an end to hydraulic power, which still had a bright future ahead of it.[148]

79 In an article that appeared in the journal *L'Histoire,* Mathieu Arnoux justly stresses that interdisciplinary imagination and curiosity are indispensable to the historian of energy.[149] Thinking globally of an energy that involves all human activities without exception, and whose coherence as a concept is not easily grasped, is a genuine challenge. We should be delighted that a growing number of historians are tackling the subject.

148 On this subject see the conference given by Daumalin Xavier, "La transition énergétique au regard de l'histoire", *Cahiers des Fellows de l'IMéRA*, https://imera.hypotheses.org/510, 2017. See also Daumalin Xavier, Raveux Olivier, "La marine marchande marseillaise en transition énergétique. Origines et enjeux d'un choix socio-écosystémique", *Cahiers de la Méditerranée*, forthcoming [2018].

149 Mathieu Arnoux, "200 000 ans de transition énergétique," *L'Histoire*, n°408, 2015, 8-15.

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Past, present and prospective energy transitions: an invitation to historians

Abstract

This paper argues that historians and their disciplinary practices can enhance the analysis of energy transitions by non-historians. It explains how energy economists and policy analysts have only recently taken account of historical experience and how energy studies have become more inter- and multi-disciplinary and more receptive to engagement with history and historians. The paper outlines the nature, variety and complexities of energy transitions, and then examines the growing policy focus on 'low-carbon transitions', which address the threat of climate change by seeking transitions away from greenhouse gas-emitting fossil fuels, towards low-carbon renewable and /or nuclear energy. It explores three areas in which further historical analysis is especially valuable: the duration and speed of past energy system transitions and the insights to be gained from their analysis; path dependence, lock-in and the strategies, responses and destabilisation of incumbent energy actors and institutions; and theoretical approaches to 'sustainability transitions' and innovation. The paper concludes with an invitation to historians to collaborate further with non-historians, to enhance their understanding of energy transitions and to share the findings, methods, subtleties and limitations of historical analysis.

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INTRODUCTION AND AIMS

1 This paper, written by an economist, from a discipline focused mostly on the present and the future, has four aims: to argue that historical analyses offer insights into past energy transitions that are of value to non-historians who study past, current and prospective energy transitions and, where appropriate, to policy-makers who seek to grapple with them; to show how, in one social science discipline, economics, for some time historical aspects seemed of little relevance to energy economists and policy analysts; to indicate problem areas, issues and questions, especially those concerning 'low-carbon' energy transitions, that might be illuminated by insights from history; and to invite historians to collaborate more with non-historians and engage in further analyses.

2 Major ongoing or prospective energy transitions include those in the developing world towards greater provision of modern forms of energy,[1] as well as 'low-carbon' energy transitions that aim to address the perceived threat of climate change from rising concentrations of greenhouse gases such as carbon dioxide and methane, particularly those from hydrocarbon fossil fuels.[2] The paper illustrates some contributions that history and historians might make to our individual and collective understanding, thinking and decision-making about energy transitions. It also shows how the field of energy studies has become more inter- and multi-disciplinary and more receptive to engagement with history and historians.

3 The author believes both that access to modern energy in the developing world, and the growing, albeit not universal, scientific consensus about the potential threat of climate change and the role of human-made contributions to it, warrant actions by state, market and civil society actors to advance specific forms of energy transition. Some historians will not share these views and/or will think it inappropriate for the study of the past also to address the future or try to advance policy thinking.[3] In the author's view, even if there were no insights directly applicable to policy thinking, a knowledge of history would remain valuable to non-historians wishing to understand our changing energy systems and set them in perspective.

4 The view taken here accords with economic historian Sara Horrell's response to poet and critic Samuel Taylor Coleridge's declaration about learning from history, that 'the light which experience gives is a lantern on the stern, which shines only on the waves behind us!'.[4] She wrote: 'Rather than directives it offers a storehouse of guidance, pointers as to what might be relevant considerations in conditioning and shaping outcomes. It is invaluable in broadening the base of knowledge from which we operate and enables us to identify and read signals. ... A lantern on the stern can help with navigation ahead!'.[5]

5 Nevertheless, this paper does not follow a tendency to label such insights 'lessons from the past', because doing so risks implying that such knowledge is always transferable to or offers simple analogues for present and especially future contexts and their challenges. Furthermore, even when armed with such insights, we may not necessarily be able to apply them. Historians and their disciplinary practices are essential here in conveying to non-historians both the nuances and the limits of insights from the past, their transferability and applicability.

1 Global Energy Assessment (GEA), *Global Energy Assessment: Toward a Sustainable Future* (Cambridge: Cambridge University Press, Laxenburg: International Institute for Applied Systems Analysis, 2012); International Energy Agency, *Energy Access Outlook 2017. World Energy Outlook Special Report* (Paris: OECD/IEA, 2017).

2 Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Geneva: IPCC, 2014).

3 For a contrary opinion, see Hirsh Richard F., Jones Christopher F., "History's contributions to energy research and policy", *Energy Research & Social Science*, vol. 1, 2014.

4 Coleridge Samuel T., "December 27, 1831", in Henry N. Coleridge (ed.), *Specimens of the Table Talk of S.T. Coleridge* (London: John Murray, 1835), Digitised by Project Gutenberg: https://www.gutenberg.org/cache/epub/8489/pg8489-images.htm [Accessed 20/09/17].

5 Horrell Sara, "The wonderful usefulness of history", *The Economic Journal*, vol. 113, 2003.

6 Although the author has neither space nor capacity to review them here, the point of this paper is not to underplay the extensive, valuable studies of past energy and infrastructure system developments and transitions carried out over recent decades by historians from several schools, including economic historians, business historians and historians of science, technology and society. Fine examples include: Landes,[6] Hughes,[7] Nye,[8] Chick,[9] Lagendijk,[10] Allen,[11] Wrigley,[12] Kander *et al*.,[13] Jones,[14] Beltran *et al*.[15] and Kaijser *et al*.,[16] to name but a few. Rather the aim is to invite historians to draw on and even extend their knowledge, to crystalize and share those insights from history that enhance our understanding of energy transitions. This could be in collaborative dialogue with a growing body of receptive social and physical scientists, engineers, and even those policy-makers who wish to appreciate the strengths and limitations of drawing on and interpreting historical experience.

7 Section 2 examines how and why, in this author's view and experience, until very recently historical studies of energy seemed to matter little to most energy economists and policy analysts. Section 3 discusses the nature, variety and significance of energy transitions. Section 4 examines the growing policy focus on low-carbon transitions, while Section 5 explores three areas in which further historical analysis is especially valuable: (1) the duration and speed of transitions; (2) path dependence, lock-in and the role of incumbent actors; and (3) theories and empirical analyses of sustainability transitions and innovation. Section 5 concludes the paper and ends with an invitation to historians to collaborate with and broaden non-historians' understanding of the methods, subtleties and findings of historical analysis and, for some, to engage in further dialogue with energy policy-makers.

HOW AND WHY HISTORICAL STUDIES OF ENERGY SEEMED IN THE RECENT PAST TO MATTER LITTLE TO ENERGY ECONOMISTS AND POLICY ANALYSTS AND HOW THIS HAS CHANGED

8 In writing this section, the author reflected on his experience of research into energy transitions and his growing awareness of the significance of history and how it can inform thinking about them. Consequently, some of what follows should be approached with caution, as it is clearly a partial view. In the 1980s, an economist colleague, Paul Stevens, and the author began researching transitions in developing countries between 'traditional' or 'non -commercial' energy sources and their supply and end-use technologies and 'commercial', mostly fossil-based fuels and their technologies.[17] These transitions had been proceeding rapidly in some countries and much more slowly in others; they raised and still raise important socio-economic, political and environmental issues.[18]

6 Landes David S., *The Unbound Prometheus* (Cambridge: Cambridge University Press, 1969).

7 Hughes Thomas P., *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins Press, 1983).

8 Nye David E., *Electrifying America* (Cambridge, Mass.: MIT Press, 1997).

9 Chick Martin, *Electricity and Energy Policy in Britain, France and the United States since 1945* (Cheltenham: Edward Elgar, 2007).

10 Chick Martin, *Electricity and Energy Policy in Britain, France and the United States since 1945* (Cheltenham: Edward Elgar, 2007).

11 Allen Robert, *The British Industrial Revolution in Global Perspective* (Cambridge: Cambridge University Press, 2009).

12 Wrigley E. Anthony, *Energy and the English Industrial Revolution* (Cambridge: Cambridge University Press, 2010).

13 Kander Astrid, Malanima Paolo, Warde Paul, *Power to the People: Energy in Europe over the Last Five Centuries* (Princeton and Oxford: Princeton University Press, 2013).

14 Jones Christopher F., *Routes of Power: Energy and Modern America* (Cambridge, Mass.: Harvard University Press, 2014).

15 Beltran Alain *et al*., *Electric Worlds/Mondes électriques* (Bruxelles: P.I.E. Peter Lang, 2016).

16 Kaijser Arne, van der Vleuten Erik, Högselius Per, *Europe's Infrastructure Transition* (London: Palgrave Macmillan, 2016).

17 Pearson Peter J. G., Stevens Paul J., "Integrated Policies for Traditional & Commercial Energy in Developing Countries", *Development Policy Review*, vol. 2, 1984; Pearson Peter J. G., "Energy transitions in less-developed countries: analytical frameworks for practical understanding", *Energy Discussion Paper*, vol. 40. (Cambridge: Cambridge University Energy Research Group, 1988).

18 GEA, *Global Energy Assessment* (cf. note 1); IEA, *Energy Access Outlook 2017*. op. cit. (cf. note 1).

9 During this research, not least for comparative purposes, it became important to know how energy transitions had unfolded in other places and times. There was useful information from a variety of sources about relatively recent transitions, for example ranging from America's late nineteenth century transition from wood-fuel to coal and petroleum,[19] to South Korea's more recent, remarkably rapid and heavily state-directed post-1960 transition from high dependence on wood-fuel to coal and other modern fuels.[20] While the author was also shamefully unaware of most of the work of economic historians on energy transitions, and probably thought that Britain's transition from biomass to coal was too long-drawn-out and distant to be relevant, the few sources he knew showed relatively little interest in how their insights into the past might enrich the thinking and approaches of economists and policy-makers concerned with the present. Moreover, searches of energy economics and energy policy journals at that time yielded only two papers that addressed Britain's extensive experience of energy transitions.[21]

10 Analyses of energy economics and policy issues in the 1970s and 1980s were strongly conditioned by the reverberating experiences of the two international 'oil price shocks' of 1973-74 and 1979-80. The 1973-74 shock was triggered by an oil export embargo by members of OAPEC (the Organization of Arab Petroleum Exporting Countries); it involved a fourfold increase in real, inflation adjusted prices per barrel relative to 1972, from $14 to $56, at US$2015 prices. The 1979-80 shock followed falling oil output after the Iranian Revolution; it saw a doubling of real prices relative to 1978, from $51 to $106 at US$2015 prices.[22] These shocks had major geopolitical and macroeconomic implications for both oil-exporting and oil-dependent importing countries.[23] They also spawned bodies like the International Energy Agency (IEA), set up by oil-importing industrialised countries partly in response to the perceived threat of cartelisation and embargo by OPEC (the Organisation of Petroleum Exporting Countries).

11 In oil-importing countries, the shocks led to rapid step-changes in the priorities assigned to energy policy, energy security and oil import substitution, and in the funds devoted to Research, Development and Demonstration (R, D & D) into alternatives to oil.[24] These changes led to surging, urgent demands from policy-makers for energy scenarios and forecasts. However, when estimating parameters like the responsiveness of energy demand or supply to changes in oil prices and /or incomes (income and price 'elasticities') or the responsiveness of the macro-economy and the balance of payments to such price changes, econometricians found little comfort in their data. This was not least because 'real' oil prices had been so much lower over several decades before the price shocks: between 1927 and 1972, they never exceeded $21 at US$2015 prices, a fraction of the peak prices of $56 and $106. Consequently, energy consumers' past reactions showed insufficient variations from which to extrapolate and estimate with confidence the responsiveness of energy demand or the economy to the much greater price changes of the oil price shocks. The ripples from this experience seemed to have influenced the dominant thinking and writing about energy economics and policy, which showed relatively little interest in the pre-oil shock energy experiences and data of many countries.

12 Thus, although developments had already occurred in economic history, especially in its application of

19 Schurr Sam *et al.*, *Energy in The American Economy, 1850-1975* (Baltimore: Johns Hopkins Press, 1960).

20 Kim Yoon Hyung, "Rational and effective use of energy in Korea's industrialisation", *Energy*, vol. 8/1, 1983.

21 Humphrey William S., Stanislaw Joe, "Economic growth and energy consumption in the UK, 1700–1975", *Energy Policy*, vol. 7/1, 1979; Ray George F., Morel Jenny, "Energy conservation in the UK", *Energy Economics*, vol. 4/2, 1982.

22 BP statistical review of world energy 2016 (2016), https://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-revi... [Accessed 5/10/17].

23 Hamilton James D., "Historical Oil Shocks", *in* Randall E. Parker, Robert Whaples (eds.), *Routledge Handbook of Major Events in Economic History* (London - New York: Routledge, 2013).

24 IEA, "Energy technology RD&D budgets: Overview" (Paris: OECD/IEA, 2017), https://www.iea.org/publications/freepublications/publication/EnergyTec... [Accessed 8/12/17].

the quantitative methods of cliometrics,[25] and in the study of long run economic growth,[26] historically informed approaches were relatively rare in published work on energy economics and policy. Several aspects of (neo-classical) economics as a discipline at that time also tended either not to encourage or effectively to work against interest in past data or historical studies. They included: the growing emphasis on mathematical economics and somewhat abstract modelling, for example in areas like the theory of general equilibrium (exemplified in the work of Nobel Prize winners Kenneth Arrow, Gérard Debreu and Maurice Allais); a focus on rational economic behaviour; a tendency to assume ergodicity (effectively, that economic processes are inherently ahistorical);[27] and more sharply delineated boundaries between economics as a professional discipline and other related disciplines. For many economists, the neo-classical approach focused particularly on the 'comparative statics' of moves between modelled situations of presumed equilibrium, with relatively little concern for the temporal or spatial dynamics involved, the possibilities of persistent disequilibria and the messiness and complexity of other social sciences.

13 At that time also much of macroeconomic growth theory, despite its interest in technological change and the long run quantitative comparative studies of the growth of nations led by Simon Kuznets,[28] did not engage closely with the role and contribution of energy to long run economic growth and development. And environmental and resource economics played little part in the mainstream economics journals and undergraduate textbooks of the 1960s and early 1970s,[29] although during this period the growing economic and political concerns about environmental pollution, population growth, resource depletion and fears of possible limits to economic growth[30] were catalysing interest and rapid developments in these areas.

14 As a matter of perspective, Daunton,[31] in his insightful reflections on North's[32] approach to understanding economic change and his critique of neo-classical theory, reminds us that these largely 20th C. developments in professionalising and narrowing the focus of economics differed from the wider-ranging approaches of 19th C. political economy. Thus, by the 1920s the issue of historical specificity had mostly disappeared from British economics, and was detached into the new sub-field of economic history, while the influence of the German Historical school had faded by the Second World War.[33]

15 Much has changed in economics since the 1970s, including growing recognition of research that acknowledges the importance of institutional and societal change and other social and historical processes. This recognition has been signalled, for example, by several of the Nobel Prizes in Economics, such as: to Ronald Coase in 1991 ("for his discovery and clarification of the significance of transaction costs and property rights for the institutional structure and functioning of

25 Cliometrics, originally called "The New Economic History", was developed in North America in the 1950s. Economic historians (and other social scientists), building on earlier quantitative analytical approaches, increasingly applied formal economic theory and models and econometric (statistical) methods to examine historical questions.

26 Lyons John, Cain Lou, Williamson Sam, "Cliometrics", in Robert Whaples (ed.), *EH.Net Encyclopedia*, 2009, http://eh.net/encyclopedia/cliometrics/ [Accessed 27/09/17].

27 The behaviour of an economic system or sub-system, such as a market, is ergodic if it is independent of the initial conditions. If ergodicity does not hold, initial conditions influence later behaviour, which becomes path-dependent: "history matters". Then, in the face of new initial conditions, a system may branch – or "transition" – to a different path. Its processes are inherently historical.

28 Kuznets Simon, *Modern Economic Growth: Rate, Structure and Spread* (New Haven - London: Yale University Press, 1966).

29 e. g. Cairncross Alec, *Introduction to Economics* (London: Butterworths, 1966 [1944]); Lipsey Richard G., *An Introduction to Positive Economics* (London: Weidenfeld and Nicolson, 1971 [1963]); Nevin Edward T., *Textbook of Economic Analysis* (London: Macmillan, 1966 [1958]).

30 Meadows Donella H. *et al.*, *The Limits to Growth* (New York: Universe Books, 1972).

31 Daunton Martin, "Rationality and institutions: reflections on Douglass North", *Structural Change and Economic Dynamics*, vol. 21, 2010.

32 North Douglass C., *Understanding the Process of Economic Change* (Princeton: Princeton University Press, 2010).

33 Dorfman Joseph, "The Role of the German Historical School in American Economic Thought", *American Economic Review*, vol. 45/2, 1955.

the economy"); to Douglass North and Robert Fogel in 1993 ("for having renewed research in economic history by applying economic theory and quantitative methods in order to explain economic and institutional change"). North was a leading figure in the development of a 'new institutional economics', to "make more sense out of long run economic, social and political change".[34] Fogel and Engerman's 1974 *Time on the Cross*, on the economics of slavery in the US, while generating much controversy about its findings and its use of cliometrics, became a classic and stimulated further work in both areas.[35] In 2009, the Prize was shared by Elinor Ostrom ("for her analysis of economic governance, especially the commons") and Oliver E. Williamson ("for his analysis of economic governance, especially the boundaries of the firm"). Other prizes, including the 2017 prize awarded to Richard Thaler ("for his contributions to behavioural economics"), have acknowledged the value of work on economic psychology and behavioural economics.[36]

16 As noted, we have also seen rising interest in environmental and resource economics. Environmental economics has drawn heavily on the distinction between the private and social costs and benefits of economic activities and the gaps between them. These gaps provide an economic rationale for public intervention to correct this 'market failure' through non-economic regulation or economic incentives like pollution taxes or tradable permits (quotas). Much of this work, although not all (e.g. that of Coase) has been largely ahistorical, although growing concerns about sustainability and climate change have stimulated attention to longer-run processes of environmental change and degradation.

Resource economics addresses issues of the17 allocation, exploitation, depletion, valuation and pricing of renewable and non-renewable natural and human-made resources on land, air and water.[37] It has addressed the nature of property rights over them and the roles of communities, the market and the state in their governance. For example, Ostrom explored how people and communities interact with and may manage ecosystems. She developed a new institutional approach to the governance of the commons or 'common-pool resources'.[38] Her approach, which will resonate with some historians, showed: a concern with how such institutions evolve and function; extensive use of empirical case studies; acknowledgement of the complex constellation of variables involved when people in field settings try to fashion rules to enhance individual and joint outcomes; a reluctance to "try to encompass this degree of complexity in a single model";[39] and a recommendation to draw on the intellectual efforts of Hobbes, Montesquieu, Hume, Smith and others.

The newer and more heterodox fields of eco- 18
logical economics[40] and evolutionary economics, while drawing on the ideas of neo-classical economics, have also challenged its key premises, including economic rationality, often replacing it with the notion of 'bounded rationality'.[41] The evolutionary approach borrows ideas from biology, a recourse to which Nelson and Winter modestly claimed economists are "entitled in perpetuity by virtue of the stimulus our

34 North Douglass C., "Addendum to Douglass C. North Biographical", 2015, https://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/199... [Accessed 27/09/17].

35 Weiss Thomas, "Review: Time on the Cross: The Economics of American Negro Slavery", *EH.net*, 2001, https://eh.net/book_reviews/time-on-the-cross-the-economics-of-american... [Accessed 27/09/17]; Lyons, Cain, Williamson, "Cliometrics" (cf. note 26).

36 https://www.nobelprize.org/nobel_prizes/economic-sciences/fields.html

37 Hartwick John M., Olewiler Nancy D., *The Economics of Natural Resource Use* (Reading, Mass.: Addison-Wesley, 1998 [1986]).

38 Ostrom Elinor, *Governing the Commons* (Cambridge: Cambridge University Press, 1990). See also: Dietz Thomas, Ostrom Elinor, Stern Paul C., "The Struggle to Govern the Commons", *Science*, vol. 302, 2003; Stavins Robert N., "The Problem of the Commons: Still Unsettled after 100 Years", *American Economic Review*, vol. 101, 2011.

39 Ostrom, *Governing* (cf. note 38).

40 Martínez-Alier Joan, Røpke Inge (eds.), *Recent Developments in Ecological Economics vol. I & II* (Cheltenham: Edward Elgar, 2008).

41 Simon Herbert A., "Rational decision making in business organizations" [Nobel Memorial Lecture], *American Economic Review*, vol. 69/4, 1979.

predecessor Malthus provided to Darwin's thinking".[42] The approach focuses on organisational 'routines' and includes the "substitution of the "search and selection" metaphor for the maximisation and equilibrium metaphor".[43] It is also argued that these ideas are consonant with approaches to theorising from Adam Smith's time to the Second World War, and that they have some compatibility with those of Marx.[44]

19 These four approaches have paid growing attention to issues of sustainability and intra- and inter-generational equity and justice,[45] including those relating to climate change, and whether and how economic progress might be reconciled with preserving the planet.[46] Stimulated by the long time-scales and complexity of climate change processes, these concerns have led to growing interest in historical processes, although not necessarily in the methods and findings of historical enquiry.

20 Despite these developments, it took time for economists and other non-historians concerned with energy transitions to recognise the value of history for their thinking. Again - to draw on experience viewed through the distorting lens of personal experience - in the late 1980s and early 1990s, the author began studying transitions away from greenhouse gas-emitting fossil fuels in developing and industrialised countries. By the mid-1990s, the author and his colleague Roger Fouquet became convinced of the value of studying historical transition processes, to see what insights might be gained into current and prospective energy transitions and the influence of the past on them. For some time, we found it hard to interest UK social science research funders in studies of this kind. Although, of course, this may simply have reflected the quality of our applications, few if any studies of this type seemed to be funded. Nevertheless, we published papers that drew on historical studies and Fouquet's newly-assembled centuries-long energy data sets,[47] and both of us have continued to work with researchers from several disciplines, including branches of history.[48] From the mid-2000s, however, energy economists and a broader range of research funders have increasingly acknowledged that the multi-faceted nature, causes and consequences of energy transitions, particularly low-carbon transitions, and the research and policy questions that they pose, can be enriched by knowledge of historical processes and historical thinking, as well as greater inter- and multi-disciplinarity.

21 This section has argued that energy economists have only relatively recently begun to take account of historical experience and approaches. It suggested that this neglect was partly because of the long stability of oil prices before the oil price shocks of the 1970s, and partly because

42 Nelson Richard R., Winter Sidney G., *An Evolutionary Theory of Economic Change* (Cambridge Mass.: Belknap Press, 1985).

43 *Ibid*., 227.

44 For a critical survey of theories and concepts that economics can offer for transition research, see Van den Bergh Jeroen C. J. M., Kemp René, "Transition lessons from Economics", Ch. 4 *in* Jeroen C. J. M. van den Bergh, Franck R. Bruinsma (eds.), *Managing the Transition to Renewable Energy* (Cheltenham: Edward Elgar, 2008).

45 Simpson R. David *et al*. (eds.), *Scarcity and Growth Reconsidered* (Washington, DC: Resources for the Future, 2005).

46 e.g. *Heal Geoffrey, Endangered Economies. How the Neglect of Nature Threatens Our Prosperity* (New York: Columbia University Press, 2017).

47 Fouquet Roger, Pearson Peter J. G., "A Thousand Years of Energy Use in the United Kingdom", *The Energy Journal*, vol. 19/4, 1998; Fouquet Roger, Pearson Peter J. G., "Five Centuries of Energy Prices", *World Economics*, vol. 4/3, 2003; Fouquet Roger, Pearson Peter J. G., "Seven Centuries of Energy Services: The Price & Use of Light in the United Kingdom (1300-2000)", *The Energy Journal*, vol. 27/1, 2006; Pearson Peter J. G., Fouquet Roger, "Long Run Carbon Dioxide Emissions & Environmental Kuznets Curves: different pathways to development?", Ch. 10 *in* Lester C. Hunt (ed.), *Energy in a Competitive Market (Essays in Honour of Colin Robinson)* (Cheltenham: Edward Elgar, 2003); See also: Fouquet Roger, *Heat, Power and Light: Revolutions in Energy Services* (Cheltenham: Edward Elgar, 2008).

48 Fouquet Roger, Pearson Peter J. G., "Editorial: Past & prospective energy transitions: Insights from history", *Energy Policy*, vol. 50, 2012; Fouquet Roger, Broadberry Stephen, "Seven Centuries of European Economic Growth and Decline", *Journal of Economic Perspectives*, vol.29/4, 2015; Arapostathis Stathis, Pearson Peter J. G. (Guest Eds.), "How History Matters: Governance, Public Policies and the Making of Sociotechnical Transitions", *Environmental Innovation and Societal Transitions*, Special Issue, 2019 [forthcoming].

of features of neoclassical economics at that time. However, recent developments in areas like resource and environmental economics and in ecological and evolutionary economics, reflecting concerns about environmental degradation, resource scarcity and sustainability, have encouraged greater interest in long run processes of change, including those involved in energy transitions, and in how historical approaches and methods may yield insights into them. The next section explores the nature and significance of energy transitions and points to why an understanding of history is so valuable in addressing them.

ENERGY TRANSITIONS: NATURE, VARIETY AND COMPLEXITIES

22 This section begins with an outline of energy transitions' contributions to human welfare and the involvement of energy transitions with much wider transition processes, such as industrial revolutions. It then looks at how energy transitions have been defined and the multifarious forms they can take.[49] It ends by indicating some areas where historical insights and methods might enrich the understanding of non-historians who seek to analyse and decode transitions.

23 Energy transitions have often enhanced human welfare by contributing to sustained increases in productivity and economic output and to the production and use of new commodities, services and lifestyles. They have often also influenced and been influenced by industrial revolutions[50] or 'long waves' of economic development,[51] and the non-energy transitions involved in them.[52] Indeed, as with some interpretations of the British Industrial revolution, energy transitions are sometimes thought to lie at their heart.[53] As Section 4 discusses, the 'dark side' of energy transitions includes their potential for ecological and environmental damage, resource depletion and impacts on health and welfare.

24 The many definitions of 'energy transitions' reflect their variety, the epistemological challenges of identifying, classifying and understanding them, and the diverse preoccupations of those who address them. An energy transition is sometimes (over)simply defined as a changeover from one leading fuel or energy carrier to another. Another frequent definition is "the *change in composition (structure) of primary energy supply*, the gradual shift from a specific pattern of energy provision to a new state of an energy system".[54] Both definitions indicate a slowly changing tendency for 'headline' definitions - and many past and present energy policy strategies - to focus on transitions essentially as processes of (often large-scale, centralised) energy production, supply and delivery, with much less attention to changing patterns of energy access, energy use and energy-using practices.[55] Laird,[56] for example, stresses the need to broaden the concept of an energy transition and give more attention to the social and political features involved. This is an approach

49 Smil Vaclav, *Energy Transitions: History, Requirements, Prospects* (Santa Barbara, CA: Praeger, 2010); Pearson Peter J. G. "Energy Transitions", *in* Steven N. Durlauf, Lawrence E. Blume (eds.), *The New Palgrave Dictionary of Economics*, Online Edition, 2016, http://www.dictionaryofeconomics.com/dictionary.

50 Allen, *The British Industrial Revolution* (cf. note 11); Mokyr Joel, *The Enlightened Economy* (London: Penguin Books, 2009); Kander Astrid, Stern David I., "Economic growth and the transition from traditional to modern energy in Sweden", *Energy Economics*, vol. 46, 2014; Fouquet, *Heat* (cf. note 47); Wrigley, *Energy* (cf. note 12); Gordon Robert J., *The Rise and Fall of American Growth: The U.S. Standard of living since the Civil War* (Princeton, NJ: Princeton University Press, 2016).

51 Freeman Chris, Perez Carlotta, "Structural Crises of Adjustment: Business Cycles and Investment Behaviour", *in* Giovanni Dosi *et al*. (eds.), *Technical Change and Economic Theory* (London: Pinter, 1988), 38-66; Freeman Chris, Louçã Francisco, *As Time Goes By* (Oxford: Oxford University Press, 2001).

52 See also Nuvolari Alessandro, "Understanding successive industrial revolutions: A 'development block' approach", *Environmental Innovation and Societal Transitions*, Article in press, corrected proof, 2018. https://doi.org/10.1016/j.eist.2018.11.002 [Accessed 2/12/18].

53 Wrigley, *Energy* (cf. note 12).

54 Smil, *Energy Transitions* (cf. note 49).

55 Shove Elisabeth, Walker Gordon, "CAUTION! transitions ahead: politics, practice and sustainable transition management", *Environment and Planning A*, vol. 39, 2007.

56 Laird Frank N., "Against transitions? Uncovering conflicts in changing energy systems", *Science as Culture*, vol. 22/2, 2013.

that resonates with that of the 'sustainability transitions' literature (see Section 5.3), which has for some time called them 'socio-technical transitions'. The term aims to acknowledge that many transitions have co-evolved or been entangled with other broader socio-economic, demographic, technological and environmental changes and processes.[57]

25 Energy transitions can involve shifts in how, where and by whom energy is extracted, produced, transformed, supplied, accessed and used. They can unfold at global, regional, national, local or sectoral scales. These shifts have led to new, often much higher, amounts and qualities of fuels produced, to novel technologies and to fresh uses and behaviours. Over the centuries, large-scale, sometimes called 'grand', energy transitions have involved slow shifts from early humans' reliance on fuel-wood and human labour, to increasing employment of animal labour and more complex processing and uses of biomass fuels, to wind and water power, and to coal, oil, town and natural gas and electricity.[58] They have developed over multiple decades and sometimes centuries. And while the new energy sources may eventually dominate, overlapping, often extended, processes of change are involved. Thus, while the incumbent energy source(s) and their associated energy-using technologies tend to grow much more slowly than before, they may maintain a foothold for a considerable time after the new source(s) have gained ascendancy (e.g. the use of fuel-wood and candles persisted in Britain well after the dominance of coal and gas and electric light).[59]

26 Transitions occur in both primary and secondary energy sources. They occur in the use of primary energy sources, such as fossil and nuclear fuels, solar and wind energy. They also happen in secondary energy forms or energy-containing carriers, such as electricity, gasoline, and hydrogen, converted from primary sources and delivered for final use. When introduced, the secondary energy forms were often of higher quality, such that they could be employed in a broader and/or more valuable range of economically productive or satisfying activities.[60] They tend to be more expensive, especially when first introduced, partly because of the conversion processes and losses associated with producing and delivering them (e.g. electricity and gasoline cost more than the primary fuels transformed during their production). Nevertheless, users have been willing to pay these higher prices because of their broader range of valuable uses. For example, electrical power and electric motors proved more flexible and efficient in use than mechanical power from coal-fired steam engines, enhancing factory productivity; and liquid and gaseous fuels have powered the internal combustion and aero engines that have enhanced the speed, reliability and efficiency of transportation. These attractive attributes of modern fuels and energy-using technologies mean that they have been increasingly demanded as incomes and living standards grow,[61] as developing world experience vividly demonstrates.

27 The extent and pace of transitions are significantly affected not only by the spread of more advanced technologies of energy exploration, extraction, capture, processing, conversion, and end-use but also, as noted, by the development of energy transport, delivery and distribution

57 Geels Franck W., Schot Johan W., "The dynamics of transitions: a socio-technical perspective", *in* John Grin, Jan Rotmans, Johan Schot (eds.), *Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change* (London: Routledge, 2010); see also Kanger Laur, Schot Johan, "Deep transitions: Theorizing the long-term patterns of sociotechnical change", *Environmental Innovation and Societal transitions*, In press, Corrected Proof, 2018. https://doi.org/10.1016/j.eist.2018.07.006 [Accessed 2/12/18].

58 Smil, *Energy Transitions* (cf. note 49); Fouquet, *Heat* (cf. note 47); Kander, Malanima, Warde, *Power* (cf. note 13); Pearson, "Energy Transitions" (cf. note 49).

59 Fouquet, Pearson, "Seven Centuries of Energy Services" (cf. note 49).

60 Cleveland Cutler J., Kaufmann Robert K., Stern, David I., "Aggregation and the role of energy in the economy", *Ecological Economics*, vol. 32, 2000; Stern David I., "Energy quality", *Ecological Economics*, vol. 69/7, 2010; Gentilvaite Ruta, Kander Astrid, Warde Paul, "The role of energy quality in shaping long-term energy intensity in Europe", *Energies*, vol. 8, 2015.

61 Fouquet, *Heat* (cf. note 47); Fouquet Roger, "Long run demand for energy services: income and price elasticities over 200 years", *Review of Environmental Economics and Policy*, vol. 8/2, 2014.

infrastructures (the historian Christopher Jones argues, for example, that developments in energy transmission in mid-Atlantic USA from 1830-1920 were as important as changes in the source of energy).[62] These infrastructures include land, water and air transport systems, as well as pipeline or wire networks at local, national and international scales, and - increasingly – communication and information technology networks. Behind these changes in 'hard' energy technologies and infrastructures, as indicated, lie changes in 'softer' social, cultural and political institutions, structures and behaviours, including those of industries, markets, prices and consumers and their governance and regulatory systems and interest-groups, and the social capital of knowledges and skills.

28 Transitions have involved much larger flows of energy services, such as thermal comfort, mobility and illumination.[63] It has been argued that the thirst for such services can be a key stimulus of transitions.[64] Moreover, the implicit costs of these services have fallen strikingly over the past two centuries, especially the cost of light, which in Britain declined nearly three thousand-fold between 1800 and 2000, as fuels changed and mostly because the efficiency with which lighting devices converted fuel inputs into light rose.[65] The demand for fuels and end-use technologies can grow rapidly but at changing and eventually declining rates when incomes and living standards rise and energy service costs fall.[66] The rates at which such demand has grown or might grow under such stimuli and be contained, or not, by saturation effects, improved efficiencies, or behavioural changes are of concern to economists and energy policy-makers, as is the financing of transitions.

29 As indicated, there are many kinds of transition, from the grand to the not-so-grand, and from those that might myopically be viewed 'purely' as energy transitions, to those intimately bound up with non-energy transitions and/or with much more comprehensive and usually longer-term transitions. And transitions have and might unfold, slowly or more rapidly, smoothly or discontinuously, in steady or more turbulent situations, facilitated or constrained by wider social, economic, demographic, environmental or (geo) political factors. The complexity of transitions and transition processes and their interactions in different or changing temporal and spatial contexts partly explains why energy transitions are challenging to define, identify, analyse and generalise from. Historians are well-placed to offer key insights into these challenges and how to approach them, not least because they are "experts at comprehending the establishment of trends and changes in them"[67] and because they "spend much of their energy grappling with the question of why responses to similar situations differ between time and place".[68]

30 This section has briefly explored the nature, variety and complexities of energy transitions, indicated some of the epistemological and practical issues involved in defining, identifying and analysing them; and it has suggested areas where historians could make valuable, much-needed contributions. The next section addresses the growing policy attention given to energy transitions and to whether and how they might be guided.

THE GROWING POLICY EMPHASIS ON ENERGY TRANSITIONS

31 This section briefly examines the growing policy emphasis on energy transitions, particularly low-carbon transitions. Why focus on this transition? Because, while many governments wrestle with the 'energy policy trilemma', as the centre of gravity moves between three policy objectives

62 Jones Christopher F., *Routes of Power* (cf. note 14).
63 Fouquet, *Heat* (cf. note 47).
64 Grubler Arnulf, "Energy transitions research: Insights and cautionary tales", *Energy Policy*, vol. 50, 2012.
65 Fouquet, Pearson, "Seven Centuries of Energy Services" (cf. note 49).
66 Fouquet, "Long run demand for energy services" (cf. note 61); Grubler Arnulf, "Energy transitions", *The Encyclopedia of Earth*, 2008, http://www.eoearth.org/view/article/152561/. [Accessed 29/09/17].

67 Hirsh, Jones, "History's contributions to energy research and policy" (cf. note 3), 106.
68 Daunton, "Rationality and institutions: reflections on Douglass North" (cf. note 31), 148.

(energy security; affordability and international competitiveness; and environmental quality), climate change and the low-carbon transition involve one of the most significant policy challenges of this century, not least because of the potential implications of climate change for future generations.[69] The section begins by discussing the various harmful impacts associated with energy transitions. It then moves to a more detailed consideration of the recent development of policies that focus on the low-carbon transition.

32 In contrast with their beneficial effects, changing mixes of energy resources associated with energy transitions and growing energy use can result in harmful impacts, with consequences for environmental quality, health and welfare that can be especially damaging for poorer and less resilient people and nations. The varied chemical properties of fossil, renewable and nuclear fuels and their differing forms, scales and places of extraction, capture, conversion and use create new temporal and spatial patterns of short- or long-term impacts on air, land and water.[70] Current policy responses to these impacts include attempts to govern, guide and manage transitions and their pathways to a different and much greater extent than in most earlier energy transitions.[71]

33 From the late 1980s, along with continuing debate about petroleum resource depletion, the volatile geopolitics of oil and gas, and ideas of sustainable development, there has been a sharpening policy priority given to the widely perceived societal threat of damage from climate change exacerbated by the enhanced greenhouse effect from human-induced greenhouse gas emissions from fossil fuels.[72] Thus, government policy on transitions in many countries now embraces transitions towards low-carbon fuels and technologies, to cut greenhouse gas emissions. This agenda involves branching to pathways away from long-established, highly-valued and energy-dense fossil fuels, their technologies, institutions and practices, towards less energy- and power-dense and, in some cases variable, forms of renewable energy, and nuclear energy, which bring their own often different side-effects and policy trade-offs.[73]

34 In most previous transitions, however, individual energy producers and consumers could gain or capture significant private financial or non-financial rewards from choosing to develop or adopt new energy sources and carriers. In contrast, until very recently such private benefits have been less immediately evident for most low-carbon fuels, except in niche applications, although this is diminishing as the costs of photovoltaics and wind fall. This gap between the private and societal climate-related benefits and costs of a low-carbon transition poses a challenge for public policy significantly different from previous, largely endogenous transitions.[74] Moreover, in economists' language, the moderation of climate-related damage and the externalities that exacerbate it is a global 'public good', i.e. it is 'non-rival' (one nation's benefit from avoided emissions does not reduce the benefit available to other nations) and 'non-excludable' (because over time greenhouse gas emissions tend to spread evenly through the atmosphere, nations cannot be excluded from the benefits of avoided damage, even if they have not contributed to this avoidance – a chance to 'free ride'). These properties mean that, although all countries have some (though diverse), incentives to limit greenhouse gas emissions, the development of successful worldwide strategies has required new and much-contested forms of global governance and international agreement.

69 IPCC, *Climate Change 2014: Synthesis Report* (cf. note 2).

70 National Research Council, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use* (Washington, DC: The National Academies Press, 2010); Epstein, Paul R. *et al.*, "Full cost accounting for the life cycle of coal in 'Ecological Economics Reviews'", *Annals of the New York Academy of Sciences*, vol. 1219, 2011; IPCC, *Climate Change 2014: Synthesis Report* (cf. note 2).

71 Pearson Peter J. G., Foxon Timothy J., "A low carbon industrial revolution? Insights & challenges from past technological and economic transformations", *Energy Policy*, vol. 50, 2012.

72 IPCC, *Climate Change 2014: Synthesis Report* (cf. note 2).

73 Smil, *Energy Transitions* (cf. note 49).

74 Pearson, Foxon, "A low carbon industrial revolution?" (cf. note 71).

35 Despite the progress made in the 2015 Paris climate change agreement,[75] it continues to prove challenging to construct and implement (illustrated by President Trump's abrupt 2017 announcement of his intent to withdraw the USA from the agreement and his subsequent reversal of much of US domestic federal energy and climate policy). The historical dominance of greenhouse gas emissions from industrialised countries and the now rapidly growing emissions from China, India, Indonesia and several other large, highly-populated countries in the developing world, have raised issues of global and intergenerational equity, justice and compensation. They also pose dilemmas for the many countries that wish to provide modern energy and rising living standards to fast-growing populations, yet are troubled by the costs of restraining fossil fuel exploitation and use.

36 This section has outlined some of the harmful effects associated with growing energy use and the changing energy mixes associated with energy transitions. It has focused on the rising but diverse worldwide policy emphasis on one problem, climate change (although other environmental impacts, such as the health and ecological damage associated with other forms of local and regional air and water pollution, are also of grave concern). The long, complex dynamics of the greenhouse effect and climate change, the centuries-long, path-dependent, persistent use of fossil fuels, issues of equity and justice, and the difficulties of national and global governance and our capacity to govern, underlie many of the challenges involved. These attributes of climate change and governance indicate numerous aspects where historical knowledge might enhance our understanding of energy transitions, and of our capacities and potential to address them. The next section explores three such aspects.

THREE AREAS IN WHICH HISTORICAL ANALYSIS IS PARTICULARLY VALUABLE

37 This section explores three aspects of the study of energy transitions that can be further enriched by historical analysis: the duration and speed of transitions; path dependence, lock-in and the roles of incumbents; and sustainability transitions and innovation theory approaches.

The duration and speed of past and prospective transitions

38 A significant element of recent energy transition debates concerns how long transitions have taken, might take and especially, given the perceived urgency of low-carbon transitions, whether and how the pace of change might be accelerated.[76] Historical evidence and analysis are directly relevant here, as are searching analyses of whether, how far and in what ways prior experience can help to think about and in practice influence energy and climate futures.

39 A recent set of exchanges initiated by Sovacool[77] in the journal *Energy Research and Social Science* is a good example of such a debate. Sovacool asked whether the 'mainstream' view of energy transitions as long drawn-out, taking decades or centuries to unfold[78] remained persuasive or whether evidence that some transitions had been accomplished more quickly might be more relevant for modern, purposive transitions.[79] The debate turned on several issues: on issues of scale and comparability, including

75 UNFCCC (United Nations Framework Convention on Climate Change), *Adoption of the Paris Agreement*, FCCC/CP/2015/L.9/Rev.1. (Paris: UNFCCC, 2015), http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf [Accessed 8/10/17].

76 Grubler Arnulf, Wilson Charlie, Nemet Gregory, "Apples, oranges, and consistent comparisons of the temporal dynamics of energy transitions", *Energy Research and Social Science*, vol. 22, 2016.

77 Sovacool Benjamin K., Geels Franck W., "Further reflections on the temporality of energy transitions: A response to critics", *Energy Research & Social Science*, vol. 22, 2016.

78 Grubler, Wilson, Nemet, "Apples, oranges, and consistent comparisons" (cf. note 76); Smil Vaclav, "Examining Energy Transitions: A Dozen Insights based on Performance", *Energy Research and Social Science*, vol. 22, 2016.

79 Bromley Peter S, "Extraordinary interventions: Toward a framework for rapid transition and deep emission reductions in the energy space", *Energy Research and Social Science*, vol. 22, 2016; Kern Florian, Rogge Karoline, "The pace of governed energy transitions: agency, international dynamics and the global Paris agreement accelerating

differences between 'grand' global or country level transitions, such as transitions from biomass to coal, and transitions at end-use or sectoral scale, such as for lighting or transport; on measurement issues such as the delineation of the temporal or spatial phases and boundaries of a transition, including start- and end-points and formative phases;[80] on issues of temporal dynamics, such as whether the processes involved in transitions necessarily constrain attainable rates of change or have changed and become more open to influence in a more globalised world; on the changing agency of actors and policy instruments; on differences between analytical approaches and their foci; and on different ontological assumptions about the relationships between markets and the state.

40 Underlying much of this debate lie the problems of comparability, of knowing and agreeing what kinds of transitions are being compared and whether they are commensurate, of the choice of periods for comparison, and of what the differences between past and present contexts enable us to conclude. These are all areas in which historical understanding and methods can help to tighten the focus and quality of analysis.

41 Sovacool and Geels[81] suggest that Grubler and Smil see transitions as slow because of techno-economic rationales, including the time taken to construct large infrastructures, for innovative technologies to benefit from learning and scale economies, and because of reluctance to abandon sunk investments early. In contrast, they suggest that Kern and Rogge and Bromley see low-carbon transitions being potentially faster because political will and a sense of urgency, supported by wider publics and changed cultural discourses, may yield policies that change market and selection environments (such as financial incentives) and even phase out technologies early (as with Germany's nuclear power plants): "So, the core of their argument is that politics may trump economics...".[82] And Sovacool and Geels go on to advance the contestable view that, "We endow the fossil fuel regime with perhaps more agency than it actually has or need have",[83] an issue discussed further below.

42 A recent study illustrates how historical knowledge has been used to assess the plausibility of the duration and speed of technology adoption in future low-carbon scenarios. Thus McDowall[84] found that studies of future hydrogen fuel cell vehicle uptake have tended to be relatively optimistic about their possible rates of adoption compared with analogous historical situations in which alternative fuel motor vehicles have diffused. Moreover, although rapid transitions to alternative fuel vehicles have occurred historically, this was often in unusual conditions, such as Brazil's transition from 1975 to vehicles fuelled by ethanol produced from domestic sugarcane.

43 This transition was led by the Brazilian military government's development of a vigorous import substitution policy in response to four convergent stimuli: surging imported oil prices from the 1973-74 oil shock, restrictive European trade preferences on sugar imports, including those from Brazil; US substitution of corn syrup for imported Brazilian sugar, and the collapse in world sugar prices. While the specific circumstances of this transition might be thought to make it problematic to draw insights from it, Meyer *et al.*[85] claim that the key 'lesson' from the Brazilian experience is the importance of a consistent long-term policy framework, although they also suggest the decades-long continuity in policy made the innovation policy of Brazilian alcohol unique.

decarbonisation processes?", *Energy Research and Social Science*, vol. 22, 2016.

80 Bento Nuno, Wilson Charlie, "Measuring the duration of formative phases for energy technologies", *Environmental Innovation & Societal Transitions*, vol. 21, 2016.

81 Sovacool, Geels, "Further reflections on the temporality of energy transitions" (cf. note 77).

82 *Ibid.*, 233.

83 *Ibid.*, 236.

84 McDowall Will, "Are scenarios of hydrogen vehicle adoption optimistic? A comparison with historical analogies", *Environmental Innovation & Societal Transitions*, vol. 20, 2016.

85 Meyer Dustin et al., "Brazilian ethanol: Unpacking a success story of energy technology innovation", Ch. 20 *in* Arnulf Grubler, Charlie Wilson (eds.), *Energy Technology Innovation* (Cambridge: Cambridge University Press, 2014).

44 Clearly there is a risk that those of us engaged in energy transition research select specific, sometimes inappropriate or perhaps unique, historical energy transition experiences from which to draw insights for current or future transitions, without being aware of the limitations of such inferences. Comparative studies by historians of unusually fast and unusually slow past transitions, and advice on the methods and pitfalls of selecting and interpreting such evidence, could be particularly helpful for transition researchers.

45 A study by Tim Foxon and the author,[86] which critically examined claims that a low-carbon transition might amount to another industrial revolution, suggested that caution is needed before assuming that past experiences of high-carbon transitions based on fossil fuels can provide simple analogues for today's new low-carbon transitions, or that insights drawn from them are necessarily and simply transferable to them. The study also suggested that climate change policy may have more in common with late 19th C. policy developments for the public good, than with more narrowly framed technological challenges viewed mainly in the context of private markets. For example, developments during that period in the UK in clean water supply, public sanitation and sewerage infrastructure (e.g. Bazalgette's London sewerage system)[87] and in other aspects of public health, produced big gains both for society and private actors, as in many other countries.[88] These developments were partly inspired by the work of Edwin Chadwick and others, who had exposed the inequalities and market failures of capitalist industrial and urban development, including pollution, congestion and disease, and/or campaigned for actions to address them.[89]

46 This sub-section has considered the speed and duration of transitions and illustrated some challenges of selecting and drawing from historical experience. Historians might engage with and share critical contributions that help non-historians in three areas: to appreciate how we might better understand the relationship between the pace and duration of past and prospective transitions; why a rapid low-carbon transition in today's world might present similar or different challenges and opportunities from those of past high-carbon transitions; and to assess whether and in what ways low-carbon transitions may be commensurate or incommensurate with historical experiences.

Path dependence, lock-in and the strategies, responses and destabilisation of incumbent actors

47 This section explores the influence of processes of path dependence and lock-in. It begins by outlining path dependence and lock-in and their influence on energy transitions. It then explores how incumbents can influence energy transitions, considers the roles incumbents can play in delaying and sometimes in advancing a transition, and the importance of destabilising them to reduce their capacity to impede desired transitions.[90]

48 As Foxon[91] and Fouquet[92] discuss, energy system evolution can be path dependent, in that a system's present and future trajectories are influenced by the sequence of events that led to its

86 Pearson, Foxon, "A low carbon industrial revolution?" (cf. note 71).

87 Bazalgette Joseph W., *On the Main Drainage of London: And the Interception of the Sewage from the River Thames* (London: William Clowes and Sons, 1865).

88 Gordon Robert J., "Does the 'new economy' measure up to the great inventions of the past?" *National Bureau of Economic Research Working Paper 7833* (Cambridge, Mass.: 2000) http://www.nber.org/papers/w7833 [Accessed 19/6/18].

89 Mokyr, *Enlightened* (cf. note 50).

90 See also: Pearson "Energy Transitions" (cf. note 49); Pearson Peter J. G., "Path dependence & path creation: roles for incumbents in the low carbon transition?", *British Institute of Energy Economics Conference: Innovation and Disruption: the energy sector in transition* (St John's College, Oxford, 21 September, 2016).

91 Foxon Timothy J., "Technological lock-in and the role of innovation", *in* Gilles Atkinson, Simon Dietz, Eric Neumayer (eds.), *Handbook of Sustainable Development*, Ch. 9 (Cheltenham: Edward Elgar, 2007); Foxon Timothy J., "A co-evolutionary framework for analysing transition pathways to a sustainable low carbon economy", *Ecological Economics*, vol. 70, 2011.

92 Fouquet Roger, "Path dependence in energy systems and economic development", *Nature Energy*, vol. 1, 2016.

present state.[93] A system's state may become locked in because of past experiences, even though the conditions conducive to that lock-in are no longer relevant. Arthur[94] showed that four kinds of increasing returns may result in technological 'lock-in' (Klitkou *et al.*,[95] proposed five more lock-in mechanisms). Consequently, the incumbent technology or industry accumulates socio-technical advantages, including falling costs, impeding adoption of a potentially superior alternative. North[96] proposed that institutions (i.e. social rule systems) also experience forms of increasing returns. And Pierson[97] argued that such returns may prevail in institutions like market or regulatory frameworks, sometimes enabling incumbents to exercise undue influence.

49 Studies have shown both the negative and the positive aspects of path dependency. Arapostathis *et al.*[98] and Pearson and Arapostathis,[99] for example, show the advantages – how the late 1960s development of the UK's natural gas system benefited from the earlier construction of a 'backbone' distribution pipeline system for liquified natural gas - and the disadvantages - how previous developments reduced the UK gas industry to a state of uncompetitive 'incoherence' before the Second World War, inhibiting its development.

It has been shown how co-evolutionary processes and positive feedbacks led to the lock-in of current high-carbon energy systems, so-called 'carbon lock-in',[100] raising systemic barriers to investment in low-carbon technology systems. Some carbon actors have lobbied to dispute climate science and/or to resist institutional and policy changes that favour low-carbon technologies. They include some fossil fuel producers and the established large German electricity utilities that lobbied in the 1990s for the repeal of renewable energy feed-in regulations and tariffs. 50

While co-evolutionary thinking highlights the difficulty of leaving an energy system pathway widely supported by powerful actors, if increasing returns to the adoption of alternatives can be enabled, this might lead to virtuous cycles of change. Garud and Karnøe[101] argued for 'path-creation', whereby incumbent entrepreneurs may choose to branch away from structures and technologies they have developed. Historical studies have also suggested that lock-in can be avoided through forming diverse alternative technological options and ensuring promising options benefit from increasing returns and learning, to challenge dominant technologies.[102] 51

The 'sailing ship' effect (SSE) or the 'last gasp effect of obsolescent technologies' (LGE) arises where competition from new technologies and 52

93 David Paul A., "Path dependence, its critics and the quest for 'historical economics'", *in* Pierre Garrouste, Stavros Ioannides (eds.), *Evolution and Path Dependence in Economic Ideas: Past and Present* (Cheltenham: Edward Elgar, 2001).

94 Arthur W. Brian, *Increasing Returns and Path Dependence in the Economy* (Ann Arbor: University of Michigan Press, 1994).

95 Klitkou Antje *et al.*, "The role of lock-in mechanisms in transition processes: The case of energy for road transport", *Environmental Innovation & Societal Transitions*, vol.16, 2015.

96 North Douglass C., *Institutions, Institutional Change and Economic Performance* (Cambridge: Cambridge University Press, 1990).

97 Pierson Paul, "Increasing returns, path dependence, and the study of politics", *American Political Science Review*, vol.94/2, 2000.

98 Arapostathis Stathis, Pearson Peter J. G., Foxon Timothy J., "UK natural gas system integration in the making, 1960–2010: Complexity, transitional uncertainties & uncertain transitions", *Environmental Innovation and Societal Transitions*, vol. 11, 2014.

99 Pearson Peter J. G., Arapostathis Stathis, "Two centuries of innovation, transformation and transition in the UK gas industry: Where next?", *Proceedings of the Institution of Mechanical Engineers*, *Part A: Journal of Power and Energy*, vol. 231/6, 2017.

100 e.g. Unruh Gregory C., "Understanding carbon lock-in", *Energy Policy*, vol. 28, 2000; Unruh Gregory C., "Escaping carbon lock-in", *Energy Policy*, vol. 30, 2002; Unruh Gregory C., Carrillo-Hermosilla Javier, "Globalizing carbon lock-in", *Energy Policy*, vol. 34, 2006.

101 Garud Raghu, Karnøe Peter, "Path creation as a process of mindful deviation", *in* Raghu Garud, Peter Karnøe (eds.), *Path Dependence and Creation* (London: Lawrence Erlbaum, 2001).

102 Arapostathis, Pearson, Foxon, "UK natural gas system integration" (cf. note 98); Pearson, Arapostathis, "Two centuries of innovation, transformation and transition" (cf. note 98).

firms provokes innovation and improvements in incumbent firms and their associated technologies. There is now a substantial, diverse literature on the SSE/LGE, much of it with a management or innovation slant. There has been some debate about whether all cited instances of the SSE bear closer scrutiny,[103] including that of the sailing ship itself.[104] Nevertheless, recent evidence suggests that the idea that some firms react positively when the ascendancy of their technologies is threatened by competition from distinctive new technologies deserves further conceptual and historical investigation. Sick *et al*.[105] combined ideas about the SSE with the rationales of path dependence to show how such behaviour may be economically rational in the automotive industry. Similarly, Dijk *et al*.[106] argued that vehicle manufacturers have tended to avoid costly and risky radical technical innovation and disruption, partly by hybridisation, i.e. incorporating new technological developments into an existing technology: they describe this response as an SSE. And Furr and Snow[107] explored situations in which incumbent technologies might show a sudden performance leap.

53 The period after the Second World War merits further research into the many situations in which established technologies and their industries had to respond to the threat of significant technological and design innovations. Bergek *et al*.[108] contest two explanations of the 'creative destruction'[109] of existing industries from discontinuous technological change. According to Schumpeter, creative destruction involves, "competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives".[110] Bergek *et al*. discuss how the two 'competence-based'[111] and 'market-based'[112] explanations of creative destruction suggest that incumbents are challenged only by 'competence-destroying' or 'disruptive' innovations, that render the firms' knowledge base or business models obsolete. Incumbents are burdened with 'core rigidities' of organization and strategy and outdated technologies: innovations will be pioneered by new entrants, who take market shares from incumbents.[113]

The cases analysed by Bergek et al. in the auto- 54
motive and gas turbine industries suggest, however, that these analytical approaches tend to: overestimate new entrants' ability to disrupt established firms; and underestimate incumbents' capacities to grasp the potential of new technologies and integrate them with existing capabilities via processes of 'creative accumulation'. Creative accumulation requires firms to rapidly fine-tune and evolve existing

103 Howells John, "The Response of Old Technology Incumbents to Technological Competition - Does the Sailing Ship Effect Exist?", *Journal of Management Studies*, vol. 39/7, 2002; but see Arapostathis Stathis *et al*., "Governing transitions: Cases and insights from two periods in the history of the UK gas industry", *Energy Policy*, vol. 52, 2013.

104 Mendonça Sandro, "The 'sailing ship effect': reassessing history as a source of insight on technical change", *Research Policy*, vol. 42, 2013.

105 Sick Nathalie *et al*., "The legend about sailing ship effects - Is it true or false? The example of cleaner propulsion technologies diffusion in the automotive industry", *Journal of Cleaner Production*, vol. 137, 2016.

106 Dijk Marc, Wells Peter, Kemp René, "Will the momentum of the electric car last? Testing an hypothesis on disruptive innovation", *Technological Forecasting & Social Change*, vol. 105, 2016.

107 Furr Nathan R., Snow Daniel C., "Intergenerational hybrids: spillbacks, spillforwards, and adapting to technology discontinuities", *Organization Science*, vol. 26/2, 2014.

108 Bergek Anna *et al*., "Technological discontinuities and the challenge for incumbent firms: Destruction, disruption or creative accumulation?", *Research Policy*, vol. 42/6–7, 2013.

109 Schumpeter Joseph A., *Capitalism, Socialism and Democracy* (London: Routledge, 2010 [1942]), 72-75. See also: Reinert Hugo, Reinert Erik S., "Creative Destruction in Economics: Nietzsche, Sombart, Schumpeter", *in* Jürgen G. Backhaus, Wolfgang Drechsler (eds), *Friedrich Nietzsche (1844–1900), The European Heritage in Economics and the Social Sciences, vol. 3* (Boston, Mass.: Springer, 2006).

110 Schumpeter, *Capitalism*, 74 (cf. note 109).

111 Tushman Michael, Anderson Philip, "Technological discontinuities and organizational Environments", *Administrative Science Quarterly*, vol. 31, 1986.

112 Christensen Clayton M., *The Innovator's Dilemma. The Revolutionary Book That Will Change the Way You Do Business* (New York: HarperCollins Publishers, 1997/2003).

113 See also: Geels Frank, "Disruption and low-carbon system transformation: Progress and new challenges in socio-technical transitions research and the Multi-Level Perspective", *Energy Research & Social Science*, vol. 37, 2018.

technologies, acquire and develop new technologies and resources, and integrate novel and existing knowledge into superior products and solutions.[114] Bergek et al.'s findings help explain why some new energy technologies may find it harder to penetrate than might be anticipated. They also suggest, however, that some incumbents have or may develop the ability to embrace new technologies, particularly when hybridisation – as with hybrid powered motor vehicles - makes it possible to extend the life of established technologies.[115]

55 Thus, some incumbents may have the potential capacity to recognise both longer run opportunities and the writing on the wall of changing public attitudes and government policies towards climate change, and engage in processes of creative accumulation. Moreover, if policies seek to address climate change rapidly, this may require non-incremental, often time-consuming low-carbon developments and investments, at a pace and scale that new entrants may struggle with. In such circumstance, to rely solely on new entrants risks missing opportunities to build on and modify potentially responsive incumbents' accumulated technical and managerial capacities, infrastructures and learning.

56 Nevertheless, policy strategies aimed at stimulating innovation in and the penetration of low-carbon technologies also require policies that address path dependence and lock-in and reflect the importance in some circumstances of acting to 'destabilise' high-carbon incumbent firms, technologies and associated institutions. Thus, in their studies of the long, slow decline of the UK coal industry and the factors that destabilised it, Turnheim and Geels argue that, "...industries are committed to existing industry regimes, and are likely to resist major change in technical competencies, core beliefs and mission. (...) Weakening the cultural, political, economic and technological dimensions of fossil-fuel related industries is just as important as stimulating green options".[116] Turnheim and Geels' analyses are rare examples of studies of how and why energy path dependence and lock-in collapsed. Given the power and persistence of fossil fuel incumbents and institutions, further studies by historians and others of such historical precursors would be particularly valuable in identifying and interpreting further precedents.[117]

Sustainability Transitions and innovation

57 This section addresses an area of literature that reflects the widespread international interest in more sustainable energy futures,[118] and is one in which practitioners, mainly non-historians, have made extensive use of historical analyses (including Arapostathis *et al.*;[119] Geels;[120] Verbong and Geels;[121] Johnson *et al.*;[122] Martínez

114 Pavitt Keith, "'Chips' and 'trajectories': how does the semiconductor influence the sources and directions of technical change?", *in* Roy MacLeod (ed.), *Technology and the Human Prospect* (London: Frances Pinter, 1986).

115 See also: Furr, Snow, "Intergenerational hybrids" (cf. note 107).

116 Turnheim Bruno, Geels Franck W., "Regime destabilisation as the flipside of energy transitions: Lessons from the history of the British coal industry (1913-1997)", *Energy Policy*, vol. 50, 2012, 47, 49; see also Turnheim Bruno, Geels Franck W., "The destabilisation of existing regimes: Confronting a multi-dimensional framework with a case study of the British coal industry (1913–1967)", *Research Policy*, vol. 42, 2013; Geels Franck W., "Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective", *Theory, Culture & Society: explorations in critical social science*, vol. 31/5, 2014.

117 See also Kungl Gregor, Geels Frank W., "Sequence and alignment of external pressures in industry destabilisation: Understanding the downfall of incumbent utilities in the German energy transition (1998–2015)", *Environmental Innovation and Societal Transitions*, vol. 26, 2018; and for a recent critical review of approaches to incumbency, see Stirling Andy, "How Deep Is Incumbency? Introducing a 'Configuring Fields' Approach to the Distribution and Orientation of Power in Socio-Material Change", *SPRU Working Paper Series SWPS* 2018-23,http://www.sussex.ac.uk/spru/research/swps [Accessed 2/12/18].

118 GEA, Global Energy Assessment (cf. note 1).

119 Arapostathis, "Governing transitions" (cf. note 103).

120 Geels Franck W., "Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study", *Research Policy*, vol. 31, 2002.

121 Verbong Geert P. J., Geels Franck W., "The ongoing energy transition: lessons from a socio-technical, multi-level analysis of the Dutch electricity system (1960-2004)", *Energy Policy*, vol. 35/2, 2007.

122 Johnson Victoria C. A., Sherry-Brennan, Fionnguala, Pearson Peter J. G., "Alternative liquid fuels in the UK in the interwar period (1918–1938): Insights from a failed

Arranz[123]). According to the research agenda of the influential Sustainability Transitions Research Network, research in this area recognises that many environmental problems require deep structural changes in key areas of human activity and society, including energy systems. It asserts, as discussed in Section 5.2, that a key "challenge for sustainable development is the fact that existing systems tend to be very difficult to 'dislodge' because they are stabilized by various lock-in processes that lead to path dependent developments and 'entrapment'".[124] These mutually reinforcing processes that tend to perpetuate existing systems are identified as a 'socio-technical regime', a notion that brings ideas from evolutionary economics together with insights from the history and sociology of technology. It emphasises how scientific knowledge, engineering practices and processes are socially embedded.

58 The overarching aim of sustainability transitions research is to study societal transformations involving governance and guidance,[125] through which systems shift towards more sustainable modes of production, consumption and lifestyles, while recognising that such transitions are complex, long drawn-out processes.[126] Thus, sectors like energy are seen as socio-technical systems with interacting networks of actors (people, firms, etc.), broadly-defined institutions, material artefacts and knowledge. An energy transition is thus likely to involve a shift to a new regime in which multiple actors engage with new commodities and energy services, with changes in social practices, business models and organisations, and altered technological and institutional structures, with repercussions beyond energy.

Studies of prospective and historical energy 59
transitions and processes have often drawn on the multi-level perspective (MLP), an approach that grew out of works by Kemp, Rip and Schot.[127] The MLP combines concepts from evolutionary economics, science and technology studies, structuration theory and neo-institutional theory. It proposes that transitions can emerge out of dynamic non-linear interactions between three analytical levels, niches (the locus for radical innovations), socio-technical regimes (the locus of established practices and associated rules that stabilise existing systems) and an exogenous socio-technical landscape; transitions involve shifts from one regime to another.[128] Different interactions could then lead to various kinds of transition pathway, including pathways to future energy systems.[129] The MLP, although subject to a range of criticisms,[130] con-

energy transition", *Environmental Innovation and Societal Transitions*, vol. 20, 2016.

123 Martínez-Arranz Alfonso, "Lessons from the past for sustainability transitions? A meta-analysis of socio-technical studies", *Global Environmental Change*, vol. 44, 2017.

124 STRN, "A mission statement and research agenda for the Sustainability Transitions Research Network", 2010, http://transitionsnetwork.org/files/STRN_research_agenda_20_August_2010... [Accessed 8/6/17].

125 Smith Adrian, Stirling Andy, Berkhout Frans, "The governance of sustainable socio-technical transitions" *Research Policy*, vol. 34, 2005.

126 See also: Markard Jochen, Raven Rob, Truffer Bernhard, "Sustainability transitions: An emerging field of research and its prospects", *Research Policy*, vol. 41, 2012; Geels Franck W., Berkhout Frans, van Vuuren Detlef P., "Bridging analytical approaches for low-carbon transitions", *Nature Climate Change*, vol. 6/6, 2016.

127 Kemp René, Rip Aarie, Schot Johan, "Constructing transition paths through the management of niches", *in* Raghu Garud, Peter Karnøe (eds.), *Path Dependence and Creation* (London: Lawrence Erlbaum, 2001); Rip Arie, Kemp René, "Technological change", *in* Steve Rayner, Elizabeth L. Malone (eds.), *Human Choice and Climate Change – Volume 2: Resources and Technology* (Columbus: Battelle Press, 1998).

128 Geels, "Technological transitions as evolutionary reconfiguration processes" (cf. note 120).

129 Geels Franck W., Schot Johan W., "Typology of sociotechnical transition pathways", *Research Policy*, vol. 36, 2007; Geels Franck W. *et al.*, "The enactment of socio-technical transition pathways: A reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–2014)", *Research Policy*, vol. 45/4, 2016.

130 e.g. Smith, Stirling, Berkhout, "The governance of sustainable socio-technical transitions" (cf. note 125); responded to by Geels Franck W., "The multi-level perspective on sustainability transitions: Responses to seven criticisms", *Environmental Innovation and Societal Transitions*, vol. 1/1, 2011; see also Geels Franck W., "Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective", *Theory, Culture & Society: explorations in critical social science*, vol. 31/5, 2014.

tinues to be widely and usefully - although not always discriminately – applied and developed.

60 Concerns with how transitions might be accelerated led to ideas about procedures to guide transitions.[131] The guiding principles for 'transition management', including 'strategic niche management' were informed by thinking about existing sectors as complex, adaptive systems and viewing management as a reflexive, evolutionary governance process.[132] Transition management has been explored in practice in the Netherlands with mixed outcomes,[133] while the political and practical feasibility of trying to 'manage' national level transitions through such processes has rightly been challenged. Shove and Walker, for example, questioned whether societies necessarily have the ability to transform themselves, and argue that transition management approaches "can...obscure their own politics, smoothing over conflict and inequality; working with tacit assumptions of consensus and expecting far more than participatory processes can ever hope to deliver".[134] Similarly, Meadowcroft[135] argued that transforming energy systems "will prove to be a messy, conflictual, and highly disjointed process."

61 Indeed, key questions concern our capacity and ability to respond to the nature and scale of the threat of climate change, given the state of political institutions and economies, especially in the Western world - and after the economic fallout from the recent financial crisis. So, we need much better knowledge about: whether and in what respects climate change and low-carbon transitions form unprecedented challenges; how political, institutional and technical capacities to respond to apparently existential crises have or have not been developed in the past, and might be developed for the future; and whether history helps us to judge whether the responses to such challenges might be treated effectively in a piecemeal fashion, so that they become more manageable.

62 While much energy transition pathways research has been qualitative, increasing efforts are being devoted to forward-looking quantitative approaches[136] and to bringing them together with qualitative analyses[137] or to developing a hybrid approach.[138] McDowall and Geels,[139] however, question whether transitions can be represented within a single encompassing framework and suggest instead the pursuit of plural, diverse approaches. Further interdisciplinary work, especially that of historians, might play a valuable role in such endeavours.

131 Kemp René, Loorbach Derk, "Transition management: a reflexive governance approach", *in* Jan-Peter Voss, Dierk Bauknecht, René Kemp (eds.), *Reflexive Governance for Sustainable Development* (Cheltenham: Edward Elgar, 2006), Ch. 5.

132 Voss Jan-Peter, Smith Adrian, Grin John, "Designing long-term policy: rethinking transition management", *Policy Sciences*, vol. 42, 2009.

133 Smith Adrian, Kern Florian, "The transitions storyline in Dutch environmental policy", *Environmental Politics*, vol. 18/1, 2009; Kemp René, "The Dutch energy transition approach", *International Economics and Economic Policy*, vol. 7, 2010.

134 Shove, Walker, "CAUTION! transitions ahead"(cf. note 55), 768; Shove Elisabeth, Walker Gordon, "Transition Management™ and the Politics of Shape Shifting", *Environment and Planning A*, vol. 40/4, 2008; Rotmans Jan, Kemp René, "Detour Ahead: A Response to Shove and Walker about the Perilous Road of Transition Management", *Environment and Planning A*, vol. 40/4, 2008.

135 Meadowcroft James, "What about the politics? Sustainable development, transition management, and long term energy transitions", *Policy Sciences*, vol. 42, 2009, 323.

136 Li Francis G. N., Trutnevyte Evelina, Strachan Neil, "A review of socio-technical energy transition (STET) models", *Technological Forecasting & Social Change*, vol. 100, 2015; Holtz Georg *et al.*, *Prospects of modelling societal transitions: position paper of an emerging community, Environmental Innovation and Societal Transitions*, 17, 2015.

137 Trutnevyte Evelina *et al.*, "Linking a storyline with multiple models: a cross-scale study of the UK power system transition", *Technological Forecasting and Social Chang*, vol. 89, 2014; Turnheim Bruno *et al.*, "Evaluating sustainability transitions pathways: bridging analytical approaches to address governance challenges", *Global Environmental Change*, vol. 35, 2015.

138 McDowall Will, "Exploring possible transition pathways for hydrogen energy: A hybrid approach using socio-technical scenarios and energy system modelling", *Futures*, vol. 63, 2014; Geels, Berkhout, van Vuuren, "Bridging analytical approaches for low-carbon transitions" (cf. note 126).

139 McDowall Will, Geels Frank W., "Ten challenges for computer models in transitions research: Commentary on Holtz *et al.*", *Environmental Innovation & Societal Transitions*, vol. 22, 2017.

63 Innovation is a significant element of low-carbon transitions. Truffer *et al.*[140] critically examined the energy-related areas of the socio-technical 'innovation systems' literature. This literature spans four innovation system approaches: national (NIS), regional (RIS), sectoral (SIS) and technological (TIS) innovation systems. The NIS was created in the 1980s, stimulated by a desire to explain key ongoing economic challenges more effectively than approaches drawn from neo-classical economics. The RIS, SIS and TIS went outside national boundaries, encompassing broader influences like those of multi-national corporations. Truffer *et al.* argued that the TIS tradition has been the most productive of these areas in the energy field.[141] TIS studies have gone from examining energy innovations in specific countries, often focusing on those 'functions' of an innovation system required for it to operate well,[142] to inter-country comparisons and to some regional and global analyses of technological innovation systems. While Europe has been the main focus of existing studies, greater attention is now being paid to emerging economies. Truffer et al. suggested that the four approaches could be more effectively integrated, and would benefit from further conceptual and empirical development, as well as attention to the analysis of longer term energy transitions and their dynamics. Indeed, Weber and Rohracher[143] proposed combining insights from the innovation systems and MLP approaches.[144]

64 Despite the need for and value of energy-related innovation, as a matter of perspective, Fagerberg[145] cautions against the tendency to view all innovations as comprehensively 'good'. In solving specific problems, innovation may also create new, unanticipated problems, of which the 'financial innovations' festering below the 2008 crisis are but a recent example. Energy is rich with instances, both particular (e.g. the development of tetra-ethyl lead additives for gasoline, now removed) and general (fossil fuels). Historically-informed insights from such episodes might help us to better anticipate such innovation pitfalls.

65 This sub-section has discussed recent approaches to sustainable transitions, their governance and guidance, and energy-related innovation. While research in these areas includes historical case studies and goes some way towards acknowledging the social, political, cultural, technological and path-dependent complexities and entanglements that historians embrace, this work would benefit from a deeper, broader and more rigorous acquaintance with historical methods and findings. Many practitioners would welcome more of this kind of collaboration.

CONCLUSION AND AN INVITATION TO HISTORIANS

66 This paper had four aims: to argue that historical analyses can offer insights into past energy transitions that are of value to non-historians who study energy transitions, including policy-makers; to show how, in one discipline, economics, for some time historical aspects seemed of little relevance to energy economists and policy analysts; to indicate problem areas, issues and

140 Truffer Bernhard *et al.*, "A literature review on Energy Innovation Systems. EIS Radar paper", 2012, http://www.eis-all.dk/~/media/Sites/EIS_Energy_Innovation_Systems/engli... (Accessed 19/6/18).

141 See also: Markard Jochen, Hekkert Marko, Jacobsson Staffan, "The technological innovation systems framework: response to six criticisms", *Environmental Innovation and Societal Transitions*, vol. 16, 2015.

142 Hekkert Marko *et al.*, "Functions of Innovation systems: a new approach for analysing technological change", *Technological Forecasting & Social Change*, vol. 74, 2007.

143 Weber K. Matthias, Rohracher Harald, "Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework", *Research Policy*, vol. 41, 2012.

144 See also: Fagerberg Jan, "Mission (im)possible? The role of innovation (and innovation policy) in supporting structural change & sustainability transitions", *TIK Working Papers on Innovation Studies*, n° 20180216. https://ideas.repec.org/p/tik/inowpp/20180216.html [Accessed 2/12/18); And for a more ambitious synthesis, see: Cherp Aleh *et al.*, "Integrating techno-economic, socio-technical and political perspectives on national energy transitions: A meta-theoretical framework", *Energy Research & Social Science*, vol. 37, 2018.

145 Fagerberg Jan, "Innovation – a New Guide", *TIK Working Papers on Innovation Studies*, n° 20131119, 2013, http://www.sv.uio.no/tik/InnoWP/tik_working_paper_20131119.pdf [Accessed 7/10/17].

questions, especially those concerning low-carbon transitions, especially suited to historical insights; and to invite historians to engage in further such analyses of energy transitions and to collaborate more with non-historians.

67 Section 1 explained the author's normative views about climate change and low-carbon transitions, and about the type of contribution that historical insights and knowledge can offer to non-historians' thinking. Section 2 drew on personal experience and critical literature review to address the second aim. Section 3 examined the nature, variety and complexities of energy transitions, including why they are challenging to define, identify, analyse and generalise from, and why historians are well-placed to embrace these challenges and share their expertise. Section 4 discussed the growing policy interest in transitions, especially low-carbon transitions. The long, complex dynamics of the greenhouse effect and climate change, the centuries-long, path-dependent, persistent use of fossil fuels, issues of equity and justice, and the difficulties of national and global governance, both underlie many of the policy challenges involved and suggest many aspects where historical expertise might enhance our understanding. Section 5 examined three areas in which further historical insights might be especially valuable: the duration and speed of past energy system transitions and whether they offer precedents for the future (Section. 5.1); path dependence, lock-in and the strategies, responses and destabilisation of incumbent energy actors and institutions (Section 5.2); and sustainability transitions and innovation theories (Section 5.3). Each of these sub-sections illustrated problem areas, issues and questions that might benefit from the further application of historical expertise.

68 Several of the problem areas identified, particularly but not only in Section 3, raise important, tricky epistemological issues concerning the development of knowledge about the nature, variety and complexities of energy transitions. They include the distinction between the many kinds of 'minor' and 'major' (or 'grand') transitions, with all that our ability to draw such distinctions with confidence implies for our capacity to comprehend the scale, pace, duration, smoothness and (dis)continuity or other 'special' properties of transitions, and for our ability to guide or manage them. Although the literature addresses most of these issues, because it also shows ambiguity, even contradiction, greater clarity would be valuable. A referee also suggested that, "these epistemological lines of inquiry are not only valuable intrinsically, but also are not necessarily predictive or prescriptive, and so are available to historians who baulk at either prediction or prescription."

69 Finally, this paper extends an invitation to interested historians to further share the methods, subtleties and findings of historical analysis with non-historians, to enhance our knowledge, understanding and thinking about energy transitions.

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From the jaws of defeat: France, the United States and Middle East oil, 1940-1948

Abstract
At its birth in 1924 the French state endowed the Compagnie Française des Pétroles (CFP) with a quarter share of the Turkish (later Iraq) Petroleum Company. A joint venture between the big four American and British oil companies, IPC struck oil in Iraq three years later. In the interwar period France's pretensions to oil independence rested on CFP and the access IPC gave the French to Middle East oil through the 1928 Red Line Agreement. Defeat in 1940 appeared to doom France as an oil power. The Red Line Agreement collapsed and CFP was denied her rightful share in the oilfields of Saudi Arabia. CFP and the French state weathered this energy crisis through a mixture of diplomacy and blackmail. Using previously untapped archives, this essay argues that the outcome for France – the 1948 Working Agreement – was more favourable than is usually held.

Plan of the article

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1 In April 1948 the French diplomat Jean Chauvel wrote to his colleague Henri Bonnet of his concerns regarding postwar France's place in the world. The events of 1947 had seen the leaders of the Fourth Republic draw a line under their earlier alliances with Soviet Russia. February's Communist Coup in Prague suggested that there was little hope of a viable third way between emerging American and Soviet blocs. It remained unclear, however, how France fitted into broader schemes of collective defence against Soviet aggression. Where did she figure in the United States' plans? It was unsurprising that Chauvel, Secretary-General of the French Foreign Ministry would turn to Bonnet, who had been serving as ambassador in Washington since 1945.

2 Putting himself in the position of the Americans, Chauvel argued that there were three elements likely to interest the Americans "à cette mince presqu'île dont la France constitue l'extrême pointe." First there was the question of identifying a "base de départ" for the reconquest of Europe in the event of Russian occupation. Happily, France and Britain's African bases offered plenty of departure points. The second element was the Ruhr basin, whose resources might alter the balance of power in any future conflict over Europe. The recently-signed Brussels Pact had addressed this issue, committing five western European nations to a policy of mutual defence.[1]

3 It is the third element, however, which concerns us here: "l'ensemble pétrolier d'Arabie." "Il est bien évident," Chauvel concluded, "étant donné l'assemblage d'aveugles, de borgnes et de paralytiques dont se compose le cul-de-sac oriental, que c'est en effet aux trois principaux alliés qu'incombe la charge principale, non pas seulement de la conception du plan de défense, mais aussi de son exécution."[2] Although Chauvel presumed that the governments of France, the United States and the United Kingdom would make common cause in any such hypothetical conflict, in 1948 French, American and British oil companies were locked in a very real conflict over "l'ensemble pétrolier d'Arabie," a conflict which threatened to see the French national champion, the Compagnie Française des Pétroles (CFP), utterly defeated.

4 Under the 1928 Red Line Agreement CFP had joined Royal Dutch-Shell, Anglo-Iranian (today's BP) and an American syndicate inside an international oil consortium for the Middle East known as the Iraq Petroleum Company (IPC).[3] Established in 1912 by the Anglo-Armenian oil magnate Calouste Gulbenkian, IPC secured the concession for the Ottoman vilayets (provinces) of Mosul and Baghdad a few months before the outbreak of World War One. Under the so-called Foreign Office Agreement (1914) IPC shareholders had agreed a self-denying clause, under which each promised not to seek oil within the former "Ottoman Empire in Asia" except through IPC. This area was delineated in red on the map appended to the 1928 Red Line Agreement, giving CFP access to an extraordinarily wide area: the entire Middle East, in effect, apart from Iran and Kuwait.[4]

5 CFP had played no part in this early phase. The Anglo-French San Remo Oil Agreement of 1920, however, stipulated that Deutsche Bank's share in IPC would be transferred to a French company,

1 John W. Young, *France, the Cold War and the Western Alliance, 1944-49: French foreign policy and post-war Europe* (Leicester: Leicester University Press, 1990), 171, 180. Irwin M. Wall, *The United States and the Making of Postwar France, 1945-54* (Cambridge: Cambridge University Press, 1991), 128, 145.

2 Jean Chauvel to Henri Bonnet, 21 April 1948. Archives du ministère des Affaires Étrangères, Paris [hereafter AMAE], Papiers H. Bonnet. 271PAAP/1, f. 45.

3 At the time of the Red Line Agreement the Iraq Petroleum Company was still known as the Turkish Petroleum Company, and Anglo-Iranian was still known as Anglo-Persian. TPC changed its name in 1929; Anglo-Persian became Anglo-Iranian in 1935. For simplicity's sake they are referred to as IPC and Anglo-Iranian throughout this paper.

4 The French negotiators ensured that the line was cast as widely as possible, including territories where the "Ottoman" writ barely ran. See Jonathan Conlin, "Drawing the Line: Calouste Gulbenkian and the 1928 Red Line Agreement", *in* T. G. Fraser (ed.), *The First World War and its Aftermath: the Making of the Modern Middle East* (London: University of Chicago Press, 2015).

Figure 1: The Red Line Agreement, 1928. By kind permission of History Today Magazine.

and in 1924 CFP was duly created to receive these shares. In creating CFP the government of Raymond Poincaré elected not to take a direct stake, appealing instead to independent French banks and refiners to put up the necessary capital. When this proved impossible, owing to the ties linking Paribas, BUP and the refiners' Cartel des Dix to foreign oil majors, the decision was taken to spread CFP's shares as widely as possible, in the hope that no single major would be able to control the new firm's destiny. The French state did, however, decide to take a 35% stake in 1931, when new shares were issued.

6 The 1928 Red Line Agreement gave France a place, if a rather shaky one, among the world's oil majors. CFP had a 23.75% stake in IPC, as did Royal Dutch-Shell and Anglo-Iranian. An American consortium (Near East Development Company) led by Standard Oil of New Jersey (Jersey Standard) held a fourth 23.75% stake, leaving 5% for Gulbenkian, "Mr Five Per Cent". These four IPC shareholders were known as the "Major Groups" or simply "Groups". Considering how tardy France had been in recognizing the strategic significance of oil as well as its refiners' record of subservience to Jersey Standard, this was quite an achievement. Although the world oil industry in 1928 orbited around the Gulf of Mexico, with Texas, Mexico and Venezuela setting the pace, by the outbreak of World War Two many observers recognized that the Persian Gulf

region was likely to supplant it. Thanks to CFP's position as one of the IPC Groups France was well placed to benefit from that process.

7 To reiterate, within IPC the French formed one of the four Groups, on equal standing with the British firm Anglo-Iranian, the Anglo-Dutch giant Royal Dutch-Shell and the American behemoths in the fourth Group, the American consortium Near East Development. Gulbenkian had developed this international structure to ensure that IPC did not become a national champion subservient to one nation's foreign policy. By forcing rival majors to collaborate, Gulbenkian had also sought to prevent any one Group from controlling the firm's policy. Even as they negotiated the 1928 Red Line Agreement, however, three of the IPC Groups were forming a worldwide cartel intended to restrict supply and so support oil prices. This was formalized in the Achnacarry Agreement, signed by Anglo-Iranian, Royal Dutch-Shell and Jersey Standard two months after they signed the Red Line Agreement.

8 Though CFP was theoretically their equal within IPC, outside IPC the case was very different. CFP was far too small to participate in an Achnacarry-style world cartel. While the other IPC Groups were happy to view IPC's concession area as a swing producer and exploit the Red Line Agreement to restrict the release of Middle East oil onto world markets, CFP's interest lay in developing IPC's concession area as quickly as possible. While the other Groups all had plentiful sources of supply elsewhere. CFP did not. For France IPC was a question of energy security. IPC offered an opportunity to escape dependence on American oil supplies in general and on Jersey Standard in particular. When the first IPC pipeline linking Kirkuk to the Mediterranean came on stream in 1935, therefore, it represented a turning point. At last France could satisfy some of her economy's growing demand for oil products herself, with all that that meant in terms of an improved balance of trade and the strength of the franc.

9 Unfortunately it appeared that the other Groups were only too ready to take advantage of World War Two's disruption to sideline CFP and reconstruct IPC along more advantageous (to them, at least) lines. After the fall of France in 1940 CFP's shares in the London-based IPC were sequestered by the (British) Custodian of Enemy Property. Though the sequester was lifted in February 1945, shortly afterwards CFP was informed by the other IPC Groups that they considered the Red Line Agreement void. At some point between late 1944 and May 1946 the American Group (Socony and Jersey Standard, who eventually merged to become ExxonMobil) were invited to join two other American oil companies (Socal and Texaco) in developing a hugely promising Saudi Arabian concession.[5]

10 Saudi Arabia lay within the Red Line area delineated in 1928. In obedience to the self-denying ordinance Socony and Jersey Standard were obligated to bring their fellow IPC Groups with them if they wished to produce in Saudi Arabia. Yet it was clear they had no intention of doing so: the two firms joined a consortium which became the Arab-American Oil Company (Aramco) on their own. Having served the "very useful purpose" of getting American oil companies access to "the petroleum resources" of "countries which in the past [had] been considered within the French and British sphere of influence," the Red Line Agreement was now, apparently, surplus to (American) requirements.[6] The French response to this challenging state of affairs and the new IPC Working Agreement CFP signed along with the other IPC Groups in 1948 form the focus of this paper.

11 A welter of studies of French oil policy in the years immediately after 1918 and from the 1970s onwards has neglected the intervening decades. Although we have biographies for several CFP

5 The American consortium that held a 23.75% share in IPC, Near East Development Company, originally had five members, but by 1934 Atlantic Refining, Pan-American and Gulf had sold out, leaving Socony and Jersey Standard.

6 This candid assessment by Socony's Harold Sheets is cited in Robertson to John A. Loftus, 11 Feb. 1946. National Archives and Records Administration, College Park, MD [hereafter NARA], RG59 Office on Int. Trade Policy, Petroleum Div., 1943-49, Box 3 "Middle East (General)".

executives,[7] we still lack a scholarly history of the company, such as exist for BP, Royal Dutch-Shell and the American giant, Standard Oil of New Jersey.[8] The 1945-8 dispute between CFP and the other IPC Groups has nonetheless been considered by Anand Toprani as well as by André Nouschi and Philippe Tristani.[9] Several doctoral theses also consider the episode.[10] Toprani based his account almost exclusively on State Department archives, however, while the others only consulted French ones. This essay represents the first study based on study of both these archives, as well as those of Calouste Gulbenkian, the Foreign Office, BP, Royal Dutch-Shell and IPC itself – all the IPC Groups, that is, except ExxonMobil, whose archives are not accessible to researchers.[11] It offers the first comprehensive study of the dispute, considering various hypotheticals before reaching an assessment of how well CFP and the French state played the poor hand they had been dealt. It challenges the consensus among French scholars that the 1948 Working Agreement represented a defeat for France.

12 For CFP and for France the stakes were high: despite the best efforts of CFP and its predecessors the French failed to find oil in workable quantities either inside France or her empire until 1956, when it was discovered in Algeria. CFP's 23.75% of IPC's Iraqi production was France's only source of "franc oil" (all other oil had to be purchased using scarce dollars and sterling), a vital source of energy for the Monnet Plan for the reconstruction of France's heavy industry. How did France balance her strong legal and moral position against her pitifully weak economic situation as well as the collapse of any status she may have previously had in the Middle East? How, in short, did the French oil industry survive the worst crisis in its history?

"DEMANDEURS À TOUS LES POINTS DE VUE": CFP UNDER SEQUESTER, 1940-1944

13 The fall of France scattered and divided the management of CFP, making it difficult to formulate any coherent policy. As a precaution CFP had transferred several million dollars into its account at J. P. Morgan in New York before the outbreak of war, and given power of attorney to its IPC partner Socony, along with $1m to meet any calls on its IPC shares.[12] Unfortunately IPC was registered in London, and so CFP's 23.75% holding was

7 Emmanuel Catta, *Victor de Metz: de la C. F. P. au groupe Total* (Paris: TEVA, 1990); Maurice Guierre, *Robert Cayrol 1883-1959: de la mer au pétrole, l'unité d'une vie* (Paris: Perceval, 1960); Richard F. Kuisel, *Ernest Mercier: French technocrat* (Berkeley: University of California Press, 1967); François Pelletier, "Ernest Mercier, le pétrole et la France" (PhD. diss., Université de Paris I, 2016).

8 Jean Rondot, *La Compagnie Française des Pétroles, du franc-or au pétrole-franc* (Paris: n.p., 1962) and André Nouschi, *Luttes pétrolières au Proche-Orient* (Paris: Flammarion, 1970) are unreferenced and full of errors of fact. Harvey B. Feigenbaum, *The Politics of Public Enterprise: Oil and the French State* (Princeton: Princeton University Press, 1985) and David Styan, *France and Iraq: oil, arms and French policy making in the Middle East* (London: I. B. Tauris, 2006) focus on more recent developments, and their accounts of pre-1948 developments is also prone to errors. For the general inter-war context, see Jean-Marie Bouguen, *Le pétrole en France* (Paris: L'Harmattan, 2013); Gregory P. Nowell, *Mercantile States and the World Oil Cartel, 1900–1939* (Ithaca, NY: Cornell, 1995); André Nouschi, *La France et le pétrole de 1924 à nos jours* (Paris: A. and J. Picard, 2001); Mohamed Sassi, "The Emergence of the French Oil Industry between the Two Wars," *Business and Economic History On-Line*, 1, 2003. http://www.thebhc.org/publications/BEHonline/2003/Sassi.pdf (accessed 2 March 2013). See also Kévin Wursthorn, "La Compagnie Française des Pétroles au Qatar de 1935 à nos jours" (Master, Université de Paris I-Panthéon Sorbonne, 2010).

9 André Nouschi, "Un tournant de la politique pétrolière française: les Heads of Agreement de novembre 1948", *Relations Internationales*, no 44, 1986; Anand Toprani, "The French Connection: a new perspective on the end of the Red Line Agreement, 1945-8," *Diplomatic History*, vol. 36/2, 2012; Philippe Tristani, "L'Iraq Petroleum Company, les États-Unis et la Lutte Pour Le Leadership Pétrolier au Moyen-Orient de 1945 à 1973", *Histoire Economique et Société*, vol. 29, no 2, 2010.

10 Pascale Gemignani-Saxtad, "La France, le pétrole et le Proche-Orient de 1939 à 1958" (Ph.D. diss., Université de Paris IV-Sorbonne, 1997); Constance Hubin, "Stratégie industrielle de la Compagnie Française des Petroles (1945-1975)" (PhD. diss, Université de Ouest Nanterre La Défense, 2012); Philippe Tristani, "L'Iraq Petroleum Company de 1948 à 1975" (PhD. diss., Université de Paris IV-Sorbonne, 2014).

11 The archive of IPC is now held by Abu Dhabi Petroleum Company (ADCO). I am grateful to all these companies for allowing me to consult their archives.

12 René de Montaigu to Socony Vacuum, 12 Sept. 1940. Archives du Groupe Total [hereafter Total], SC89/4, "Extraits du Dossier de M. de Montaigu Lisbonne".

sequestered by the Custodian of Enemy Property, who liaised with CFP's London solicitor, Leslie Burgin of Denton Hall Burgin, but who could not undertake any new commitments, as to do so would have been to invest British government funds in a private company, something which would have needed a special act of Parliament.

14 Meanwhile CFP's René de Montaigu fled to Algiers, where he set up a CFP office in July 1943 under the aegis of the Comité Français de la Libération Nationale. In September these "Free French" sought to lift the sequester, with Montaigu declaring in front of the British consul in Lisbon that he would not obey orders from Paris were control of CFP restored to him. In January 1944 the Foreign Office had to inform its Ambassador in Lisbon that despite such promises the sequester could not be lifted. As early as 1935 France had entered secret agreements with His Majesty's Petroleum Executive (the British government agency for oil policy), intended to ensure that even in event of war French military forces would be able to draw on CFP's oil direct from the IPC pipeline terminals at Haifa and Tripoli. This agreement had been made by Louis Pineau of the Office National des Combustibles Liquides, however, not CFP. This and further 1938 and 1939 agreements intended to safeguard supplies for the French air force were never invoked.[13]

15 What of those who remained in Paris? On 20 September 1940, a few months after the fall of France, CFP chairman Ernest Mercier met to discuss policy with Charles-Albert de Boissieu, Secretary-General of the Délégation Générale du Gouvernement Français dans les Territoires Occupés (DGTO), the body set up by the Vichy regime to liaise with the German occupying forces. Confronted with German demands that the French hand over their investments in Romanian oil production, Boissieu wondered if they shouldn't take the risk of inviting the German authorities to consider CFP's Iraqi interests as well. By being so forthcoming the DGTO might extract a German promise to respect CFP's 23.75% share in IPC and only seize the other Groups' shares. The potential contribution of CFP's oil towards the "relèvement économique du Pays tout entier" had to be balanced against the risk of Britain finding out about any such demarche and stripping CFP of its IPC shareholding entirely.[14] In August 1941 an agreement was indeed reached whereby CFP was allowed to retain its 23.75% of IPC, while the German authorities proposed to seize the shares owned by Royal Dutch-Shell and Anglo-Iranian, which would have given them 47.5% of IPC (the American Group's shares would not have been touched).[15] The failure of the Nazi-supported Rashid Ali coup in Iraq, which was successfully put down by British forces in May 1941, scotched any hopes of implementing this arrangement, however.

16 A corporatist who had founded a short-lived ginger-group of technocrats and businessmen, the Redressement Français, back in 1925, Mercier's guiding philosophy, described by Léon Blum as "a kind of industrial Bonapartism" was at home in Vichy France. Pétain's chief advisor, Lucien Romier, had been Redressement spokesman, and Pétain considered calling his "Révolution nationale" the "Redressement Français." Along with Mercier leading CFP managers Jules Mény and Robert Cayrol also elected to remain inside Vichy France, with Cayrol leading the Comité d'organisation for liquid fuels.[16] Although some information is available, a number of tantalizing questions remain which we are simply not in a position to answer with the archives currently available, including whether the Nazi authorities were correct to accuse the Vichy authorities of plotting to have CFP sell its IPC shares to an American company.[17]

13 See "Pourparlers avec les gouvernements étrangers : Collaboration franco-britannique, 1938-39" among ONCL archives. Archives Nationales, Pierrefitte [hereafter AN] F12 9927.

14 Mercier to Charles-Albert de Boissieu, 21 Sept. 1940. Total, SC89/4, "Documents anciens CFP".

15 Nouschi, *La France et le pétrole*, 112 (cf. note 8).

16 Cited in Kuisel, Mercier, 79 (quote), 145-7 (cf. note 7).

17 See Michel (Deutschen Devisenkommisar in Frankreich) to ministère des Finances and De Wailly to Michel, 23 Apr. and 28 May 1942. These letters appear among unrelated papers in Centre des archives économiques et financières, Savigny-le-Temple [hereafter CAEF], B0032311. For German oil policy in this period see Anand Toprani, "Germany's Answer to Standard Oil: the Continental Oil Company and Nazi Grand Strategy, 1940-1942" *Journal of Strategic Studies*, vol. 37, 2014.

17 IPC had sought legal advice on the status of the 1928 Red Line Agreement in September 1940. Although this advice indicated that under English law the Agreement had been "frustrated" when two of the partners became "enemies," the three other IPC Groups and Gulbenkian decided to continue as if the Agreement was still in force. After Italy's entry into the war it was no longer possible to transport IPC's crude out of the Mediterranean. But there was a small refinery at Haifa that allowed the other IPC Groups to refine and sell their own IPC liftings to the Allies. This refinery was enlarged during the war, and these Groups took advantage of the opportunity to exceed their quotas. From de Montaigu and even Leslie Burgin's perspective, therefore, it could sometimes appear as if peacetime oil politics was being practised under the cover of temporary wartime measures.[18]

18 These and other, state initiatives suggested that the British and American governments and the British and American oil majors were collaborating to lay the foundation of a post-war world in which Middle East oil production would be controlled exclusively by them. The US/UK Petroleum Agreement signed by Lord Beaverbook and Edward Stettinius in August 1944 confirmed the worst fears of one leading French official, Pierre Mendès-France, Commissaire aux Finances: "Il semble, qu'une fois encore, les Britanniques et les Américains, ont réalisé, sur une question qui nous intéresse directement, une entente bilatérale qu'ils essayeront par la suite de nous faire entériner." Mendès-France urged the Ministry of Foreign Affairs to make representations to the British and Americans, asking that France be represented in such talks, even as he admitted that France held few cards. "Nous sommes demandeurs à peu près à tous les points de vue." Hope was not entirely lost, however. "Toutefois, nos droits dans l'IPC nous donnent dans une certaine mesure une possibilité de nous défendre qu'il me paraît indispensable d'exploiter."[19]

19 This French tendency to lump the British and Americans together as *les anglo-saxons* made it difficult for Mendès-France and others to realize the very real tensions between the two powers over oil policy: the so-called "oil war," which had been running since 1918.[20] This was itself founded on American suspicions that Britain was using wartime special measures (in 1914-18 as well as 1939-45) to strengthen the position of Anglo-Iranian in the Middle East, and in particular using funds borrowed from the United States to purchase the friendship of the King of Saudi Arabia and other potentates. Much was made of His Majesty's Government's 50% stake in Anglo-Iranian (acquired in 1914), which was incorrectly assumed to make Anglo-Iranian a puppet of the British state.

20 Not only were *les anglo-saxons* far from a united front, United States oil policy was itself contested. A draft "Foreign Petroleum Policy of the United States" drawn up in February 1944 had been approved by the State Department, and contained commitments to "the principle of equal opportunity in exploration and development," "the assurance of economic benefits to the foreign areas in which petroleum is located" as well as the "safeguarding" of existing concessions held by American interests, with a view to conserving reserves in the western hemisphere while pursuing "substantial and orderly expansion of Middle East production."

21 But in May 1947 this policy document was still classified "Secret."[21] Unlike in Britain and France the American oil industry was split between small domestic independent producers and the majors. The former were quite prepared to use their congressional representatives to hound their larger international rivals on grounds of anti-competitive behaviour, and to resist any

18 Leslie Burgin to Hugh Dalton, 24 Nov. 1944; Burgin to R. W. Sellars, 2 Dec. 1944. Total, 81.1/75 (81ZX916-75), "Correspondance avec le Dr. Burgin".

19 Pierre Mendès-France to MAE, 10 Aug. 1944. CAEF, "Affaires Interalliées, Pétroles, 1944-9", red folder. B0033849.

20 See Fiona Venn, "The wartime 'special relationship'? From Oil War to Anglo-American Oil Agreement, 1939-45," *Journal of Transatlantic Studies*, vol. 10/2, 2012; Simon Davies, "'Keeping the Americans in Line': Britain, the United States and Saudi Arabia, 1939-45: inter-allied rivalry in the Middle East revisited", *Diplomacy & Statecraft*, vol.8/1, 1997.

21 "Wartime Evolution of Postwar Foreign Oil Policy", 29 May 1947, 4-5. NARA, RG59 811.6363/5-2947.

suggestion of capping their domestic oil production in the name of "conservation". Despite growing American investment in the Middle East the State Department was slow to create new diplomatic posts necessary to make its voice heard in the region.[22]

22 Though its Department of Near East Affairs accused the British of living in a nineteenth-century imperial dreamworld, in fact the British had recognized their reduced circumstances and were ready to see the United States share the self-imposed burden of policing "Arab Street" - something unlikely to occur without American investment in the region's oil. In the cases of Bahrain (1927), Kuwait (1932) and Saudi Arabia (1933) the Foreign Office faced down the unwillingness of other branches of the British and Indian governments to admit American oil companies to what some of them still saw as a British "sphere of influence."[23] In 1939 the Foreign Office vetoed attempts by the British Admiralty and Air Ministry to secure Saudi oil; far from defending British claims under the Red Line Agreement, it urged Saudi King Ibn Saud to enlarge the American concession, for fear the Americans might otherwise leave. Ironically enough, as late as 1941 British diplomats were trying unsuccessfully to persuade President Roosevelt of the strategic importance of Saudi Arabia.[24] When Socal urged Roosevelt to help it take on the burden of subsidizing Ibn Saud it was told that Saudi Arabia was "a little far afield" for the United States to take an interest.[25]

23 In February 1943 Roosevelt changed his mind, and declared that the defence of Saudi Arabia was a vital US interest. The United States now paid Ibn Saud his subsidies, and in 1946 added a $10m soft loan from the Export-Import Bank and a $4m airbase at Dhahran: the foundation of a relationship which still shapes the region today. Like the August 1944 Petroleum Agreement itself, this shift in foreign policy was the brainchild of Harold Ickes, head of the United States' Petroleum Administration for War. Persuaded that domestic oil reserves were dwindling, Ickes shared the State Department's "almost hysterical" view of British machinations.[26] He differed markedly in his proposed response, however, advocating direct state intervention rather than arm's length diplomatic support of private enterprise.

24 Appropriating a scheme first floated by Navy Petroleum Board planners, Ickes made a Gulf-to-Mediterranean pipeline through Saudi Arabia part of his scheme for a state-administered Petroleum Reserves Corporation (est. July 1943), "an American holding company created for the purpose of acquiring sizeable governmental oil reserves in the large producing areas of the world."[27] The Trans-Arabian Pipeline (Tapline) was designed to serve the massive Dammam field held by Aramco under the original 1933 concession to Socal.[28] Although Socal built an ocean terminal on the Gulf at Ras Tanura, Tapline offered the potential to bypass the Gulf, Aden and Suez (three points of strong British presence) entirely. Ickes saw Tapline as a lever with which to persuade the British to sign up to what became the 1944 Anglo-American Oil Agreement, which sought to lay the foundation for an inter-governmental petroleum body that would enshrine the aforementioned principles

22 A consulate was established at Aden in 1918, but there was no representative in the Kingdom of the Hedjaz/Saudi Arabia until May 1942, and even then he was a lowly chargé d'affaires, without ambassadorial rank. There was not even a consulate in Kuwait until 1951. See John A. de Novo, *American Interests and Policies in the Middle East 1900-39* (Minneapolis: University of Minnesota Press, 1963), 361-65, 393.

23 See Fiona Venn, "A Struggle for Supremacy? Great Britain, the United States and Kuwaiti Oil in the 1930s", *University of Essex Department of History Working Papers*, vol. 2, 2000.

24 Davies, "Inter-allied rivalry", 102-3 (cf. note 20).

25 Quoted in Irvine H. Anderson, *Aramco, the United States and Saudi Arabia* (Princeton: Princeton University Press, 1981), 32.

26 Aaron Miller quoted in Davies, "Inter-allied rivalry", 98 (cf. note 20).

27 "Wartime Evolution of Postwar Foreign Oil Policy," 29 May 1947. NARA, RG59 811.6363/5-2947.

28 In 1936 Socal agreed to collaborate with the Texas Company. Socal's Delaware-registered Saudi subsidiary California Arabian Standard Oil Company (Casoc) became Caltex, which in turn became Aramco in 1943. Dammam produced 3.9m barrels in 1939 and 5.1m in 1940.

of orderly development, equal opportunity and economic advancement of producing countries.

25 While Ickes viewed the US/UK Petroleum Agreement as a means to stymie the British and Mendès-France saw it as an *anglosaxon* stitch-up, the State Department saw the Agreement's potential to act as international regulator. The Agreement was drafted such that it could be expanded to include other producing nations, almost as a kind of proto-OPEC. It remained to be seen, however, if Senate would ratify the Agreement. Doubts on this score may have lessened any resentment British negotiators may have felt at being bounced into the agreement. For their part the British Chiefs of Staff welcomed Tapline as a $200m line in the sand, a line the United States could presumably be counted on to defend against a Russian invasion.[29]

"UNE SITUATION DEPASSÉE": THE END OF THE RED LINE 1944-46

26 Like CFP, Gulbenkian's residence in Vichy France from 1940 until his move to Lisbon in March 1942 had led to his IPC shares (the famous 5% of "Mr Five Percent") being sequestered. Like CFP, he wanted to be compensated for lost revenue in this period. René de Montaigu and Gulbenkian had got to know each other well in their Lisbon exile, and in December 1944 Gulbenkian invited Montaigu to discuss how CFP and Pandi (Participation and Investments, the company through which Gulbenkian held his 5% share of IPC) might work together. By that point Gulbenkian had already resisted one attempt by the other IPC Groups to buy him off.[30] The assistant chief of the State Department Petroleum Division had implored Socony President Harold Sheets "as a genuine friend" to do his best to accommodate CFP and Pandi's demands "in a true spirit of partnership in IPC." Sheets feared that Gulbenkian and CFP might make their grievances public, which would in turn reveal the vast untaxed profits Socony and Jersey Standard had been taking from IPC (a British company) during the war. In particular the State Department feared the British parliament's hostile reaction to such a revelation.[31]

27 What was the point of CFP allying itself with Gulbenkian? Calouste Gulbenkian and his son Nubar had secured supplies of oil and soft loans for France from Royal Dutch-Shell during the First World War, and after 1918 Gulbenkian *père* had helped Henry Bérenger negotiate for the transfer of Deutsche Bank's quarter share in IPC to a notionally French company (of which Royal Dutch-Shell held 49%), the Société pour l'Exploitation des Pétroles (SEP). As it happened the shares were not given to this firm, but to a separate entity under Mercier, which became CFP. Gratitude and oil did not mix well together: the seventy five year-old Gulbenkian had to offer more to interest CFP.

28 One intriguing reason for an alliance with Gulbenkian lay in northern Iran, where Gulbenkian had been working off and on for a concession since at least 1919. Although Gulbenkian and Léon Wenger of the Franco-Belgian firm Pétrofina developed plans for an international syndicate in 1927, logistical challenges and the post-1929 slump led to them being shelved.[32] Any concession in north Iran would require Soviet participation, as the only outlet lay to the north, via the Caspian. Mercier had certainly supported closer Franco-Soviet relations. In the wake of the controversial Franco-Soviet Pact (1935) he had flown to Moscow to dine with Stalin. On his return

29 Anderson, *Aramco*, 84 (cf. note 25).

30 Calouste Gulbenkian to René de Montaigu, 4 Dec. 1944; Gulbenkian memo, 17 Dec. 1944; "Memorandum de Mr. G. resumant ses entretiens avec M. de Montaigu", 7 Jan. 1945. All filed in folder "Gulbenkian et TWED". Total, 81ZX916-75 (81.1/75).

31 James C. Sappington to Harold Sheets, 14 Nov. 1944. NARA, RG59 Office on Int. Trade Policy, Petroleum Div., 1943-49, Box 13, "France 1945".

32 These plans were involved working with a Russo-Iranian company, Kevir-Khurian, whose concession was listed in Russo-Iranian trade conventions of 1931 and 1935, but dropped from that of 1940, apparently allowing an American firm, Amiranian and a Dutch rival to slip into northern Persia, albeit without getting very far. For the state of play in 1944 see Office of Strategic Services, "Survey of Iranian Oil Concessions," 8 April 1944. NARA, RG59 Office on Int. Trade Policy, Petroleum Div., 1943-49, Box 5 "Iran Oil Concessions 1944-46"

Mercier claimed that Russia was becoming less communist, and should be viewed as a trusted partner for trade and security.[33] Unfortunately, this boosterish view of Stalin's Russia was not widely shared, and left the Iranians suspecting the French as too pro-Russian.[34]

29 The north Iranian concession is a saga with a convoluted history, which does not directly concern us here. As Montaigu himself noted, in 1944 "les affaires d'Iran [were] en suspens," and so there was no call for the services Gulbenkian was offering as ally. On meeting with IPC's managing director, John Skliros, a few days later in London, however, Montaigu had been struck to hear Skliros remark that of the IPC Groups only CFP seemed interested in pushing on with production. Without building new pipelines to supplement the two 16-inch lines (to Haifa and Tripoli) that had come onstream in 1935 this could not be done.

30 Skliros was right. Unlike CFP, Royal Dutch-Shell, Anglo-Iranian and the Americans had little incentive to push for an increase in IPC output. These Groups all had plentiful supplies elsewhere on the globe. While they were prepared to negotiate a new IPC Working Agreement, they were in no hurry to build new pipelines or increase production. They wanted to keep Iraq a swing producer. The Americans' lack of interest was linked to their desire to escape the Red Line's self-denying clause and accept Socal and Texaco's invitation to enter Aramco.[35] It was here that Gulbenkian's real value for CFP lay: he was in the same boat as them. As the founder of IPC who had played a key role in the development of Royal Dutch-Shell from its origins to 1925, Gulbenkian also knew the other IPC Groups in a way nobody else did. He also had access to documents dating back to the pre-1914 origins of IPC which CFP lacked, yet which would prove of great importance in supporting CFP in its legal and moral claims.[36]

31 In 1945 CFP's American partners in IPC, Jersey Standard and Socony were preoccupied with a special Senate committee that was busy investigating petroleum reserves, as well as with working out whether and how to accept Socal and Texaco's invitation to join them in Aramco and Tapline.[37] While it was clear that both needed vast amounts of capital, this did not mean that these companies were keen on Ickes' proposal that the US government buy them out or take a 50% or 33% share. A media campaign and lobbying had ensured that Senate tore the Anglo-American Petroleum agreement to pieces in November 1944. So far so good: the American majors had never liked the Agreement. But what if congress went on to investigate the American majors for non-competitive practices? The climate had changed since 1928, and Jersey Standard/Socony were not being entirely disingenuous when they expressed concern that the Department of Justice might prosecute them if they continued to honour the Red Line Agreement.[38]

32 For their part the Foreign Office recognized that it was better for Jersey Standard and Socony to enter Aramco than for the US government to do so. In May 1945 the Foreign Office recognized that the Red Line Agreement's self-denying clause represented an obstacle for this, but seemed happy enough for it to be ignored, and certainly was not going to join France in making trouble (as the State Department feared).[39] A few

33 Kuisel, Mercier, 127-9 (cf. note 7).

34 See the comments of the Second Secetary of the Iranian legation in London cited in Nubar Gulbenkian to Calouste Gulbenkian 22 Jan. 1945. Gulbenkian Foundation, London [hereafter FCG], PRS00669.

35 CFP to Calouste Gulbenkian, 25 Jan. 1945. Total, 81.1.75.

36 For an example see de Grouchy memo, 27 Nov. 1947. Total, 81.1.81.

37 Democratic Senator Francis T. Maloney of Connecticut launched the committee on 23 March 1944, and it reported on 31 January 1947, under the chairmanship of Senator Joseph O'Mahoney of Wyoming (Maloney having died).

38 That said, State Department officials were well aware that such fears could be wielded as excuses for abandoning the Red Line Agreement. See the comments of Loftus and others cited in Theodore A. *Xanthaky to Gulbenkian*, 9 Nov. 1946. FCG, Caixa CSG 14, File S-X (1946-55).

39 State Department had feared that the British government might support France "for political reasons, and in order to obtain credit for doing something for France." Memcon, 22 March 1945. NARA, RG59 Office on Int. Trade

months later Emanuel Shinwell signed a new, watered-down version of the Anglo-American agreement on behalf of the new British administration. Though Clement Atlee's Labour government was presumably more open to state intervention in the oil industry (it nationalized the coal industry), otherwise Ickes' agenda had been losing momentum ever since Roosevelt's death in April.[40] After Ickes' retirement in February 1946 the agreement went into limbo. That July Jersey Standard and Socony began negotiating to enter Aramco in earnest. They informed the other IPC Groups in September that they considered the Red Line voided by something called "supravening illegality," and again referred to the risk they faced of prosecution under the Sherman Act (i.e. for non-competitive practices). But that did not mean they were not ready to draft a new Working Agreement for IPC and build a new 24-inch IPC pipeline.[41]

33 CFP and Gulbenkian were both nervous of tinkering with the 1928 Red Line Agreement. Quite apart from the question of whether the American Group would allow them to participate in Aramco there were many other sleeping dogs which might start barking, asking for other aspects of IPC to be "updated" to reflect a changed world. Venezuela's astonishing coup in placing its relations with foreign oil producers on a "50:50" basis in 1943 had got the attention of all Middle Eastern governments. Iraqi Minister of Economics Bab Ali began demanding that IPC become a public company, honouring old promises to allow a 10% Iraqi participation.[42] "The history of petrol concessions in Iraq reminds one of those films in which one sees how 'the white man' sallies forth into the remote corners of the world," wrote Mohammad Al Hadid in one Baghdad newspaper, "and trades toys with ignorant tribes for considerable resources."[43]

34 Although the sentiment was far from new, the speaker was hardly an unsophisticated nationalist. Born in Mosul, educated at LSE and an admirer of the British Labour Party, Hadid was Vice President of the social democratic National Democratic Party. The Gulbenkians recognized that it was high time to recognize views like Hadid's and consider creating a fifth group within IPC, before tempers frayed and IPC found itself facing nationalization. 10% of IPC's shares could be transferred to an Iraqi holding company, who could then offer them to the Iraqi public, helping to assuage as well as inform Iraqis. In keeping with France's orientalist views of Arab leaders as a bunch of "aveugles, borgnes et paralytiques" CFP refused to consider it.[44] Iraq was, admittedly, given the right to nominate a director to the board of an IPC subsidiary, Basrah Petroleum.[45]

35 Meanwhile CFP's Victor de Metz challenged Harold Sheets, President of Socony, as well as John Loftus of the State Department's Petroleum Division (then in Paris) to justify the Americans' actions in throwing over the 1928 Red Line Agreement, which had taken four years to negotiate, in order to cheat the IPC Groups out of their rightful share of red line oil in Saudi Arabia. He found them singing off the same hymn sheet. CFP were nonetheless wrong to see their

Policy, Petroleum Division, 1943-49, Subject Files, Box 13, "France (Importations of Iraq Crude) 1945." [Stack location: 250/46/9/5] See also National Archives, Kew [hereafter TNA]. TNA, FO 371/50385/10686/12/76.

40 Sounded out about the new Labour government's intentions, Minister of Fuel and Power Shinwell told the Americans he had no "immediate" plans to nationalize the UK oil industry. James C. Sappington to State, 31 Aug. 1945. NARA, RG59 841.6363/5955/8-3145.

41 Note of meeting, 16 Sept. 1946. BP Archive, University of Warwick Modern Records Centre, Coventry [hereafter BP], 126859. Near East Development to CFP, 3 Oct. 1946. Total, 04AH026-9. Gemignani-Saxtad, "La France, le pétrole", 512 (cf. note 10).

42 To be precise, these demands were addressed at IPC as well as Basrah Petroleum Company and Mosul Petroleum Companies, through which the same IPC partners controlled concessions covering the whole of Iraq. Bab Ali to IPC, 19 Aug. 1946. Total, 04AH026-89 (92.36/89)

43 Transcript (in French translation) of article in unidentified newspaper, 27 Aug. 1946. Total, 04AH026-89 (92.36/89)

44 Nubar Gulbenkian presented his father's proposals at an IPC meeting on 8 Oct. 1946. BP, 126859. While John Skliros agreed with such proposals, otherwise it must be admitted that nobody else did. Skliros to Armand de Grouchy, 4 Sept. 1946; de Grouchy to de Montaigu, 5 Sept. 1946; notes of group meetings, 9 Oct. 1946 and 16 Oct. 1947. Total, 04AH026-89 (92.36/89).

45 A decision reached at an Extraordinary General Meeting of IPC held on 29 July 1943. For minutes and related correspondence with Iraqi ministers see Total, 04AH026-89.

American partners as thinking in purely tactical terms, as de Metz was underestimating the risk posed to them by the Sherman Act. Thanks to this 1890 Act against uncompetitive business practices the American majors lived with the fear that exposure of their collusive activities would result in prosecution, of the kind which had led to the forced breakup of Standard Oil in 1911.

36 As for Saudi Arabia, the same concern for the "open door" which had led the State Department to look askance at the 1928 Red Line Agreement would also ensure that it made Caltex (the original concessionaire, a joint-venture of Socal and Texaco) admit other firms, lest it appear too much like a duopoly in Saudi Arabia. "La découverte que le Group Agreement était mort joint aux effets du Sherman Act et la politique générale du State Department permet aujourd'hui de résoudre le problème en signant un nouveau Group Agreement sans les clauses restrictives" paraphrased De Metz in his report. A handwritten marginalia makes CFP's view of these fine words clear: "prétextes!"[46] Loftus was strictly speaking correct: although the initiative came from Jersey Standard/Socony rather than being imposed on them by State, Caltex had indeed admitted new companies. Loftus had never promised they would be French ones.

37 Up until this point Anglo-Iranian had seemed somewhat embarrassed by the whole situation. In September 1946 they stated that they did not consider the Red Line Agreement abrogated. After taking legal advice in November, however, they stated that they did. On 20 December they signed a massive 20 year contract under which Anglo-Iranian agreed to sell a total of 133m tons of its Iranian and/or Kuwaiti crude to Jersey Standard and Socony, to be delivered via a new Anglo-Iranian pipeline from the Gulf to the Mediterranean, to be completed in 1951. The amounts involved represented more than 25% of Anglo-Iranian's total production.[47] Having bought Anglo-Iranian off with this massive deal, six days later Jersey Standard felt itself free to announce what everyone had surmised for months: that it had arranged to take a 30% share in Aramco, with Socony taking 10%. IPC's pipeline was now to be squeezed between two game-changing Gulf-to-Mediterranean pipelines (Tapline and Anglo-Iranian's), or, more likely, simply allowed to stagnate. While Gulbenkian had his own ways of getting even, for CFP and France things just kept getting worse. Two days later Henri Bonnet paid a visit on the State Department to discuss it all with Loftus.

38 Bonnet subsequently cabled his report to Paris. The Quai d'Orsay should spare no efforts "pour démontrer l'inconvenance du point de vue moral et du point de vue juridique, de la position prise [illegible] la circonstance par les C[ompagn]ies americaines en regard des engagements qu'elles avaient contracted [sic] en 1928." Paris did so, instructing its ambassadors in Washington and London to point out that the 1928 Agreement was no obstacle to full development of Middle East oil. They were also to note that the aforementioned sale-and-pipeline contract between Anglo-Iranian and Jersey Standard/Socony was "une contrepartie substantielle accordée à la Grande-Bretagne, en vue d'obtenir son acceptation de l'abandon des arrangements de 1928."[48] The British had been suborned, in other words. In Washington Bonnet made further protests to Undersecretaries of State Dean Acheson and Undersecretary of State for Economic Affairs William L. Clayton, culminating in a diplomatic note of 13 January 1947 which rehearsed all the arguments noted above. Reporting on a similar protest made to him in Paris, US Ambassador to France Jefferson Caffery noted that CFP was lining up to join Gulbenkian in hitting IPC and its IPC partners with writs in London's Court of Chancery.[49]

46 Memcon Sheets/de Metz, 7 Oct. 1946; Memcon Loftus/de Metz, 13 Oct. 1946. Total, 04AH026-8 (92.36/8).

47 James Bamberg, *The History of the British Petroleum Company, vol. 2 The Anglo-Iranian Years, 1928-1954* (Cambridge: Cambridge University Press, 1994), 301-7.

48 MAE to Washington and London, 2 Jan. 19[47]. CAEF, B0033849, "CFP: Négociations avec l'IPC pour le rétablissement de ses droits, 1944-9".

49 Jefferson Caffery to State Department, 13 Dec. 1946 and 4 Jan. 1947; Dean Acheson to Caffery, 11 Jan. 1947. NARA, RG59, 800.6363/12-1346 and /1-447.

39 The State Department's 41-page "Critical Evaluation" indicates that Bonnet's note was taken seriously enough for officials to investigate France's position within IPC and associated agreements carefully. This memo concluded that, while the US government had facilitated negotiations towards the 1928 Red Line Agreement, it had not given "explicit approval" to the final agreement, stating "only that it saw no objections...from a policy point of view." "The Self Denial or Red Line Clause were [sic] always considered by the Department to be private business arrangements."[50] While the French insisted that the Red Line Agreement had been an inter-governmental agreement the "Critical Evaluation" and Secretary Clayton denied that the United States government had any obligation to ensure compliance with the Agreement, and Clayton pointed out that the Anglo-Iranian/Jersey Standard deal fell outside the red line area.

40 Just because the United States denied that IPC arrangements had been an inter-governmental matter back in 1928 did not, however, mean that they took the same view now. Though it had not been spelled out in the Agreement, the 1944 US/UK petroleum talks had (according to Loftus) agreed that "the broad policies of the IPC should be subject to international control at the government level."[51] Loftus also recognized a need to honour principles recently discussed at the inaugural London conference of the International Trade Organisation. Unfortunately the State Department's appetite for inter-governmental supervision of Iraqi oil production and the world petroleum industry generally could not be openly avowed "without provoking acute internal political controversy."[52] Finalized in 1948, the ITO charter ended up, like the Anglo-American Petroleum Agreement, a casualty of Congress.

41 In his original December cable Bonnet conceded that these diplomatic representations were unlikely to bear fruit. Although the State Department had kept abreast of the four-year negotiations which culminated in the 1928 Agreement, it now refused to accept Bonnet's argument that an infringement of it represented a matter for inter-governmental discussion:

> Mais il paraît malheureusement douteux que nous puissions obtenir sur le plan du [missing word] un redres[s]ement pratiquement satisfaisant pour nous de la situation cr[éé]e ([à] la suite) [de la] dénonciation des accords. Il semble qu['']en revanche tout en nous montrant intransigeants sur la question de droit ce soit dans le sens d'un arrangement de fait sous forme d'une participation concrète aux avantages que les compagnies americaines sont en train (de s') assurer en Arabie Seoudite, que la Compagnie Fran[ç]aise des Pétroles ait (interêt) à (chercher) la solution du problème d'importance nationale que le retrait de la Standard Oil de [New Jersey] et de la Socony vient de poser pour nous. D'après ce que M. Loftus a dit [à] M. [missing word] c'est dans cette direction que M. Demetz lui aurait marqué il y a quelques jours l'intention de s'orienter.[53]

42 While the Quai d'Orsay could continue pushing Washington on CFP's behalf, in insisting on moral arguments and legal rights, it should not be overly legalistic, "en cherchant toutefois l'application pratique [à] l'avenir plutôt que dans une tentative pour revenir [à] une situation que en fait paraît désormais dépass[é]e."[54]

50 Walter J. Levy to Charles B. Rayner, John A. Loftus and David A. Robertson, "Critical Evaluation of the French Note of 13 January 1947 on the Iraq Petroleum Company Group Agreement," 6 Mar. 1947, 3-4. NARA, RG59 Office of Int. Trade Policy, Petroleum Div., Subject Files, 1943-49, box 6.

51 Loftus, memcon Loftus/Linebaugh, 31 May 1945. NARA, RG59 841.6363/5955/5-3145. This did not, however, mean that the State Department supported the Red Line Agreement. It informed the British at the informal November 1946 oil talks that it "appeared to be incompatible with the preservation of competition in the international oil trade, in view of the increasing importance of Middle East supplies." See NARA, RG59 841.6363/5955/12-646.

52 Loftus to Raymond Vernon, 23 Dec. 1946. NARA, RG59 Bureau of Econ. Affairs, Office of Econ. Defence and Trade Policy, Business Practices and Tech. Staff, Subject Files 1944-52, A1 1494D, box 32, "Petroleum - Middle East."

53 Bonnet to MAE, 28 Dec. 1946. AMAE, 91QO228, f. 29.

54 While the words in square brackets are my own, those in parentheses were inserted after his telegram arrived in Paris.

"SOME KIND OF PAY-OFF": A NEW WORKING AGREEMENT, 1947-48

43 Among the painful realities facing CFP in early 1947 was the recognition that, with France effectively bankrupt, facing severe coal and food shortages, inflation and dependent on American aid, it was ludicrous to imagine that she would be able to stump up her share of developing Aramco's concession. In the June quarter of 1947 51% of France's crude oil imports were paid for using US Interim Aid and European Cooperation Administration (i.e. Marshall Aid) dollars.[55] Had Socal and Jersey Standard honoured the self-denying clause their combined 40% share of Aramco would have had to be split five ways among the IPC Groups: 23.75% apiece to CFP, Royal Dutch-Shell, Anglo-Iranian and Near East Development (the Socal/Jersey Standard consortium), and 5% to Gulbenkian's Pandi. Near East would have been left with just under 9% of Aramco, to be shared between Socal and Jersey Standard.[56] France would have had to provide 9% of Aramco's capital, as well as an equivalent share of the cost of Tapline and the associated dead-rents and subsidies (payable in gold) to Ibn Saud.

44 How much of a commitment would this have been? Between 1946-50 Socony and Jersey Standard's calls on their combined 40% stake in Aramco totalled more than $102m dollars; its 40% share of Tapline (constructed 1947-50) brought the cost to $450m.[57] Leaving the subsidies and soft-loans to one side, CFP would have had to invest at very least $107m, without seeing a drop of oil, and with the risk that Arab reaction to US support of the new state of Israel in May 1948 would either deny Tapline a Mediterranean terminus or, even worse, lead Ibn Saud to cancel Aramco's concession and turn to the Russians.[58] Given France's treatment of the Syrians in 1945 and policy towards Israel, Ibn Saud's view of Aramco would not have softened as a result of French participation.[59]

45 Indeed Ibn Saud had supposedly attached a secret rider to the 1933 Saudi concession granted to Socal forbidding Socal from selling the concession on or giving participations in it to non-Americans. CFP only seems to have become aware of this in January 1947, when Gulbenkian informed them.[60] A few days later Ibn Saud informed Loy Henderson that he was "now much disturbed by the possibility that the Red Line Agreement may still be in force, or if not actually in force will still be honored in some way." As Henderson noted, "What he fears is that this will prove an 'open door' through which British, French, and the other oil interests can get a foothold in the development of Arabian oil."[61]Toprani rightly notes the lack of evidence for Ibn Saud's demand.[62] The closer one looks, the less firm this "condition" appears. Just a few days after the exchange quoted above, the Saudi Foreign Minister apparently told the US Ambassador to Portugal that the way the American companies had treated the French was "peu correcte."[63] Why would he have said this, if the Saudis had ruled out any French participation? Given Ibn Saud's record of playing the United States and United Kingdom off against each other, it seems unlikely that such a demand (even assuming it was made in 1933) was made in earnest – or that Socal would have felt itself constrained to honour it.

55 Olaf Sundt to State, 27 Sept. 1948. NARA, RG59 851.6363/6273/9-2748.
56 As the 40% was split 30/10 Jersey Standard/Socony this hypothetical 8.8% would have been divided to give 6.6% to Jersey Standard and 2.2% to Socony. Such calculations are moot, however, as Jersey Standard/Socony would never have been satisfied with such a small share of Aramco.
57 Toprani, "French Connection", 271 (cf. note 9).
58 Neuville to MAE, 9 May 1946. AMAE, 91QO228, f. 24.
59 For Ibn Saud's views of France in January 1947, see Toprani, "French Connection", 290 (cf. note 9).
60 Gulbenkian to CFP, 10 Jan. 1947. Cited in Gemignani-Saxtad, "La France, le pétrole", 519 (cf. note 10).
61 Loy Henderson to Dean Acheson, 16 Jan. 1947. NARA, RG59 890F.6363/1-1647.
62 Toprani, "French Connection", 287 (cf. note 9). For Ibn Saud's supposed Anglophobia see Edward Fitzgerald, "The Iraq Petroleum Company, Standard Oil of California and the Contest for Eastern Arabia, 1930-33," International History Review vol. 13/3, 1991, 461-3.
63 French Embassy Lisbon to MAE, 20 Jan. 1947. AMAE, 91QO228, f. 74.

46 In early 1947, therefore, all parties recognized privately that, even though CFP and French diplomats like Bonnet were insisting on the validity of the 1928 agreement – and had now launched legal proceedings in London against the other IPC Groups and against IPC itself – in fact they were angling for something else. To quote one official at the American embassy in London, their goals were "to receive more oil in order to fulfil their expected requirements under the Monnet plan; to ensure that the American participants in I.P.C., who now have alternative Middle East sources of supply, do not become reluctant to extend production further in Irak, and lastly, to make some provision for the receipt of oil from Arabia." Jersey Standard's London representative, David Shepard conceded to this official that Victor de Metz' position was "warranted, as Irak is the sole major source for French crude supplies." As far as he was aware France only wanted Saudi oil as "an alternative emergency supply." Indeed, Shepard claimed that CFP had not actually asked for a guaranteed supply of Arabian crude at a set price, "let alone pressed for what was originally, and apparently incorrectly, considered their major demand: actual participation as a shareholder in Aramco."[64] Shepard's boss, Orville Harden put it more bluntly: the French position was "essentially an effort to extort some kind of pay-off under threat of reprisals." He was ready to allow CFP a sales contract for Aramco's crude, without a direct participation.[65]

47 Compensatory crude had in fact been found further afield. At some point in 1945-6 Jersey Standard offered to make room for CFP in Venezuela, where it had a joint venture with William F. Buckley's Pantepec. Although all the other IPC Groups (even Gulbenkian) had been active in Venezuela in one way or another for decades, this was virgin territory for the French. The details of the arrangement as well as the timing are uncertain, but it seems that under its terms CFP took an operating share, putting up part of the drilling costs and receiving 1m tons from Pantepec's El Roble and Mulata fields in 1947, and another 1m tons in 1948. This oil was intended to help tide France over until IPC's new 30-inch pipeline was completed in 1952. France not having the funds itself, America supplied the investment on her behalf through the ECA.[66] Though a short-term scheme, it was nonetheless significant.

48 De Gaulle's choice as head of the Direction des Carburants (successor to the Office National des Combustibles Liquides), Pierre Guillaumat, nonetheless declared the following month (March 1947) that he would not be satisfied "until the American companies enabled CFP to compete with them for international markets and until the French controlled the source of all their requirements." He even threatened to punish Jersey Standard and Socony's French subsidiaries using the French state's extensive powers over the domestic market. CFP's Robert Cayrol was more circumspect. While he admitted that CFP was beginning to wonder if taking the Americans to court would bring much by way of a result, he hinted darkly about the possible effects on French public opinion were the case to reveal all that IPC and its partners had been doing to hide their profits. The French would be "very angry if they realized how American companies had broken their word, how French interests had been hurt, how France was considered an enemy."[67]

64 Donald B. Calder to State, 10 Feb. 1947. NARA, RG59 841.6363/5955/2-1047.

65 Memcon Loftus/Harden/Sheets, 9 Jan. 1947. NARA, RG59 Office on Int. Trade Policy, Petroleum Div., 1943-49, Box 3, "Red Line Agreement 1947."

66 See Richard Funkhouser, "Annual Petroleum Report for France 1946," 14 Feb. 1947 and Olaf Sundt to Robert Eakens, 23 July 1948. NARA, RG59 851.6363/6273/2-1447 and /7-2348. The efforts of a certain Chenault on the French Supply Council to acquire Venezuelan petroleum supplies through Pantepec is, however, noted in a State Department memo (cited below, note 67) of June 1945, and Toprani cites earlier Funkhouser reports of October 1946 reporting to the deal. This suggests that the idea had been around for some time. Toprani, "French Connection," 286 (note 58). See also Antoine Brandalac, "Le mythe revisité de l'Eldorado: aventures et mésaventures de la Compagnie Française des Pétroles au Venezuela de 1945 à 1957" (Master, Université de Paris IV- Sorbonne 2014).

67 Funkhouser, "Monthly petroleum report for France", 14 March 1947. NARA, RG59 800.6363/3-1447.

49 Not having any domestic public opinion to worry about, this apparently desperate strategy of *fiat justicia, ruat caelum* was one Gulbenkian was particularly fond of. Even if he and CFP lost their court battle, they could still win the war for public opinion. Though defeat would carry costs, the potential costs for the "winners" were potentially greater than those borne by the "losers". For Jersey Standard and Socony as well as the State Department the prospect of Gulbenkian haemorrhaging IPC secrets was particularly unwelcome, both in view of Senate's appetite for investigating the sector's massive profits and Middle East governments' agitation for Venezuelan-style 50:50 royalties. The Americans took at face value Gulbenkian's claims that Iranian protests over Anglo-Iranian's profits (which would culminate in Iran's 1951 nationalisation of Anglo-Iranian's fields and facilities, including the world's largest oil refinery at Abadan) had been provoked by Gulbenkian's providing the Iranians with evidence of Anglo-Iranian's manipulation of the figures upon which royalties were calculated.[68]

50 Thanks to various delays CFP and Gulbenkian were able to keep the threat of court hearings hanging over the heads of their IPC partners throughout the rest of 1947 and on, to November 1948. Publicity thus represented one card in CFP's hand, one which it played very well. It ensured that their IPC partners stayed the long and weary course of negotiating a replacement for the 1928 agreement, a set of agreements finally signed between 1:30 and 2:00am on Wednesday, 3 November 1948: eight hours before the latest delay negotiated with the London judge expired.

51 Having secured extra supply for two years from Pantepec, CFP still needed IPC's new pipeline to go ahead. In January 1947 it demanded a double 16-inch and a 24-inch line, rejecting a counter-offer of the 24-inch line alone.[69] Here again it was in a weak position: the only country able to provide steel pipe in the quantities needed was the United States, and given the many demands on American steel its export was subject to tight control by the United States government.[70] As Ickes' adviser Max Thornburg noted, this gave them the power "to paralyze oil developments in all countries which look to us for such supplies, or to force modification or cancellation of concessions by reason of non-performance resulting from material shortage."[71] Here again Senate could interfere, for example when Senator Kenneth S. Wherry of Nebraska objected to the export of pipe to Iraq in October 1947.[72] Thanks to Anglo-Iranian's deal with Jersey Standard/Socony there were now three major pipeline projects in the Middle East. Though IPC's was the shortest, politically and diplomatically it was at the back of the line.[73] Ironically enough, strike action and associated political unrest within Iraq caused by frustration at the slow development of that nation's oil reserves could itself serve to provide Socony with grounds for yet more delays.[74]

52 In 1947 IPC was also seeking to fill in the gaps in the Red Line Map, that is, to set up subsidiaries and secure concessions in Transjordan, the Saudi-Kuwaiti Neutral Zone and other areas that had yet to be exploited, as it had done so already in Oman, Syria, Bahrain and Cyprus. A concession for Transjordan was secured in May, and negotiations were begun with the Sheikh of Kuwait. Gulbenkian saw discussion over these areas and over the terms under which any oil reserves they contained would be exploited by the IPC Groups as an attempt by the latter to distract attention from the more important matter of Saudi Arabia. CFP agreed to follow his

68 Mattison to Funkhouser, "Oil Topics for Chiefs of Mission Discussions," 8 Nov. 1949. NARA, RG59 Bureau of Near Eastern Affairs, Subject Files, 1941-54, Lot File 57D298 [Stack location: 250/63/7/7] Box 1, "AIOC 1949."

69 For a detailed account of the negotiations see "Group Agreement Negotiations", 12 Aug. 1947. BP, "Group Agreement 1928, Pt 4", green file, 126859.

70 Skliros cited in de Grouchy to de Montaigu, 28 Feb. 1947. Total, 04AH026-9.

71 Cited in Venn, "Oil War", 122 (cf. note 20).

72 Bonnet to Georges Bidault, 6 Oct. 1947. AMAE, 91QO228, f. 108. Wherry later served as Senate Minority Leader.

73 MAE to Bonnet, 9 May 1947. AMAE, 91QO228, f. 94.

74 See the comments of Socony's Harding in Mattison to Funkhouser, "Oil Topics for Chiefs of Mission Discussion," 8 Nov. 1949. NARA, RG59 Bureau of Near Eastern Affairs, Subject Files, 1941-54, Lot File 57D298 [Stack location: 250/63/7/7] Box 1, "AIOC 1949."

lead. As it happens Jordan contained no worthwhile deposits (nor have any been discovered since). The Neutral Zone did, but Gulbenkian's stance meant that Pandi and CFP missed the Kuwaiti Sheikh's May deadline for bids.[75]

53 CFP remained focussed on Iraq, and in April 1947 began negotiating a set of flexibility clauses to be incorporated in the new Working Agreement. These would allow those who, like CFP, desired to "lift" more than their alloted share of IPC production to do so on payment of compensation to other partners for the resulting reduction in the size of the accessible reserves. This is not the place to go into the alternative models (of different levels of "stiffness") proposed and debated, nor the discussions over programming: that is, the arrangements under which IPC partners would indicate several years in advance the desired amount they wished to "lift."[76]

54 By July 1947 CFP had drafted a satisfactory set of flexibility clauses and secured a compromise on the pipeline: instead of two 16-inch and one 24-inch line a single 30-inch line was to be constructed by 1952. CFP was now willing to draft the new Working Agreement. Unfortunately Gulbenkian was still determined to get a share of Saudi oil, or at least to hold out for more Iraqi oil in the form of free crude over and above his 5%. Whether by accident or design, Gulbenkian's partners had repeated their mistake of 1924-8 (the negotiations of the original 1928 agreement) in assuming that discussion with him regarding his 5% rights could be left until all other matters had been settled. Gulbenkian now seemed to be holding up the entire show: a tiny dog in the oily manger.

55 Given their historic links the Americans, Anglo-Iranian and Royal Dutch-Shell were prone to see Gulbenkian alternately as the CFP's Svengali or as its puppet. Internal CFP records suggest that, while they acknowledged a certain loyalty to Gulbenkian for past services, they were serious about issuing him with an ultimatum in September 1947, according to which he either had to sign the Working Agreement or see his partners proceed without him. As a minority shareholder, however, Gulbenkian's rights under English law were clear. The story of the final push to a settlement does not concern us here, but eventually saw Gulbenkian secure an extra 250,000 tons of crude per year, among various other guarantees.

56 When one considers the state of play in 1944, the 1948 Working Agreement seems a good outcome for CFP and for France. It could have been a lot worse. Seeing as the capital, materiel and know-how necessary to build the new IPC line were all borrowed or donated from the United States, the 1948 settlement is above all a reflection of that country's commitment to rebuilding the French economy and fostering a prosperity that would, the Americans hoped, stymie Communist agitators. Despite the French habit of playing on their exaggerated fears in this regard, there were limits to American largesse, however.[77] Regardless of what Ibn Saud might have thought about French participation, it was unrealistic for CFP to expect to be helped into Aramco. Behind their public insistence on CFP's rights and on the status of the 1928 Red Line as an inter-governmental, rather than merely commercial agreement French diplomats recognized this.

57 Given the French Foreign Ministry's long interest in inter-governmental economic coordination (dating back to the Wheat Executive, Etienne Clémentel and Louis Loucheur in 1916-9) and its subsequent role in establishing the European Coal and Steel Community in 1951 it is striking that this administration did not take more action to develop the 1944 US/UK Petroleum Agreement into an international body for the coordination of world oil supplies. That Agreement fell, a casualty of British skepticism and the conflict between

75 Gemignani-Saxtad, "La France, le pétrole", 512 (cf. note 10).
76 *Ibid.*, 529-30.

77 Toprani notes State Department fears in early 1947 that France might turn to Russia for oil supplies if she felt herself snubbed by her IPC partners. There is no evidence on the French side, however, that this was considered, even as a canard with which to intimidate the Americans. Toprani, "French Connection", 285 (cf. note 9).

American domestic and foreign oil production. Although Gulbenkian had designed IPC in a spirit of international collaboration, he saw the 1944 agreement as "a grandiose scheme to serve as a sounding board for internationally ambitious men," lacking the "teeth" necessary to ensure the super majors complied with its "idealistic views of cooperation."[78]

58 There are shreds of evidence that Jean Monnet's French Supply Council was internally divided over whether post-war France should adopt a *dirigiste* or *laissez-faire* approach to the petroleum industry – and that American officials like Clayton, rather than seeking to direct them one way or the other, simply wanted them to pick one approach and follow it consistently.[79] Jean-Pierre Rioux has noted how little thought was given at this time to "the strategic question of the public sector's future role."[80] What passed for policy in this first phase of French post-war planning was, he contends, little more than a series of reactions to events. France's gas and electricity sectors were nationalized by the Minister of Industrial Production, the Communist Marcel Paul, in April 1946. But CFP was left untouched, as a public company in which the state held a large stake. Alongside French indecision, therefore, another reason for missing this opportunity may simply lie in the French tendency to put coal and the Ruhr before oil and the Middle East. Though oil's share of France's energy mix had risen almost ten percent since 1944, it was still only 25% in 1958.[81]

59 This hypothetical aside, however, the events of 1940-48 remain a remarkable tale of survival. In the short term France and CFP secured a new source of oil in Venezuela. Though the Pantepec adventure proved something of a disappointment, it gave CFP a foothold in South America. In the medium-term CFP secured the right to "overlift" Iraqi crude. In the long term they secured a commitment under which IPC would build a new pipeline. Without the pressure exerted by the French Foreign Ministry and the counsel provided by Gulbenkian the other IPC Groups could well have left Iraqi production to stagnate, with all that meant in terms of worsening political climate within that troubled country. For France, therefore, the story told here is one of survival against the odds. A weakened CFP that could so easily have been snuffed out not only lived to fight another day, but secured increased production and revenue. These in turn formed the foundation of CFP's post-war growth into the supermajor we know as Total.

60 In 1948 the Working Agreement was hailed by CFP's own staff as a victory, as the "début de la fortune de la CFP" in René de Montaigu's words.[82] French historians' insistence on interpreting it as a defeat remains something of a mystery, therefore. In his survey of French oil history *La France et le pétrole* (2001), Nouschi writes of how "malgré l'action menée à la fois par la CFP et le gouvernement français, les Americains triomphent…La loi du plus fort était la meilleure."[83] Tristani agrees.[84] The exclusion of CFP from Saudi Arabia forms their main argument for perceiving this episode as a defeat. Yet neither pause to consider whether it was even possible for CFP to participate, and in particular to raise the vast sums Aramco's shareholders had to supply to build Tapline and other infrastructure necessary to bring the Saudi reserves on stream. Guillaumat of the Direction des Carburants was

78 To quote the "gist" of his comments, relayed in Franz von Schilling Jr. to Charles F. Darlington, 28 Feb. 1945. NARA, RG59 883.6363/2-2845.

79 For a flavour of this dissension, involving a certain Beranger and Chenault, see Memcon, 15 June 1945. NARA, RG59 Office on International Trade Policy, Petroleum Division, 1943-49, Box 13, "France 1947." For American frustration see Richard F. Kuisel, Capitalism and the State in Modern France: Renovation and Economic Management in the Twentieth Century (Cambridge: Cambridge University Press, 1983), 222.

80 Jean-Pierre Rioux, *The Fourth Republic, 1944-58, trans. Godfrey Rogers* (Cambridge: Cambridge University Press, 1987), 69.

81 *Ibid*., 323.

82 Cited in Tristani, "L'Iraq Petroleum Company", 9 (cf. note 23). See also Rondot, *La Compagnie Française des Pétroles*, 100 (cf. note 8).

83 Nouschi, *La France et le pétrole*, 201-202 (cf. note 8).

84 Tristani, "L'Iraq Petroleum Company", 9 (cf. note 23). Tristani, "L'Iraq Petroleum Company de 1948 à 1975", 95 (cf. note 9).

hardly a shrinking violet, but in 1947 he recognized any such participation to be fantastical. As he wrote to the Minister of Industrial Production, "La France n'a ni les besoins ni les capitaux pour participer à l'aventure saoudienne, l'essentiel pour elle est de préserver ses intérêts dans l'IPC."[85]

61 As we have seen, the American majors often found their government anything but pliant: initiatives such as the Petroleum Reserves Corporation and the State Department's fondness for international coordination of the oil industry were hardly music to the ears of either Jersey Standard or Socony – both of whom were equally fearful of congressional leaders representing independent oil producers, figures only too eager to set both the Department of Justice and the Federal Trade Commission on the American majors. To claim (as both Nouschi and Tristani do) that the American majors dictated State Department's oil policy is simplistic.[86]

62 Rather than a tale of *anglo-saxons* united against France, we need to see this episode in its broader Cold War contexts, reflecting an American desire to make Europe safe for democracy and a capitalist, consumerist lifestyle. Part of this project depended on plentiful and secure supplies of Middle East oil, extracted on easy terms from pliant Middle East regimes in exchange for security guarantees. Though the 1948 Working Agreement broke the 1928 Red Line Agreement, all IPC Groups recognized that the American flag was following American investment into the Middle East. This process was one to be managed, not fought against. A strong American presence in Saudi Arabia enhanced the stability and security of the neighbouring British sphere of influence in Iraq and Iran. Once CFP and Gulbenkian succeeded in ensuring that IPC's production would increase rather than stagnate, they found little to criticize – and much to praise – in the 1948 Working Agreement which ended their eight-year struggle.

85 Cited in Hubin, "Stratégie industrielle", 29 (cf. note 10). For his part, Hubin does not see the 1948 Working Agreement as a defeat for France.

86 Nouschi, "Un tournant dans la politique pétrolière française", 387 (cf. note 9).

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Energy utopias and dystopias: History and science fiction

Franck Ekinci is the co-author of Avril et le monde truqué [April and the Extraordinary World], an animated film that imagines late nineteenth and early twentieth-century history without electricity.[1] What kind of society would have been built if electrification had not taken place? The question echoes the research of the historian Charles-François Mathis (Université Bordeaux Montaigne), which explores the debates and reflections on the future of energy that characterized late nineteenth-century British society, with a focus on the notion of "king coal."[2]

At the initiative of JEHRHE, Franck Ekinci and Charles-François Mathis remotely familiarized themselves with each other's research, before responding to our questions and exchanging their points of view.

Charles-François Mathis

Franck Ekinci

1 Christian Desmares and Franck Ekinci, *Avril et le monde truqué*, 2015, 105 minutes.
2 Charles-François Mathis, "'Renverser le roi Charbon.' Imaginer la transition énergétique en Grande-Bretagne, 1865-1914" ["'Overthrowing King Carbon": Imagining the Energy Transition in Great Britain, 1865-1914], *in* Yves Bouvier and Léonard Laborie (eds.), *L'Europe en transitions. Énergie, mobilité, communication XVIIIe-XXIe siècles* [Europe in Transitions: Energy, Mobility, and Communication, 18th-21st Centuries] (Paris: Nouveau Monde, 2016).

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The film *April and the Extraordinary World* is often presented as retrofuturist. It takes place in the past, but in a future of that past that did not come to be. Historians are now working on past imaginaries of the future as well, notably through science fiction. What makes the duo of history and science fiction so fertile?

CFM: First, their combination can reveal a history between the lines: exploring science fiction narratives is one way, among many others, to penetrate a period's way of thinking, to discover the anxieties that agitated contemporaries and perceive the imaginaries that preoccupied them. In this way we also capture history as it unfolds in all of its complexity, by banishing any sense of determinism and rediscovering possible events that didn't occur, and by exploring these failures. This is what makes counterfactual history interesting (see the fine analysis by Pierre Singaravélou and Quentin Deluermoz, *Pour une histoire des possibles. Analyses contrefactuelles et futurs non advenus* [For a History of Possibles: Counterfactual Analyses and Alternate Futures] Paris, Seuil, 2016): asking "what if…" makes it possible to evaluate the impact of a particular generally agreed causality, and to restore a role to contingency. In short, it's a way of freeing oneself from the weight of an irremediable past, which leads us in a single direction despite our best efforts. What I find interesting in the film is the choice to freeze the world in 1870, notably through the disappearance of all scientists, and to then draw the geopolitical consequences: an oppressive police state, constant threats of war connected to energy constraints, etc. This quite accurately emphasizes the fact that energy choices are inscribed within a system that is simultaneously technical, social, political, economic, etc. I also feel that the film explores the role of scientists: they're the only ones that can imagine new ways forward for energy, yet until the nineteenth century technical innovation proceeded especially through experimental trial and error on the part of engineers and non-professionals. The role of scientists did indeed increase during the nineteenth century, yet were they the only possible factor for progress?

FE: Yes, science fiction, including science fiction about the past, naturally explores the present. Depending on our culture, standard of living, and personal desires, we are all (more or less) unsatisfied with our current world to varying degrees. As a result, it can be comforting to imagine the unfolding of an alternative course of history, one that replaces the present with a more suitable standpoint.

Then on a personal level, while I of course appreciate the technological benefits of the early twenty-first-century, the speed at which they occur and the deluge of information and solicitations (and even injunctions) that flows from them is disconcerting, if not frightening. The notion of taking a break—that the world should experience a temporary stasis for more time (ethical and technical) to appropriate these upheavals—is subsequently attractive. The film broaches this aspiration in a very indirect manner.

FE: Science fiction has frequently used "real" history to drive narrative, notably in its dystopian and uchronian branches. I'm of course thinking of Philip K. Dick's *The Man in the High Castle* (the Axis powers won the Second World War), Norman Spinrad's *The Iron Dream* (frenzied fiction supposedly written by Hitler), Gibson and Sterling's *The Difference Engine* (steam-powered Babbage computers change the world beginning in the nineteenth century), among others. That said, it's difficult for me to determine what motivated these different authors, and to therefore respond more generally to the fertile relation between history and science fiction. I can only express my own desires while co-writing the script with Benjamin Legrand. Firstly, in terms of facts, having base material that is real and familiar to all (or at least supposed to be) naturally helps lend plausibility to an imaginary account. The choice of period that is explored in the film grew out of the following considerations:

- The nineteenth century and the first half of the twentieth contained an explosion of discoveries and inventions, whose scientists remain

famous today; on the contrary, researchers today are mostly unknown, with a few rare exceptions. The science of today is more anonymous, and massively handled by tens of thousands of specialists with the support of computer science (Big Data, high-speed calculation). Even when presented fleetingly, these major figures from the past personify science for the spectator with greater ease.

- It was also a matter of presenting identifiable pivotal moments in time that can be identified by a viewer with an "average" historical culture, one that is for instance supposed to have heard about the French-German wars and Napoleon III, and therefore to be capable of deducing that a Napoleonic Empire in 1941 is strange indeed...

Then, like many people (I suppose) when they think of history, I often wonder: what would have happened "if"? For example, if humanity had possessed certain inventions earlier? The technology needed for nineteenth-century inventions was available well before. We could hear the voice of Louis XIV and examine his real portrait (phonograph and photography). What if the Roman Empire had succeeded in enduring a few centuries longer? What if India or China had gained an advantage over the West during the eighteenth century? And of course, what if the plots against Hitler, Stalin, or other dictators had succeeded? What if JFK hadn't died in Dallas? And so on and so forth. At any rate, since screenplays are essentially demiurgic, they also entail a desire for playfulness, for a joy in reordering familiar events in an amusing or intriguing way.

CFM: It's amusing that the practice of history driven by the *Annales* during the interwar period precisely sought to turn away from both major actors and event-based accounts, in order to propose an approach centered on social, economic, and demographic evolutions. Did this distance science fiction from history, and subsequently give primacy to artists, before today's interest for counterfactual history? This would be a fine subject of study. What's more, the nineteenth and early twentieth centuries contributed major scientific names to memory, on which the film can base itself. This is a result of the glorification of men of science, which is not new, and an acceleration of discoveries (facilitated by the new power obtained from fossil energies), along with a policy of republican exaltation celebrating its great men (and rarely its women), at least in France.

Is energy a classic topic of science fiction, and if so why?

CFM: I'm not sure about classic, but recurrent yes. It's especially true of science fiction, because the technical aspect naturally raises questions regarding the energy that powers a particular machine. Such works offer possible judgments that are rooted in physical constraints that must be taken into consideration. We are not in the world of magic in these narratives, as Yannick Rumpala quite rightly emphasizes in his *Hors des décombres du monde. Ecologie, science-fiction et éthique du futur* [Beyond the Ruins of the World: Ecology, Science Fiction and Ethics of the Future] (Champ Vallon, 2018).

The importance of energy in futuristic novels (to broaden beyond just science fiction) is connected to the explorations underway at the time of their writing, as was the case for writing from the turn of the twentieth century, which was particularly interested in this aspect.

FE: The context or historical moment of writing is thus crucial for grasping science fiction, a genre that is paradoxically and particularly "datable" when it engages in anticipation, thereby bearing witness to its own period as well as its speculative viewpoint. This is of course more visually striking through illustrations, comic books, and films. For example, the future according to Robida (1848-1926), along with the technology presented in *Forbidden Planet* (1956) and *Alien* (1979), inform us regarding the state of technical engineering for the periods in which these works were created. In general, the

science presented in the majority of futuristic creations is often only a projection, a small additional "leap" based on existing knowledge, and rarely a radical break.

To my knowledge, one of the rare authors who is capable of such breaks, of such genuine imaginative and scientific audacity, is Greg Egan, master of the "Hard Science" genre: *Permutation City* (virtual computer universe), *Quarantine* (thriller and quantum physics)...

FE: Among the works exploring this theme of energy in science fiction, I will call attention in particular to *Ravage* [Ashes, Ashes] by Barjavel, which I believe served as a model for numerous works exploring a subject that fascinates me, namely our civilization's dependence on energy, and hence the thin line that separates us from a return to "Year Zero" in the event of scarcity or an accident.

I think this fragility fascinates authors a great deal. In putting ourselves within a vast historical scale, not so long ago we were hunter-gatherers fighting for survival, with no massive need of energy. It is thus understandable to think that a series of dramatic circumstances affecting our interconnected means of energy production can take us back to that state of vulnerability, amid a hostile nature. We can only tremble at the thought of what could have happened if a few aggravating events had combined with the initial disasters of Fukushima, Chernobyl, Three Mile Island, or the massive pollution in China today, notably because of coal.

CFM: Regarding coal, I think it's remarkable how the film presents all of the possibilities connected to coal, in an effort to depict the daily life of a society dependent on that single source (notably the superb train-cable car): it has a *logic* that captures what's most interesting about the futuristic approach. For me there are a certain number of classic approaches that are present both here and in other narratives (perhaps because we cannot reasonably contemplate anything else?). For instance, in my opinion the luxuriant subterranean world relates to one of the first science fiction narratives, Edward Bulwer-Lytton's *The Coming Race* published in 1871, which also imagines an omnipotent energy called Vril that greatly resembles electricity.

In the absence of electricity, the world of *April* is very darkly affected by increasing coal consumption, giving rise to environmental and geopolitical disorder. This representation is directly in line with late nineteenth and early twentieth-century discourses regarding the merits of the "electricity fairy" and progress. Were other alternate futures imaginable?

CFM: Of course. Much current research (that of Andreas Malm or François Jarrige for example) emphasizes the role of "traditional" energies during the beginnings of the Industrial Revolution. For example in textiles, which were the spearhead of industrialization, the hydraulic and animal energy used in households was entirely central. Similarly on the seas, sailing ships competed effectively with steamships until the 1860s. One could quite well imagine a world of energy efficiency—but not abundance—based solely on these renewable energies. That being said, the imaginaries that unfolded during the late nineteenth century were often based on the hope of *an* energy that would save humanity, which most of the time was electricity. It is very rare for a *combination* of energies to be considered in ensuring the future needs of human beings. In the film it's ultimately the discovery of oil that saves the world from scarcity.

FE: While the film is not against science, discussing instead the problems relating to its use, it is nevertheless ironic in this regard. The discovery of oil in the narrative does indeed save the world from its dependence on coal, but it's implied that oil is a "clean and inexhaustible" energy, which sarcastically heralds future problems.

FE: Renewable energies could surely have been used. However, and this is personal, I'm rather

pessimistic. Nothing is free in our universe (entropy), and I think that we would have encountered other problems as long as we are conditioned by a desire for perpetual growth. What we subtract from nature must be repaid elsewhere. Nuclear fusion could perhaps be a solution in a few decades, but I'm very concerned about our capacity to generate disadvantages, even when we have advantages in hand.

CFM: I share the notion that this question of other usable energies cannot be handled without reference to the economical, social, and political system, and in this case to the question of growth. If we consider the (controversial, and in need of nuance) distinction made by the economic historian Tony Wrigley between an organic system based on renewable energies and a fossil system, two modes of development emerge: one tends toward a production ceiling, thereby limiting population growth and imposing limits on prosperity, while the second breaks this ceiling by enabling continuous overall growth, or at least as long as it can rely on fossil energies. The essential question is to know whether growth and fossils can be disconnected from on another—and even, for some, whether it is even desirable for growth to continue (by thinking of other non-energy impacts). Nevertheless, those who thought in these terms at the turn of the twentieth century were very rare, with there being a few utopias of frugality. The Meadows report (*The Limits to Growth*, 1972) was still a long way off!

In what way does the current context relating to the energy transition drive your artistic and historical research?

CFM: The view of the past is often shaped by current issues, and that is especially true of the environmental history that I identify with. The simplistic approach taken toward today's energy problems is sometimes frightening, as we expect new cleaner and more efficient technologies to do everything, with little or no reflection on forms of consumption, societal choices and their political aspects, etc. Two things stand out for me: a kind of fatalism (is a future without oil and its uses possible?), and the simultaneous and rarely extinguished hope for salvation through technology. These two dimensions can be found in the United Kingdom during the late nineteenth century, and trying to better understand and study them can also shed some light on our contemporary world.

FE: The remark about works of the past being revisited from a present perspective is very interesting and topical. I'm probably digressing from the topic at hand, but it's a subject that speaks to me. While it's of course healthy to have a critical eye, in recent times there have been excesses in using a twenty-first-century moral or societal viewpoint to judge creations developed in a totally different context.

FE: I think this is more of a question for Charles-François Mathis. While science fascinates me and drives my projects, my interest in the problematics of energy is occasional, one that is inscribed in the context of a film. This doesn't mean that the topic no longer interests me, but that the most recent technological advances are a rich source of both narratives and reflections: artificial intelligence, nanotechnologies, biochemistry, quantum computing, "augmented" reality and humanity, etc.

CFM: I don't like politically engaged art, although it is undeniable that you can artistically broach certain contemporary issues, notably connected to energy, as clearly shown by this film. Today we speak of an environmental art that is in keeping with land art. For instance, the work of Chris Jordan, in his series *Intolerable Beauty* and *Running the Numbers*, denounces with great talent and effectiveness the damaging effects of waste and the consumer society.

In our (still unequally) electrified world, we consume more coal than ever. What does this observation inspire in you?

CFM: It puts electricity back in its rightful place, for we often forget that it's a secondary energy that must be produced by another energy. From its very origin, electricity was a vector of a powerful imaginary (see Alain Beltran and Patrice Carré, *La vie électrique. Histoire et imaginaire*, [Electric Life: History and the Imaginary] Paris, Belin, 2016), as both the ultimate life-saving and destructive force. In this sense it offered an antithesis to coal, which was itself supported by a powerful imaginary connected to steam, and seemed to offer incredible possibilities albeit at a high price (esthetic, health, social). The film shows this well, for it magnificently presents the costs of coal (even down to the level of a poster on a fence, "we are dying of soot"), as well as how electricity was seen as a fabulous tool, as the energy of the *future* and progress par excellence that offered independence from fossils. The subsequent coexistence of these two sources (electricity is still massively produced from fossil energies) serves both as a disillusionment and a reminder that we cannot expect miracles in matters of energy.

FE: What I find striking is that our current "hyper-technology," particularly embodied by the fact that information technology is seen (consciously or not) as clean and modern, actually depends on electricity that is partially generated from coal, which is associated with lexical terms including old energy, nineteenth century, pollution, dirtiness, mines, illnesses, etc.

FE: The collision of these two opposed worlds of coal-electricity is interesting. I live in the twenty-first century, and in conducting a Google search on the ecology of the future, I trigger a technological chain that requires (indirectly and partially, of course) the combustion of harmful plant sediments dating back millions of years ago.

CFM: That's a very accurate and interesting remark (except maybe for France, due to the extent of electricity from a nuclear source). In fact, the contemporary world still depends a great deal on networks, infrastructures, and choices that were made decades ago. The inertia of systems is clearly enormous, which makes efforts to abandon them all the more complicated.

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Energy in Brazil: a historical overview

Abstract
The rapid demographic growth Brazil has experienced since the installation of the First Republic (1889) was mediated by the large size of its territory and the abundance of natural resources. Industrialization was perceived by part of the Brazilian elite as a necessary step to promote economic development, but the country started very slowly to consider the exploitation of its own energetic sources as relevant to achieve the social gains that would be compatible with the desired material progress. The panorama afforded by this article will present some highlights of this process, as it unfolded in the main components of the energetic mix, i.e. fossil fuels, biofuels, nuclear energy, and electricity.

Plan of the article

INTRODUCTION

1 This paper presents an overall panorama of the history of energy in Brazil, and more specifically since the Republic replaced the Empire, in 1889. Some political and economic history aspects are mentioned where they contribute to a better understanding of the energy issues at stake, as it will become clear along the text. Brazil was a latecomer to industrialization, having long lived according to the elite's belief that it should be primarily a raw material exporter. Therefore, industry was viewed by its policy makers as fulfilling only a complementary function, both under the Empire and during significant periods of the Republic. After World Wars I and II this theme returned to politics, and the economic growth intensified the discussions and legislations that affected energy production and use.

2 Aiming at a wide scope of over a century of history of energy in Brazil, this text does not intend to be a comprehensive source of information on this matter, it rather intends to supply a survey of relevant topics that are part of that history. Some results stem from original research, while the very nature of the material presented also relies on secondary sources. The reader is referred to specialized literature in the notes, which provide detailed information.

3 Although only in recent decades the concept of energy matrix has been used by Brazilian energy authorities, the more significant sources that comprise the present matrix will be discussed - oil, gas, coal, alcohol, and nuclear fission fuel. Electricity deserves special attention, since it epitomizes very well the bottlenecks, impasses and contradictions of the national energy history. Moreover, electric power has massively meant hydroelectricity, and in Brazil rivers are considered renewable energy sources, and that will be our focus, instead of eolic or solar energy. Also lesser components of the energy array, such as turf, shale, hydrogen and others, will be not be dealt with for our purposes here.[1] Before dealing with these subjects, it is convenient to briefly consider some aspects of Brazilian history in general.

GENERAL HISTORICAL OVERVIEW

4 Brazil's independence was formally declared in 1822, later than in most other Latin America countries, which were ex-Spanish colonies whereas Brazil had been practically the only Portuguese possession in America. Another difference singled out Brazil: after independence, it became a monarchy, rather than a republic – and the first sovereign of the empire was Peter I. He was also the would-be Portuguese crown heir, who later resigned the Brazilian Empire, and became King Peter IV of Portugal. Economy during this monarchical period followed in part the general pattern of the colonial times, driven mainly by slave labor and agricultural exports, especially sugar, cotton, and later on, coffee. During colonial times, the country experienced a boom of gold and diamond exploitation, but in the 19th century the known mines were practically exhausted.

5 Although there was a public debate about industrializing the country during the monarchy, the majority of the 19th Century politicians were closely related to large plantation landowners and slave masters, who considered the absence of a local significant industry a result of some "natural" order. The population was predominantly rural, and the social framework comprised a tiny upper elite, a small middle class, and a larger impoverished population - ca. 30 million people altogether at the beginning of the 20th Century, occupying for the sake of comparison an area larger than continental USA.

6 It is therefore understandable that during much of the Brazilian history, energy proceeded directly either from animals or from the slave arms.

1 A more extensive treatment of these other matters may be found in: Antônio Leite, *A energia do Brasil* (Rio de Janeiro: Nova Fronteira, 1997); José Goldemberg, "Energia no Brasil e no mundo", *in* Adriano Branco (org.), *Política energética e crise de desenvolvimento* (Rio de Janeiro: Paz e Terra, 2002); Eduardo Rodrigues, *Crise energética* (Rio de Janeiro: José Olympio, 1975); Arnaldo Barbalho, *Energia e desenvolvimento no Brasil* (Rio de Janeiro: Eletrobrás: Centro de Memória da Eletricidade no Brasil, 1987).

Initially native Indians were enslaved, but they proved difficult to adapt to regular work, and they were soon substituted by slaves imported from Black Africa, coming from the Atlantic West Coast, as well as from Mozambique in the East Coast. Statistics were deliberately destroyed after the end of slavery, but a rough estimation gives a total number of at least around 4 million slaves introduced in the country in three and half centuries.[2] The only relatively reliable census during the Empire (1872) registered a population of 1,510,806 slaves living in the country, or 15.2% of the total population. It should be noted that Brazil was the last American country to end slavery, in 1888. One year later, a coup replaced Emperor Peter II by the military, and the First ("Old") Republic commenced.

7 In the rural areas, the large plantation system introduced during the colonial years by the Portuguese recruited large numbers of slaves for the sugarcane farms and sugar mills. Slave labor also was extensively employed in the mining and refinery of precious metals (gold, silver), and the extraction of diamonds. Slaves worked in the civil construction (houses, roads and bridges, harbors). After proclamation of the independence, Negro slaves worked in the new cotton plantations and in what became Brazil's most lucrative business for a long time, coffee farming. With the abundance of slave labor, practically very little energy was required from sources other than that provided by photosynthesis in the form of food for cattle and men. The landed aristocracy refused any manual work as debasing and proper only to slaves or poor people.[3] Despite the general elite contention that slave labor made unnecessary the introduction of machines and their energy sources, the international competition drove a first attempt of modernization in the sugarcane plantations in the Northeast of Brazil at the end of the Empire and the first decades of the Republic. Animals and slaves used in the fabrication of sugar were gradually replaced by watermills, and finally by steam engines, technical changes that were implemented thanks to the action of British capitalists and government subsidies.[4]

8 Most of the population lived in warm climate regions, with scant need for heating, and the highest demand on energy were cooking stoves that burned any kind of available wood. As for illumination, rich houses and sugar mills used whale oil, material that also provided for public illumination in the larger cities in the first half of the 19th century, gradually later substituted by kerosene, and coal gas.

9 Despite large reserves of high-purity iron ore, the independent Brazilian government moved slowly towards steel production, a vital process for industrialization that was even more difficult because local coal was scarce and energetically very poor. Industrialization lagged behind more developed nations, as national political economy continued to back up exporters who defended that the country had an agrarian "vocation". According to this dominant line of thought, the country had been endowed with an exuberant nature. Most of the ruling elite attacked industrialization as superfluous, preferring that the surplus obtained with the export of land products be traded to buy manufactured goods, according to the economic liberal credo adopted by the Empire.[5]

2 Arthur Ramos, *A mestiçagem no Brasil* (Maceió: EDUFAL, 2004, 27-33). For the 1872 census, see www.nphed.cedeplar.ufmg.br/pop72. See also: Luiz Felipe de Alencastro, *O trato dos viventes. Formação do Brasil no Atlântico Sul* (São Paulo: Companhia das Letras, 2000); Emília Viotti da Costa, *Da senzala à colônia* (São Paulo: Editora da UNESP, 1998); Caio Prado Jr., *Formação do Brasil contemporâneo* (ed. revista. São Paulo: Companhia das Letras, 2011 [1942]).

3 Sérgio B. Holanda, *Raízes do Brasil* (25ª ed. Rio de Janeiro: José Olympio, 1993 [1936]). José Murilo Carvalho. *A construção da ordem. A elite política imperial* (Rio de Janeiro: Campus, 1980).

4 The land, however, remained concentrated in the hands of a few landowners up to the present days. This process is described as "modernization without change", a feature that applies to many other industrialization aspects of Brazilian history. See Peter Eisenberg, *Modernização sem mudança. A indústria açucareira em Pernambuco, 1840-1910* (Rio de Janeiro e Campinas: Paz e Terra e Editora UNICAMP, 1977).

5 Ernesto Carrara Jr, Helio Meirelles, *A indústria química e o desenvolvimento do Brasil. Tomo II: 1844-1889. De Pedro II à República* (Rio de Janeiro: Metalivros, 1999).

10 The situation described would change only slowly, as importation of oil and cars with internal combustion engine increased, and the tracks of steam-powered railways were financed by British capital since the 1870's. The first electric lamps were displayed in the capital, Rio de Janeiro, in 1880, and the country soon realized that it had an important asset in waterfalls that could be harnessed to generate electricity. More modern chemical plants started to be built in the 1920s, increasing the need for power, a demand already claimed by more food and textile industries. On the other hand, after the abolition of slavery, free labor received an impulse through the large influx of immigrants to Brazil, most notably Italians, Japanese, Portuguese, Spaniards and Germans, who came in at first to work in plantations in Southern Brazil, especially in the State of São Paulo. Soon the immigrants moved to cities, where they became the core of the emerging middle class, as well as small or even large-scale entrepreneurs.[6] In São Paulo a more continued industrialization surge began at the end of the Empire, and increased specially after the import substitution propitiated by the First Word War.

11 The Republic proclaimed in 1889 had strong positivist influences (through the French philosopher Auguste Comte's philosophical system), visible even nowadays in the motto inscribed in the Brazilian flag ("Order and Progress"). However, despite the ideology of progress did bring a renewal of the debates in favor of modernization, it did not fulfill the promise of deeper industrialization, with the notable exception of São Paulo State, as cited above.

12 The Old Republic remained tied to economic free-trade liberal principles, which lasted until 1930, when another military coup started a new period. The "New Republic" of President Getúlio Vargas began as a nationalist dictatorship, but in some ways it meant a more progressive era, which lasted 15 years. It favored a stronger role of the State, with several implications on energy issues, specially electricity and oil, as subsequently presented in this paper. The fall of Vargas' regime resumed the democratic republic, which would continue as such until the military took over in 1964.

13 As consequence of the country's rising above what could be considered mostly a lethargic economic state, energy became an explicit concern for the government, and already in 1920 the Ministry of Agriculture, Industry and Commerce created a Commission to study hydraulic power.[7] After a sterile discussion that started in 1905 about who owned the title to inland water, President Vargas decreed the Water Code in 1933, and instituted the National Commission of Water and Electric Energy in 1939. Vargas was also responsible for later launching the state-owned oil and gas company Petrobrás, after a long struggle against privatizing and anti-nationalist interests.[8] The Ministry of Mining and Energy is, however, relatively a recent initiative (1960), so is Eletrobrás (1961), a state company in charge of electricity generation, and even newer is the National Council on Energy Policies (1997), responsible for planning resources of oil and natural gas, electricity, and biofuels.

14 Before proceeding to show some decisive developments in the history of the main energetic sources in Brazil, Table 1 sketches their relative distribution in a 70-year period, starting at the end of the first Vargas administration.

6 Nícia Luz, *A luta pela industrialização do Brasil* (São Paulo: Alfa-Omega, 1975). Luiz Carlos Bresser-Pereira, *Desenvolvimento e crise no Brasil. História, economia e política de Getúlio Vargas a Lula* (5ª ed. São Paulo: Ed. 34, 2003 [1968]), 77-98.

7 A noteworthy early exception to the lack of integrated discussion of energy sources in Brazil is the address given in 1928 by Calógeras, a mining engineer and Minister, to the student's body of the Politechnic School in São Paulo. Pandiá Calógeras, "Fontes de energia", *Revista Polytécnica*, nº 85-86, 1928, 103-132.

8 Getúlio Vargas returned to power after winning the democratic presidential election in 1950, until he committed suicide in 1954, after an insidious rightist press campaign against him.

SOURCES	1945	1955	1965	1975	1985	1995	2005	2015
Oil and natural gas	5.5	20.9	28.7	48.5	39.8	46.8	48.2	51.0
Coal	5.0	4.3	3.2	3.5	7.6	7.3	6.0	5.9
Hydroelectricity	1.6	2.3	3.8	6.8	11.8	15.3	14.9	11.3
Wood and charcoal	85.7	69.3	59.0	36.3	25.1	14.3	13.1	8.2
Sugarcane	2.2	3.2	5.2	4.6	13.6	14.0	13.8	16.9
Uranium and others	0.0	0.0	0.0	0.4	1.9	2.4	4.1	6.6

Figure 1: *Table 1 - Energy Supply in Brazil (%)*
Source: Balanço Energético Nacional (Rio de Janeiro: EPE/ Ministry of Mines and Energy, 2016) – data further compiled by the author

OIL AND GAS

15 The search for technical independence and capacity to extract and refine oil intertwines the main Brazilian political and social events in the second quarter of the 20th Century. By 1915, the Republic's Geological and Mineralogical Service, directed by engineer Pandiá Calógeras, concentrated its fossil fuel research looking for coal deposits. That Service had only 25 oil probes, and nothing resulted in this direction, while the main goal was to find more and better coal to foster the national steel production.

16 Coffee prices had sharply dropped in the 1920's, and the economic crisis deepened after the 1929 Wall Street crash. The so-called "Revolt of Lieutenants" signaled the end of the Brazilian First Republic in 1930, accused of an oligarchical political attitude that favored rural landowners. The power was handed to Getúlio Vargas, who undertook a series of reforms aligned with modernization and economic development, enforcing the bourgeoisie and answering the appeal to accelerate the country's industrialization.[9] It was in this context that the search for oil was declared a matter of "national dignity", and in 1934 Vargas sanctioned the Mining Code, which defined the subsoil riches as national property, instead of private possession.

17 In 1936, the very popular writer and entrepreneur Monteiro Lobato criticized the government in a book, *The scandal of petrol and iron*, accusing the National Mineral Production Department of being allied to the international oil trusts (fig. 2). The federal government had hired American geologists as consultants, and they recommended abandoning oil prospection, alleging that their surveys indicated the non-existence of oil under the Brazilian soil. This conclusion gained support from some ministers otherwise known as leaning towards foreign investors.[10] On the other hand, years before that, foreign oil companies had already bought large extensions of land considered promising from the point of view of future oil prospection. The government image was shaken when a campaign led by Monteiro Lobato to increase the number of oil prospection drills did find petroleum in the state of Bahia in 1938.

18 The imminent war situation facilitated an industrialization surge, coupled with a thrust to improve the economic infrastructure, which resulted in duplication of existing roadways, thus incentivizing the use of gasoline. A new "Oil National Council" (CNP) was formed in 1938, headed by the nationalist General Horta Barbosa, and the CNP demanded the creation of a "national company" for oil refineries. An ideological battle ensued between defenders of

9 Pedro Fonseca, *Vargas; o capitalismo em construção, 1906-1954* (São Paulo: Brasiliense, 1989).

10 Gabriel Cohn, *Petróleo e nacionalismo* (São Paulo: Difel, 1968).

the national production of oil and the groups against it, which had the open support of Standard Oil. After World War 2 ended, Vargas was ousted and subsequently both the military and the civil society split around the issue of national petroleum. The group favoring a state monopoly of oil was led again by General Horta Barbosa, while the conservative political current around General Juarez Távora proposed an alliance between American and Brazilian capital. In 1948, the nationalist forces were able to launch the movement known as "Petroleum Campaign".

19 The dispute involving oil increased as the country had already experienced an industrialization surge during World War 2. The demand for refined oil after the war was the triple of the prewar years, and the federal government planned to buy tanker ships and build several oil refineries. Getúlio Vargas returned to the political scenario as President in 1951, winning a democratic election with support of the leftists, which reflected his personal popularity, despite having been a former dictator. One of the popular expectations was exactly the one related to the oil question, and Vargas' personal attempt was to find a middle term between the state oil monopoly, defended by leftists and nationalists, and the foreign presence, favored by economic liberalism forces. After long and fiery discussions in Congress, a law was approved in 1953, creating a new state company, Petrobrás. The company resembled more the monopoly defended by nationalists, who were accused by the Congressional right wing of being "communist". A strong opposition by rightist groups against Vargas culminated in his suicide in 1954, yet his death actually enforced the nationalist position. New refineries were built, which were instrumental to the economic development induced by the government of President Juscelino Kubitschek in the 1950's. However, the discovery of oil fields was not immediately so successful, bringing again the suspicion of merely small oil reserves in the subsoil deposits in the country. Even so, to this initial phase can be credited the creation of geology courses in several universities, a capacity which the country lacked until then. In 1963, Petrobrás decided to create its Research and Development Center (CENPES), which would prove essential in later years, and especially in the 21st century, for the exploitation of very deep reserves.[11]

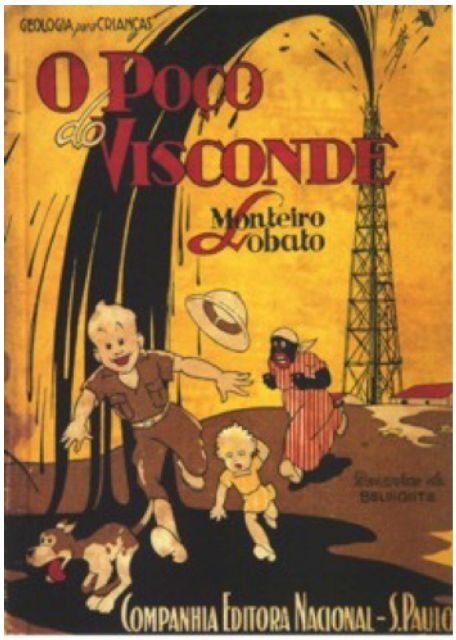

Figure 2: Cover (first edition, 1937) of Monteiro Lobato' children book *The Viscount's well* in favor of national oil policy. The previous book by Lobato, *The scandal of oil*, had been censored and apprehended, so Lobato transformed it into a successful book for the young readers. In the story American geologists try to hamper oil drilling, and afterwards international speculators try to buy the oil-rich lands. Oil was indeed found in Brazil in 1939, and Lobato's campaign arose public opinion to press Brazilian government to create Petrobras. Source: IEB, University of São Paulo

20 The *coup d'État* in 1964, which had a then secret participation of the American government, overthrew the government of President Jango Goulart, accused of leftist inclinations. The military regime would last 21 years, and a distinctive feature of the period was the strengthening of the petrochemical industry in Brazil, with the adoption of the so-called

11 Victor Mourão, "CENPES-Petrobrás: capacitação tecnológica e redes de conhecimento em uma empresa da periferia econômica Mundial". I Seminário de Pós-Graduandos em Ciências Sociais do Estado do Rio d Janeiro, 2011. Fábio Erber, Leda Amaral, "Os centros de pesquisa das empresas estatais: um estudo de três casos", *in* Simon Schwartzmann, *Política industrial, mercado de trabalho e instituições de apoio* (Rio de Janeiro: Fundação Getúlio Vargas, 1995).

tripod model, under which the government incentivized the association of Petrobrás with Brazilian private companies and foreign corporations.[12] in 1975, as a result of the world oil crises, President General Ernesto Geisel made an unexpected movement in terms of energetic policy, changing the law to break the state monopoly of Petrobrás. The prospection and exploitation of oil and gas in certain land areas and sea basins were allowed under risk contracts, a long-standing demand from oil multinationals like Shell.[13] in a first moment the resulting contracts were not very fruitful, however, except for the discovery of large deposits of natural gas, in the Amazon region and the Midwest, as well as in the continental maritime platform. These discoveries represented a considerable contribution given by the newly-developed Brazilian engineering expertise in geophysical seismic exploration.

21 The large reserves of oil and gas found between 2000 and 2002 in the basins of Campos and Santos, in the Southeast of Brazil, made it feasible to speak for the first time of the country's self-sufficiency in terms of oil and gas. The new status of oil exporter changed the traditional oil-importing profile of the country, yet the price paid by consumers continued to be high, relative to the low national average income. To better understand this, it is necessary to recall that in Brazil transportation of goods is primarily a function performed by trucks, given the inexistence or precariousness of railways or waterways. The same applies to public transportation, in charge of buses and not trains. As trucks and buses use diesel motors, the government has traditionally subsidized the price of diesel oil with taxes levied on gasoline. Even so, the cost of oil-based transportation has a strong impact on the budget of workers, and there is a consequent pressure on food prices as well, so that the burden of the transportation oil cost has been basically supported by the middle and lower classes.

22 The dawn of the 21st Century witnessed the internationalization of Petrobrás, which became very active in drilling and exploiting oil wells in Latin America and elsewhere. A technical landmark was achieved in 2005, when for the first time Petrobrás employed new techniques for deep sea drilling developed by its Research Center, and found immense oil and gas reserves in the "pre-salt" layer, located in the subsoil at a depth of 4,000 to 6,000 meters, and plus under an additional 1,000 to 2,000 meters of seawater.

23 Petrobrás' technical and economic success transformed the company in a gigantic political asset, which contributed significantly to its subsequent problems. As became worldwide known, after the end of the military regime and re-democratization of the country in 1985, and most notably during the neoliberal era of President Fernando Henrique Cardoso (1995-2003), unchanged by the Workers' Party governments (2003-2016) of Presidents Lula da Silva and Dilma Rousseff, Petrobrás made a series of dubious political and economic decisions, which brought huge losses.

24 From 1997 onwards, the newly-created ANP (National Petroleum Agency) started auctioning oil areas, giving 30 year-concessions and the right to export oil. Foreign companies won 40% of the winning bids.[14] Contrary to expectations, instead of using the abundant gas reserves and the gas pipelines already built for distribution in the Southeast, Brazil invested heavily in Bolivia and signed a contract in 1996 to use their natural gas (fig. 3). However, in 2006 Bolivia expropriated and nationalized foreign companies, including Petrobrás, which suffered heavy economic losses. Additionally, the international price of oil dropped from US$ 130 a barrel to US$ 30, which made it uneconomical for Brazil to extract the pre-salt oil and gas. Only recently

12 Peter Evans, *A tríplice aliança. As multinacionais, as estatais e o capital nacional no desenvolvimento dependente brasileiro* (Rio de Janeiro: Zahar, 1980).

13 Getúlio Carvalho, *Petrobrás: do monopólio aos contratos de risco* (Rio de Janeiro: Forense Universitária, 1977). Fausto Cupertino, *Os contratos de risco e a Petrobrás* (Rio de Janeiro: Civilização Brasileira, 1976).

14 Sergio Ferolla, Paulo Metri, *Nem todo o petróleo é nosso* (Rio de Janeiro: Paz e Terra, 2006).

Figure 3: Piratininga thermoelectric station in São Paulo City. Built in 1954 to run with fuel oil, it changed in 2001 to use natural gas provided by Petrobrás' pipelines. Source: wikipamia

the slow elevation of prices has made it possible to resume the exploitation, so that the present daily production of oil and gas by Petrobrás is slightly below 3 million barrels equivalent of petroleum, and over 110 million cubic meters of natural gas, with a more significant contribution of the pre-salt layer.[15]

25 Table 2 shows the advances in the production of Brazilian oil and natural gas in about 50 years after the consolidation of Petrobrás. The domestic extraction of oil and gas has enabled the country to be potentially independent of the imported fuels, while Petrobrás' technological expertise led the company to be an important global partner, drilling oil in the North Sea and other places.

26 The most devastating effect for the company, however, came from a common evil, the charge of widespread practice of corruption. As the recent evidence demonstrated, there was deeply entrenched corruption involving civil construction companies, politicians and Petrobrás officers, and the value of the company in the stock market plunged substantially, contracts were cancelled, and very heavy losses followed as unemployment scaled up. In a climate already shattered by a severe economic recession in Brazil, politicians were framed, executives jailed, and the damage to the public image of Petrobrás contributed to the mounting opposition against the government of President Dilma Rousseff, leading eventually to her impeachment by Congress, and an unprecedented political crisis in the country, with far-reaching consequences.

15 Petrobrás, "Boletim da produção de petróleo e gás natural", Nº 77, 2017.

PRODUCTION	1970	1980	1990	2000	2010	2016
Oil	8161	9256	32550	63849	106559	130373
Gas	1255	2189	6233	13189	22771	37610

Figure 4: *Table 2 – National production of oil and gas (103 TOE)*
Source: *Balanço Energético Nacional* (Rio de Janeiro: EPE/Ministry of Mines and Energy, 2017)

COAL

27 Coal deposits in Southern Brazil were discovered as early as 1795, yet exploitation began only in 1855, when the first mine was opened in the state of Rio Grande do Sul.[16] A group of miners from Wales set up a company led by James Johnson, and was responsible for the creation of the "Imperial Brazilian Colleries", which however went bankrupt in 1880. A new company was established in 1882, "Companhia Minas de Carvão do Arroio dos Ratos", which operated until 1908. In the neighbor state of Santa Catarina, lower quality coal mines began operating also in the second half of the 19th Century as a concession to a British company, that later gave it up to Brazilian industrialists.

28 The use of coal increased considerably due to the opening of several railways in Brazil during the Empire and the early Republic. World War 1 curtailed importations, and national coal substituted the English product, albeit at a lower quality. After the war, Brazilian coal began to fuel thermoelectric plants, and to provide gas for street illumination.

29 During the Old Republic (1889-1930), better-quality coal was imported for use in steel mills, electric generation and steam locomotives, while steam machines in factories used national coal, or they burned directly wood for that purpose. The federal government created the Coal Commission in 1905 to evaluate the amount of national reserves, which confirmed that there was relatively little coal in the country and of inferior energetic quality. With the outbreak of World War 1, the difficulty of importing coal incentivized the opening of new coal mines, especially for use in the expanding railway network, but after the war imported coal predominated again. President Vargas in his first period of government issued a decree demanding the use of 10% of national coal for the fabrication of steel.

30 The creation in 1941 of CSN - Companhia Siderúrgica Nacional (National Steel Company), a large steel mill in Volta Redonda, state of Rio de Janeiro, completed in 1946, prompted the government to issue a law, now demanding the use of 20% of national coal to produce pig iron. "Carbonífera Próspera", a private company founded in 1915 in Santa Catarina, became in 1943 state-controlled through CSN, and was very active in exploiting coal for metallurgical purposes until the 1980's.[17] With the oil shock of 1973 there was a renewed interest in using national coal. After the end of the military regime in 1985, the "New Republic" followed a neoliberal economic program, and this change of course was also felt by "Próspera", as President Collor de Mello closed their coal mines, and privatized the company in 1991. There was a large number of unemployed people and a regional economic crisis, until the mines were later reopened.

31 About half of the coal used in the country is still imported nowadays, as the Brazilian production is not enough to meet the demand, and in general that coal needs constant treatment, given its low energetic content, due to the high proportion of ashes (50%) and sulfur

16 Benedito Veit, *Assim nasce uma riqueza: a trajetória do carvão na Região Carbonífera* (Porto Alegre: Alcance, 2004).

17 Maurício Santos, Gisele Maciel, "A Carbonífera Próspera S/A: da estatização à privatização". *ABPHE*, V Congresso Brasileiro de História Econômica, 2003.

Figure 5: Coal mine workers (including women and children) in Criciúma (1938). The mandatory use of national coal prompted the increased exploitation of mines in Southern Brazil. This is the only part where coal mining is still active, especially in the states of Santa Catarina and Rio Grande do Sul. Source: Instituto Histórico e Geográfico de Santa Catarina

1970	1980	1990	2000	2010	2016
1,115	2,484	1,915	2,613	2,104	2,897

Figure 6: *Table 3 – National production of coal (103 TOE)*
Source: *Balanço Energético Nacional* (Rio de Janeiro: EPE/ Ministry of Mines and Energy, 2017)

(2.5%). The most recent estimates of coal reserves are concentrated in the states of Rio Grande do Sul (29 billion tons) and Santa Catarina (3 billion tons).

32 Thermoelectric power plants using coal as fuel were usually small, and their operational cost was disadvantageous in relation to hydroelectricity. Only in 1960 Candiota I, a larger coal-fueled electric generation unit (20 MW), was implanted in Rio Grande do Sul, followed during the military regime by Candiota II in 1974 (126 MW, presently 446 MW). Based on recent controversial decisions to implement thermoelectric plants instead of hydroelectricity, the use of coal has increased in the last decades, as shown in Table 3.

33 Charcoal is still widely used in Brazil. The average annual production of pig iron in recent years has been around 32.5 million tons, out of which roughly one third is produced with charcoal. Reforestation areas have been planted with eucalyptus and pine trees to provide most of the wood burned to this end. However, in the past, only native wood was employed for charcoal to be used in domestic stoves and diverse industries, which led to almost complete devastation of the original tropical forests.[18] Even nowadays around 40% of the charcoal proceeds from native woods, and small illegal charcoal burners spread out in vast rural and forest areas of Brazil, despite surveillance and repression of the practice.

18 Warren Dean, *A ferro e fogo. A história e a devastação da Mata Atlântica Brasileira* (São Paulo: Companhia das Letras, 1996). See also José Augusto Pádua, *Um sopro de destruição. Pensamento político e crítica ambiental no Brasil escravista (1786-1888)* (Rio de Janeiro: Jorge Zahar, 2002).

ALCOHOL AND BIOFUELS

34 The systematic study of sugarcane for ethanol production as a fuel substitution for gasoline dates from 1923, when it was conducted at the Fuel and Mineral Experimental Station in Rio de Janeiro by engineers Fonseca Costa and Heraldo de Souza Mattos. The studies included the corrosion effect of alcohol in explosion motors, and fuel efficiency. Souza Mattos was able to demonstrate the feasibility of pure (anhydrous) alcohol when he participated in the first official car race in Brazil using this fuel in 1923. During his research it was verified that adding alcohol to gasoline was better than predicted, however the miscibility was inadequate, because of using 96º GL alcohol.

35 New researches were led in the 1930's by engineer Eduardo Sabino de Oliveira at the National Institute of Technology (INT), the successor of the Fuel and Mineral Experimental Station. President Vargas' government decreed that gasoline importers must add 5% of national ethanol, and he created in 1933 the Institute of Sugar and Alcohol (IAA). This measure increased the alcohol production from 5 thousand liters/day to 225,000 liters/day in four years. Regulation of motor carburetors was hard to achieve, and the research concluded that 10% of alcohol to make the so-called "rose gasoline" could dispense with the regulation, and also that the motor could then become corrosion-free. For starting up the cold motor, Oliveira recommended an extra smaller gasoline tank.[19]

36 The Vargas administration later demanded a higher 20% addition of alcohol, a measure that lasted until the beginning of World War 2. During this time, ethanol made from manioc was also used as fuel in cars. An article published in 1946, and sponsored by the São Paulo Stock Exchange Technological Laboratory, explained how the manioc bagasse could be economically fermented using hydrolysis with sulfuric acid. They established the ideal mixture of water to the bagasse, as well as the temperature, pressure and additives necessary for the process.[20]

37 During the 1960's the National Petroleum Council authorized the addition of 10% ethanol to gasoline to compensate for the excess production and lower prices of sugar in the external market. Petrobrás was reticent as to the measure, afraid of losing its profit margin with gasoline. However, the Ministry of Industry and Commerce insisted on creating a national motor running with only hydrated ethanol, to become a basis for an automobile industry with genuine national technology and capital, and looked again at manioc alcohol production as a possible fuel source. After the oil shocks of the 1970's, the alcohol motor was finally developed by the Aeronautical Technological Center (CTA) in São Paulo state, and a caravan of cars equipped with this type of motor traveled in 1975 around the country to show its feasibility (fig. 7).

38 President Geisel then created the National Alcohol Program (Proálcool). It should be recalled that sugarcane in Brazil is overall a large monoculture plantation owned by rich landowners, while manioc is mostly planted by small farmers, and associated to several other farm and food products, such as beans and corn. It was known that the energetic content of manioc was inferior to sugarcane, yet the choice of sugarcane was a political decision, which affected the social struggle for a long-sought land reform that never occurred in Brazil, still in the hands of an extreme minority. As the sugarcane planters and alcohol distillers have had much more economic and political power, it came as no surprise that they were more effective in their lobby.

19 Eduardo Oliveira, *Álcool motor e motores a explosão* (Rio de Janeiro: Instituto Nacional de Tecnologia, 1937). See also Gildo Magalhães, "Energia e Tecnologia", *in* Milton Vargas, *História da técnica e da tecnologia no Brasil* (São Paulo: UNESP, 1994), 361-363.

20 Juvenal Godoy, Paulo Godoy, *Emprego do bagaço das fecularias de mandioca no fabrico do álcool* (São Paulo: Secretaria da Agricultura, Indústria e Comércio, 1946). See also João Luiz Meiller, *O álcool anidro puro como sucedâneo da gasolina* (São Paulo: Secretaria da Agricultura, Indústria e Comércio, 1946).

Figure 7: First Brazilian car to run with exclusive alcohol motor, developed in São José dos Campos by the Air Force Technological Center (1975). This Dodge Polara traveled all over the country leading other cars to show people the possibility of substituting ethanol for gasoline as fuel. Brazilian cars are now "flex", running on any mixture of gasoline and alcohol, including just any one of them. Source: Memorial Aeroespacial Brasileiro

39 The innovation was not used, however, for creating a national automobile industry, something the country never really achieved, for in another critical political decision the alcohol motor technology was transferred to the multinational industries operating in Brazil, which paid no royalties for this development. Those industries at first had underestimated the difficulties still present in the alcohol motor, such as cold ignition, corrosion, high consumption, and the necessary regulation of the carburetors. As a result, the alcohol-run car was a failure when sales began in 1980. The technical problems took about three years to be solved. Other measures taken by the government included the addition of 10-20 % anhydrous alcohol to gasoline, and as a consequence the urban air pollution diminished significantly. The good results became a focus of interest for other non-oil producing nations, as well as countries plagued by heavy atmospheric pollution.[21]

40 The Institute of Technological Research (IPT) and the University of São Paulo's Agriculture School in Piracicaba conducted an extensive research on using the residue of sugarcane fermentation, vinasse. However, the Alcohol Program was slowed down in 1985 because oil prices had dropped, and at the same time, the exported sugar price had risen, so that sugarcane manufacturers were now more interested in producing and selling sugar than alcohol. With a large fleet of alcohol-run automobiles, the government suddenly had to import from Europe ethanol made from grapes, and from the USA methanol made from wood, a decision that was highly criticized. The subsidized Alcohol Program for automobiles ended in 2000, as more and more car owners gave up using the fuel. However, with the new generation of flex-fuel motors, running with either gasoline or alcohol, or any mixture of both, and the concern with air pollution, which increased alcohol addition to gasoline to 22%, there came a revival of ethanol at the sugarcane mills and distilleries. Presently the annual production of alcohol is 30 billion liters, mostly processed in the state of São Paulo, and the Alcohol Program has been redirected to biodiesel,

21 Eliana Fernandes, Suani Coelho (orgs.), Perspectivas do álcool combustível no Brasil (São Paulo: USP-Instituto de Energia e Eletrotécnica, 1996).

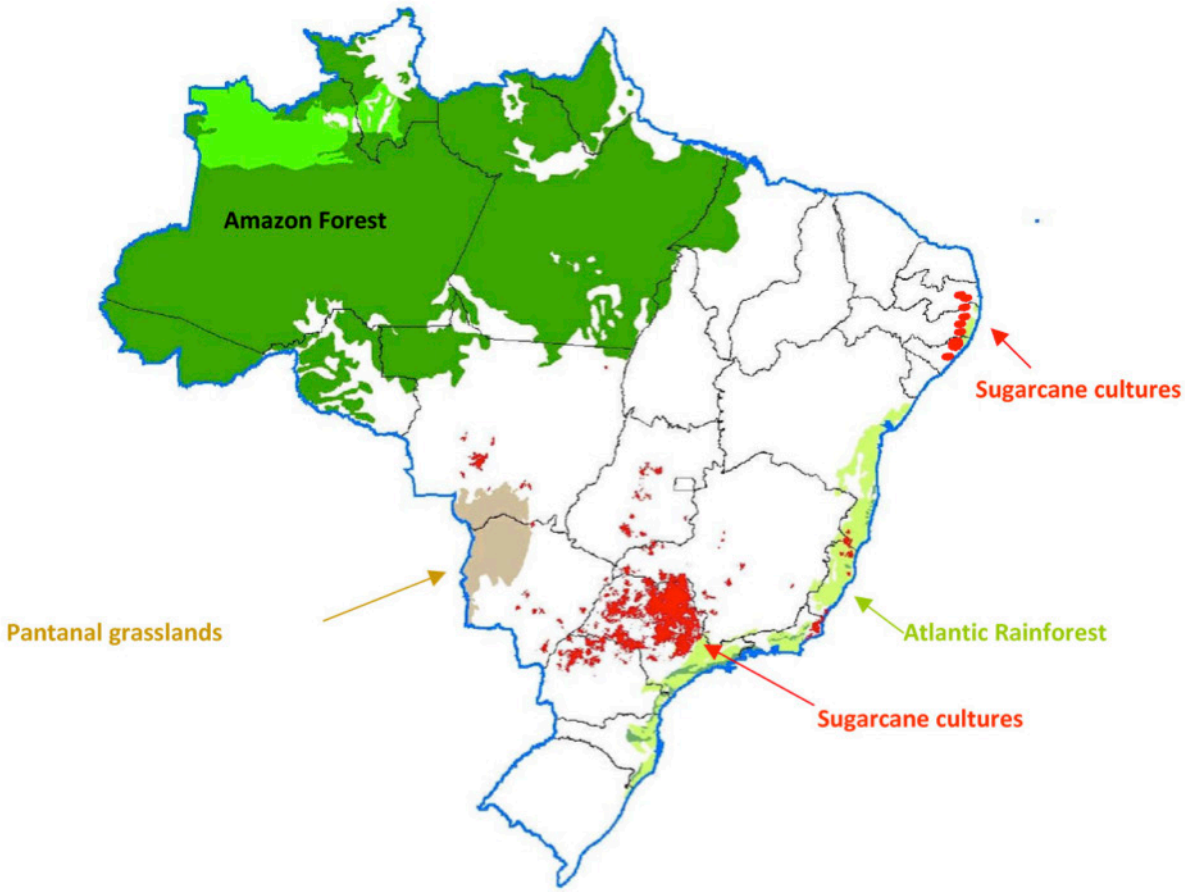

Figure 8: Sugarcane plantations in Brazil (2008). Mills and refineries produce either sugar or ethanol. Food plantations gave way to large extensions of sugarcane monoculture in the Southern State of São Paulo. Source: Wikimedia Commons/ José Goldemberg

a product obtained through a reaction of alcohol and vegetable oil. One more application of the by-products of sugarcane fermentation has been the thermal cogeneration of electricity by burning sugarcane bagasse.

41 The sugarcane harvest still utilizes non-skilled seasonal workers, even though it has become more and more mechanized, and Brazilian agricultural research made it possible to have two annual harvests. The plantation system demands a vast land extension, which has displaced or substituted food products such as corn, rice, cotton and grassland for cattle, and the monoculture landscape consisting of a monotonous "green sea of sugarcane" is also related to a poor vegetal and animal diversity in the country (fig. 8). The sugarcane plantations have contributed to maintain the conflicts with landless poor peasants and to increase the wealth concentration in Brazil, even though it has brought along more circulation of goods. This wealth concentration has extended the sugarcane farm ownership to the alcohol distilleries, as they become ever more the property of the same small number of groups, so that mini-distilleries also end up in the hands of these large groups.[22]

42 Biomass other than sugarcane is still an energy source in Brazil. In spite of being little efficient, and energetically poor, wood is still in use, burned in poor peasant's stoves, or employed to make charcoal as fuel for pig iron metallurgy. Wood can also be gasified, providing methanol, and methane generated by vegetable or animal residues has been used as fuel for urban buses in a few cities.

22 Bruce Johnson, "Impactos comunitários do Proálcool" (São Paulo: USP/FEA/IA, 1983). Fernando Melo, Eli Pelin, *As soluções energéticas e a economia brasileira* (São Paulo: Hucitec, 1984). Fernando Safatle, *A economia política do etanol. A democratização da agroenergia e o impacto na mudança do modelo econômico* (São Paulo: Alameda, 2011).

Figure 9: Almirante Álvaro Alberto power station in Angra dos Reis. Finished in 1985, this was the first nuclear unit, named to honor the nationalist admiral who fought for Brazilian independent nuclear research – yet this was built with USA's Westinghouse technology. Source: Eletronuclear

NUCLEAR

43 The Atomic Energy Commission, when created in 1946 by the United Nations, had an active participation of the Brazilian representative, Admiral Álvaro Alberto, who opposed the Baruch Plan of the dominant powers, which posed in fact their control of the world reserves of uranium and thorium. Fears that the superpowers intended to manipulate the nuclear fuels were justified, as demonstrated in 1952, when the USA imported from Brazil in a single commercial transaction all of their two-year uranium quota without the counterpart of nuclear technological transfer for electrical generation, as intended by Álvaro Alberto. Also at that time, the newspapers' headlines showed the scandal of the American trading of Brazilian monazite sand containing thorium for rotten wheat coming from the USA. In face of these difficulties, during the second Vargas government (1951-1954) Álvaro Alberto tried to make deals in Europe involving nuclear technological cooperation. He almost succeeded in secretly embarking ultracentrifuges in Germany for uranium concentration, but the manoeuver was denounced to the USA, who used its authority as occupying force in the defeated country to embargo the shipment in 1954.[23]

44 Nuclear research continued, however, at the Institute of Technological Research (IPT) and the Atomic Energy Institute (IEA), both related to the University of São Paulo, as well as at the "Argonauta", a prototype reactor of the University of Rio de Janeiro, and also in the Thorium Group of the Institute of Radioactive Research in Belo Horizonte (Minas Gerais). In 1959, Brazil successfully inaugurated its first pilot unit for uranium purification.

45 During the military regime implanted in 1964, the Nuclear Energy National Commission, together with a new state company, Nuclebrás, signed a contract with Westinghouse Electric from the USA. This was the origin of the first Brazilian

23 Shozo Motoyama, João Vítor Garcia (orgs.), *O almirante e o novo Prometeu. Álvaro Alberto e a C&T* (São Paulo: UNESP, 1996). Guilherme Camargo, *O fogo dos deuses. Uma história da energia nuclear* (Rio de Janeiro: Contraponto, 2006), 143-224.

nuclear plant, Angra 1 (640 MW), in the state of Rio de Janeiro (fig. 9). The transaction is generally considered a bad example in terms of technology, since it was essentially a "black box" arrangement, without providing for any technological transfer to Brazilians. The second nuclear deal, signed in 1975 by President Geisel with the German company KWU (controlled by Siemens), also failed to help mastering the desired nuclear technology. This Brazil-Germany Nuclear Deal foresaw the building of eight nuclear plants, but effectively only Angra 2 (1,350 MW) was initiated in 1976, but inaugurated only in 2001, due to the increasing internal political opposition, and the diplomatic external pressure reinforced by economic threats of retaliation by the USA. The construction of the following plant Angra 3 (also 1,350 MW) was paralyzed in 1986, and only recently it was continued, and because of constant delays it was rescheduled to be finished in 2018 or even later.

46 Added to the American pressure against Brazilian independent nuclear technology there was a mounting opposition of the civil society after the re-democratization of the country in 1985. This happened also in many parts of the world after the 1986 Chernobyl accident, but in Brazil additionally a dubious association was made between nuclear energy and the military dictatorship. The Brazilian Physics Society and the Brazilian Society for the Advancement of Science manifested their opposition to the uranium enrichment process, which according to them would lead to undesired nuclear weapons. The Carter administration had already prevented Brazil from getting American technology for uranium enrichment. To operate Angra 1, its only nuclear plant, Brazil had to send the locally produced "yellow cake" to Urenco in Europe, for a 3% enrichment. The dismantling of the nuclear effort was considered a victory of the new democratic civil regime, and it was completed during Collor de Mello's term (1990-1992) as President, known for his neoliberal measures and opposition to state participation in the economy.

47 In 1988, the state company Nuclebrás was closed, and the control of nuclear electric generation was passed over to Furnas, one of the companies controlled by the state-owned electricity holding Eletrobrás. The disappointed military, however, secretly maintained a parallel program of nuclear research. The Army intended to build a bomb, considered strategic in relation to the traditional competition with Argentina, but the press uncovered this plot, and the installations were shut down in 1990. However, the Navy continued working to build a nuclear propulsion submarine, together with the University of São Paulo and the Nuclear Energy Research Institute (IPEN, a successor of IEA), strategically located at the University of São Paulo campus. Although the government kept imposing severe cuts to the Navy's budget, the election of President Lula also channeled more attention to remedy the obsolescence that predominated in military equipment, and especially a preoccupation with the military defense of the Amazon region. The Brazil-France Military Cooperation Deal of 2008 is an indication of such nationalist political motivation, coupled with a desire for relative independence from the North American presence across the continent. The Navy enjoyed technological success and called international attention when it announced the development of an innovative uranium enrichment process in 2008, which has been continually perfected since then.[24]

48 Fusion energy research has also been a research target at the Universities of São Paulo and Campinas, although with severe budget restrictions. In terms of nuclear energy application, the country has a long tradition now of medical research for cancer treatment, conducted in São Paulo by IPEN, as well as food irradiation, developed by the internationally well-known Center for Nuclear Energy in Agriculture (CENA), created in 1966 at the University of São Paulo's campus in Piracicaba.

49 At this point it is interesting to compare the recent trends and relative contribution of two primary sources of energy in Brazil, one deriving from agriculture (sugarcane), and another from mining (uranium – U3O8), as in Table 4.

24 Fernanda Correa, *O projeto do submarino nuclear brasileiro. Uma história de ciência, tecnologia e soberania* (Rio de Janeiro: Capax Dei, 2010).

Source	1970	1980	1990	2000	2010	2016
Sugarcane	3601	9301	18451	19895	48852	50658
Uranium	0	0	0	2028	4821	4821

Figure 10: *Table 4 - Gross Domestic Supply (103 TOE)*
Source: *Balanço Energético Nacional* (Rio de Janeiro: MME/EPE, 2017)

ELECTRICITY

50 The first initiatives leading to the systematic use of electricity in Brazil were contemporary of, or arose immediately after, the pioneering use in Europe and the USA at the end of the 19th Century. At this moment, the leading countries were living through the so-called "Second Industrial Revolution", with applications derived from advances in chemistry and electromagnetism, with this new energy applied to create devices, machines and systems in various productive processes. The improvement of electro-mechanical generation and of electric motors, together with more efficient electric light, and regional integration of power transmission and distribution systems opened up horizons for the economic diffusion of electricity.[25] The social and cultural worldwide transformations brought about by electricity, and later by electronics, had just begun, and the fast spreading of electric applications was led by the industrialized nations – foremost Great Britain, USA, Germany and France. The less developed areas of all continents were a sizable market to invest in electricity for the capital accrued by the fast growth of the recent industrialization waves.

51 The public demonstration of Thomas Edison's incandescent lamp occurred in Brazil in 1879, a show promoted by Emperor Peter II at the main railway station of the country's capital, Rio de Janeiro. The first hydroelectric plant (250 kW) was built in 1889 to power a textile mill in Juiz de Fora, in the state of Minas Gerais. Electricity came into the Brazilians' daily life at the decline of the Empire and it sped up during the first years of the Republic (after 1889), marking the association of electricity with the long-aspired modernization symbolized by the Republic. People were at first curious about the electric novelties imported from Europe and North America, such as the telegraph and telephone, and, of course, domestic electric energy. The arrival of electrification sounded the alarm bell for reviving within the new Republican regime an old polemic: the fight around the belated industrialization of the country. The public demand was an incentive to invest in electrification the considerable gains resulting from coffee exports, and Brazilian capitalists related to this activity felt that new "power and light" companies selling electricity as a commodity would mean an opportunity to participate in a market, which was fast becoming an indispensable part of the production system of the contemporary world.

52 From the viewpoint of foreign capital, there had been successive money inflows to Brazil since, in the wake of the Napoleonic wars, the Portuguese crown transferred its administrative center from Lisbon in Europe to Rio de Janeiro in 1808. Given the economic ties of Portugal with Britain, investments continued after the independence, and British capital was applied, directly or indirectly, to interior and external commerce, as well as to mining, agriculture and a few types of manufactures and urban services, including transportation.

53 As the tradition of the national capitalist sector continued to favor investing mostly in land products and cattle, it was not difficult for foreign investors to incorporate many existing local companies that provided public electric

25 Thomas Hughes, *Networks of power. Electrification in Western society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983). David Nye, *Consuming power. A social history of American energies* (Cambridge, Mass.: MIT Press, 1998).

Figure 11: *Coffee blossoms* - Painting by Antonio Ferrigno (1903), showing a São Paulo State landscape, with coffee plantation and women cleaning the ground. In the background, a train passes by the peasant's village. Source: Museu Paulista, University of São Paulo

illumination and distributed electric power to private owners during the first three decades of the 20th century. During the Old Republic (1889-1930), the bulk of economy followed the same pattern as in the monarchy, i.e. massive heavy foreign capital affluence, first English, later on German, and increasingly American after World War 1.[26] The general political direction continued favoring importation of manufactured goods, something that was to be reverted only during Vargas' "New Deal"-style policies.

54 São Paulo Province in the South of Brazil (São Paulo State, after the Republic, not to be confounded with its capital São Paulo City, founded in 1554) remained a forlorn backward region until its fertile soil was recognized as exceptionally good for coffee plantation, during the second half of the 19th Century. The world's continuously growing demand for the black beverage gradually ensured wealth for São Paulo (fig. 11), and contrary to the usual national trend of transferring profits thereof to non-productive goals, they were reinvested in local industries, which increased at a very pronounced rate the state's urbanization.[27]

Electrification spread most conspicuously in 55
Rio de Janeiro, and at the same time in the fast industrializing state of São Paulo, where the largest cities were its capital, São Paulo City, the harbor city of Santos and their surrounding areas, such as Campinas and Sorocaba (fig. 12). São Paulo City adapted soon to the novelty, at first mainly for industrial machines and streetcar traction.[28] Electric light gave an air of modernity by substituting oil lamps in the houses and gas lamps in the streets, and soon electricity

26 Wilson Suzigan, Tamás Szmrecsányi, "Os investimentos estrangeiros no início da industrialização do Brasil", *in* Sergio Silva, Tamás Szmewcsányi (orgs.), *História econômica da Primeira República* (São Paulo: Hucitec/Universidade de São Paulo, 2002), 279-283. José Carlos Pereira, *Formação industrial do Brasil e outros estudos* (São Paulo: Hucitec, 1984). Flávio Versiani, José Roberto Barros, *Formação econômica do Brasil. A experiência da industrialização* (São Paulo: Saraiva, 1977).

27 Sérgio Silva, *Expansão cafeeira e origens da indústria no Brasil* (São Paulo; Alfa-Ômega, 1995).

28 Gildo Magalhães, "Da usina à população na velocidade da luz: fios elétricos e desenvolvimento", *Labor & Engenho*, vol. 9, nº 1, 2015, 6-18.

became an “object of desire” for the entire population. As elsewhere in the world, new working and leisure hours were thereby introduced, and new habits were created.

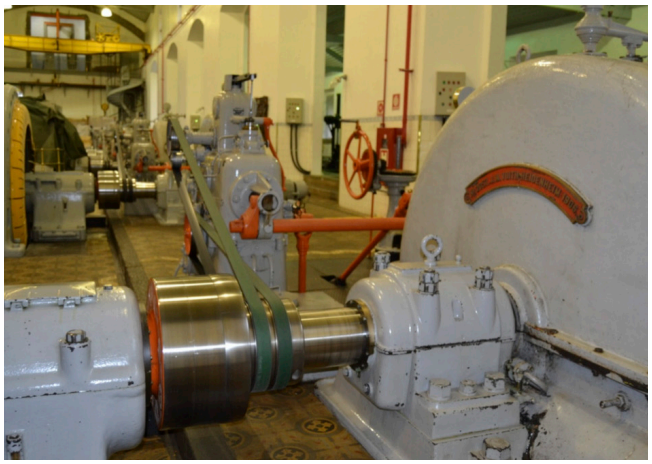

Figure 12: Itatinga power plant. Inaugurated in 1910, this plant was built to electrify the coffee-exporting harbor of Santos, and it still runs with the original equipment and buildings. Source; Electromemory Archive, University of São Paulo

With the coffee plantations’ steady boom during the early 20th Century, São Paulo State’s urban frontier moved westwards from São Paulo City and the cities near the coast. Until the 1920’s and 1930’s the Western area, comprising about half the state’s territory, remained mostly uninhabited, poorly geographically charted, and largely covered with the relatively mild (subtropical) Atlantic forests. Little touched by modern civilization, this was a land with areas still inhabited by hostile native Indians, while jaguars and snakes were not uncommon around the scattered villages. 56

On the other hand, scientific expeditions, led by São Paulo State’s Geographical and Geological Commission, had braved these areas from the 1890’s to the 1910’s, surveying their natural resources, including river courses and waterfalls (fig. 13). Those experts dutifully estimated a vast hydroelectric potential in the major rivers, and 57

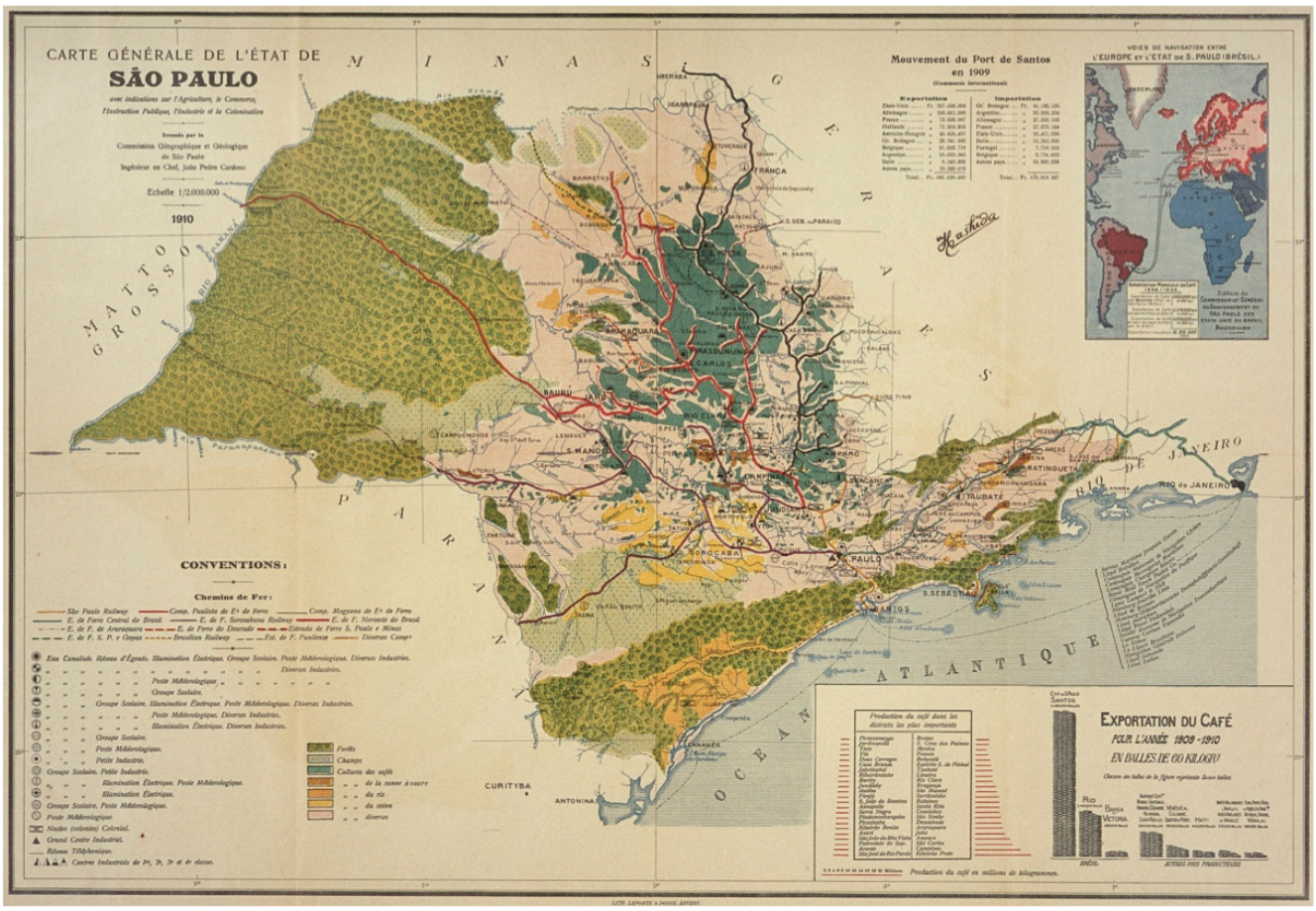

Figure 13: General chart (1910), São Paulo State Geological and Geographical Commission. This institution was responsible for surveying mineral and hydrological resources. Also depicted is the annual coffee exportation, Brazil’s main product, responsible for the first industrialization and electrification impulse. Source: Electromemory Archive, University of São Paulo

showed that the state had immense corresponding reserves of "white coal". At the time, this widely-used expression stressed that the three longest rivers in the state, Grande, Tietê and Paranapanema (which run contrary to the usual pattern from inland to the sea, and instead flow westwards from the high mountain ranges along the Eastern coastline towards the fertile plain lands limited by Paraná River basin) could indeed be used for massive electric power generation. This was quite convenient, given the expensive price of imported coal, and Brazil's small coal reserves. Due to these coal cost factors, before hydroelectric generation imposed itself, electricity was generated by burning cheaper wood after the devastation of nearby forests.

58 The ensuing urbanizing effort followed closely the advancing frontier of the coffee plantations, and together with the "white coal" available helped establish São Paulo's role as the leading Brazilian industrial center. It was also during the Old Republic that two engineering faculties were founded in São Paulo City: Polytechnic School (1894), state funded, public (free), and later (1934) incorporated to the first Brazilian university, the University of São Paulo; and Mackenzie School of Engineering (1896), privately-owned (founded by American Presbyterian missionaries), later part of Mackenzie University.

59 Both schools established electro-mechanical engineering courses in the early 1910's, and their graduates became part of São Paulo State's industrialization take-off.[29] Those engineers participated in the political life of the nation, including public debates in São Paulo's Institute of Engineering, and they took several initiatives, such as:

- Defense of national products versus imported ones.
- Suggestion of integrated use of energy resources (coal, hydro, oil, sugarcane alcohol), while emphasizing hydroelectric power as the best suited for the country.
- Promotion of professional schools for intermediate level technicians.
- Application of electric furnaces to steel production.
- Electric rail transportation (mass and freight).

60 An important spin-off of the Polytechnic School, and key to the industrialization effort was the Machine and Electrotechnic Laboratory (presently Institute of Energy and Environment, at the University of São Paulo), which in 1926 became the first national laboratory to conduct tests to standardize and to certify electric equipment for the local industries.[30]

61 With the happy conjugation of the factors of capital surplus (generated by coffee exports), expansion of labor force brought about by immigration, and technological support provided by the newly educated cadres, São Paulo State was able to reach the stage of the Industrial Revolution. This was, however, a belated achievement, in relation to the USA and the main European economies. In the beginning, all electric equipment was imported, but in 1923 electric cables began to be locally manufactured. Competition between foreign and fledgling national products appeared in several electrical applications. At first local inventors and their products displayed lower quality and higher prices, but they became increasingly better and cheaper.

62 Notwithstanding the improvement, several Brazilian electrical inventions did not materialize into products, a reflex of the lack of interest of local capitalists, and still a consequence of a traditional mistrust in the country's capacity as a manufacturer. A few relevant examples of this trend of lack of confidence during the Old Republic were: electric furnaces for metal processing (a Brazilian patent was relayed to a Belgian industry, after unsuccessful pledges of funding to the government); electrolytic

29 Gildo Magalhães, *Força e luz. Eletricidade e modernização na República Velha* (São Paulo: UNESP, 2000).

30 Only much later (in 1974) an important nationwide electric research institution was established by Eletrobrás in the state of Rio de Janeiro, the Center for Research in Electric Energy (CEPEL). See Renato Dias (coord.), *História do Centro de Pesquisas de Energia Elétrica – CEPEL* (Rio de Janeiro: Memória da Eletricidade, 1991).

transformers (the patent was sold to a French industry, which later exported them back to Brazil); submarine light-weight batteries, soon abandoned.[31] Consequently, the industrialization effort did not complete itself – a shortcoming which was felt not only in electrical innovations, but overall in Brazilian industry.

63 A further hindrance to expand the electric systems was the lack of standardization, in terms of voltages and frequencies. While the states that suffered more influence from American companies tended to adopt the frequency of 60 Hz and 110 V as final consumer voltage, the Southern states had considerable German influence, and they adopted 50 Hz and 220 V; elsewhere there were other slight variations. The 127 V value became more common after the 1960's and the frequency was standardized at 60Hz in the 1970's. This was also the period when the federal government succeeded in creating nationally integrated systems, which could efficiently and centrally dispatch electricity, in order to better distribute the load and share their electric availability. A larger integration has been more difficult to achieve with immediate Latin American neighbors.

64 The story of electrification becomes more complex when regarding the electric power companies. From 1888 onwards, small private companies in Brazil started operating thermoelectric generators using mainly wood as fuel for the steam turbines, and at the beginning they provided electricity principally to commercial houses and industries. The demand for electric energy in the state of São Paulo was also spurred by the fast diffusion of public illumination services, including small towns and villages. In the medium-sized Brazilian cities and in the larger State capitals, besides street illumination, the streetcar service also helped the electric market grow. Even though these predecessor companies did not last long, they showed that Brazil was a promising sizable market, which was in need of electricity for its economic development. Two types of companies marketed electric power from the end of the 19th century up to the 1930's. The greater number corresponded to the already-cited smaller companies, which were either municipal or operated regionally, and were organized by local landowners or businessmen. They used thermoelectric generation or small hydroelectric generation units, in some cases this latter type was an *in situ* adaptation of existing textile or lumber factories with waterwheels that supplied mechanical power to their production line.

65 The second group was far stronger in their investment capacity, and comprised foreign companies with roots in the international finance system. The foreign capital had the capacity to answer faster in this moment to the rapid growth of electricity demand by industrial and commercial consumers. They were also keener to take advantage of the other factor that benefited states like São Paulo: the large hydroelectric potential. Many small companies, unable to raise capital to build bigger dams and import generation equipment, were eventually bought up by the international groups, a movement which led power production to become concentrated in powerful and geographically expanding corporations, gaining more government-awarded concession areas. Two of the best known such foreign corporations were "Light" and "Amforp", as described in what follows.

66 In 1899, a group of British-Canadian investors established the "São Paulo Tramway, Light and Power Company", with the permit duly signed by Queen Victoria.[32] The initial investment amounted to US$ 6 million, which allowed the company (whose name was shortened by Brazilians simply to "Light") to incorporate a great deal of its competitors in the state of São Paulo in a short time, and also to expand in the direction of the neighbor state of Rio de Janeiro. As a matter of fact, Light was part of an international group of companies including interests in Belgium, Portugal,

31 Magalhães (2000), op. cit. More recently, products have had partial success, including electric motors, turbines, small or medium sized generators, and transformers.

32 Edgard Souza, *História da Light. Primeiros 50 anos* (São Paulo: Eletropaulo, 1982). Antônio Faria *et al.*, *Energia e desenvolvimento. 70 anos da Companhia Paulista de Força e Luz* (Campinas: CPFL, 1982).

Spain, Cuba; in Brazil it was under control of the holding "Brazilian Traction, Light and Power".[33] Light installed the streetcars' rails along main avenues in the city of São Paulo, while it simultaneously provided illumination and domestic electricity. In 1912 Light bought the English "The San Paulo Gas Company", responsible for the city's street illumination. By the way, as Light had the monopoly of electricity in São Paulo and Rio de Janeiro, the company opted for keeping liquefied gas for cooking, and not electricity, which is the predominant situation even nowadays, since cooking gas (natural or liquefied petroleum gas) prices are kept much lower than electricity for the household consumer.[34] The only Brazilian company that tried to oppose the economic interests of the foreign capital represented by Light, but was defeated in a series of political manoeuvers, was the industrial group "Companhia Brasileira de Energia Elétrica" (CBEE), headed by Eduardo Guinle.[35]

67 In the 1920's the Brazilian census confirmed that large areas of São Paulo State were rapidly becoming industrialized, and electrification represented an important role to achieve this result.[36] Light inaugurated large hydroelectric power plants, like Parnaíba (2MW in 1903, augmented to 16 MW in 1912), Ribeirão das Lajes (12 MW in 1908), and Cubatão (70.6 MW in 1927, 469 MW in 1949). This expansion attracted another major investor and competitor, the American & Foreign Power Co. (AMFORP), a branch of General Electric in the USA, which started operating in 1927, in the Midwest of São Paulo State. This company reached a kind of *entente* with Light, which kept for itself the axis São Paulo-Rio de Janeiro, while AMFORP bought up several smaller local businesses in the rest of the state of São Paulo, while it also reached to the neighbor state of Minas Gerais, and later to other states. By the end (1930) of the Old Republic, São Paulo had 166 power plants – 13.5 MW of thermal and 318 MW of hydroelectric generation, over 50% of Brazil's capacity concentrated in just one of the nation's 20 states, and mostly in the hands of those two foreign companies, which could also dictate the utility prices.

Soon the two foreign companies owned 80% 68
of the power concessions in Brazil, a situation that they maintained until 1960. Light and AMFORP were uninterested in improving their service quality, complaining that the government had limited their profits. Moreover, by then their installations had long ago become obsolete, and because of lack of proper maintenance, blackouts and power consuming restrictions had scratched the companies' reputation. At the same time, the automobile industry had established itself in the metropolitan area of São Paulo City, and more industry and urbanization implied a continuously growing electric demand.

The Brazilian electric sector history in mid- 69
20th Century was marked not only by this supply crisis faced by consumers, but also by the rekindling of ideological and cultural questions aroused by nationalist ideas, at this moment defended by several social sectors, with different hues. The publication of the federal Water Code in 1934 represented the first decisive state intervention act in the electric area. At the end of the 1940's the Inspectorate of Public Works was created in the State of São Paulo, subordinated to its Secretary of Roadways and Public Works. By this time, the federal government decided not only to increase its regulatory capacity, but also to start investing heavily in its own new hydroelectric plants. In the beginning of the 1950's, when engineer Lucas Garcez (a professor at the Polytechnic School) took over the office as São Paulo's Governor, the first state-owned power companies were created, and then they began the construction of higher-capacity power plants that became the largest hydroelectric generation complex in the country.[37]

33 Duncan McDowall, *The Light. Brazilian Traction, Light and Power Company Limited, 1899-1945* (Toronto: University of Toronto Press, 1988).

34 João Luiz Silva, *Cozinha modelo. O impacto do gás e da eletricidade na casa paulistana, 1870-1930* (São Paulo: EDUSP, 2008).

35 Alexandre Saes, *Conflitos do capital. Light versus CBEE na formação do capitalismo brasileiro, 1898-1927* (Bauru: EDUSC, 2010).

36 Helena Lorenzo, Wilma Costa, *A década de 1920 e as origens do Brasil moderno* (São Paulo: UNESP, 1997).

37 Catullo Branco, *Energia elétrica e capital estrangeiro no Brasil* (São Paulo: Alfa-Ômega, 1975).

Figure 14: Jupiá. Built on Paraná River (1974), this large hydroelectric was also a landmark, as it was the first power plant totally designed by national engineering. The dam is 5,495 m long, and the reservoir has an area of 330 km2. Source: CESP

70 The year 1950, besides representing a paramount crisis of electric energy, which entailed dramatic electric energy shortage in the following years, signaled also the beginning of the engineering studies for Barra Bonita hydroelectric plant, on the Tietê River in São Paulo, which came to conclusion in January, 1956. From this point on, São Paulo State's intervention and participation increased, first with the creation in 1951 of the Water and Energy Department, and subsequently, several state power companies were formed in the state. Among these were: "Paranapanema River Basin Electric Plants" (*USELPA*), in 1953; "Pardo River Hydroelectric Corporation" (*CHERP*), in 1955; and finally, "São Paulo Electric Plants" (*CESP*), in 1966, which incorporated the previous ones, as well as a large number of smaller private companies.

71 After a series of public debates, which emphasized the evident lack of interest from the part of the private companies in providing electric energy for the new cycle of economic development, public opinion pressed the government to cancel their concession.[38] The foreign companies were either expropriated or bought by the government, and so ex-AMFORP (in 1975) and ex-Light (in 1979) also became part of the state's public energy grid, which could then provide the whole chain of electric generation, transmission, and distribution, so that electricity became a "vertical" utility. Their common ownership facilitated planning and constructing the backbone of São Paulo state's electric generation: the hydroelectric plants of Bariri, Ibitinga, Caconde, Euclides da Cunha, Limoeiro, Barra Bonita, Jupiá (fig. 14), Ilha Solteira, Porto Primavera, Promissão, Avanhandava, Água Vermelha, Taquaruçu, Rosana, Capivara, Canoas 1 and Canoas 2, Chavantes, Jurumirim, Paraibuna, and Jaguari (a total of 11,094 MW).

38 Eletropaulo, "Departamento de Patrimônio Histórico, Estatização x privatização", *História & Energia*, vol. 7, 1997.

72 In the federal plan, Eletrobrás, a federal holding company, was created in 1962, after a long struggle against privatization interests, and with it the planning of the electric energy sector, which used to be regional, began to be nationwide and more rationalized. Centralized load dispatching was introduced, so that technical integration among the various state and regional systems was enhanced, resulting in their joint dispatch operation and supervision.[39] The new cycle of development of electricity and of the economy as a whole coincided with the military regime (1964-1985), when only a few electric concessions remained in private hands.[40] The subsidiaries of Eletrobrás were regrouped in four major regional companies: CHESF, a state company, already created by President Vargas in 1945, destined to exploit the hydroelectric potential of São Francisco River in the Northeast of Brazil; Furnas, active mostly in the Midwestern states; Eletrosul, for the Southernmost states; and Eletronorte, for the vast Amazon region.[41] During the military regime a treaty signed between Brazil and Paraguay allowed the construction of Itaipu, a major hydroelectric generation plant, with a maximum capacity of 14 million MW in the state of Paraná, inaugurated in 1984 (the last unit became operational in 2007). The energy generated at Itaipu is carried through high voltage (600 kV) direct current transmission lines (810 km long), as Brazil buys the excess energy generated at the Paraguayan side at 50 Hz, converting it to direct current and then reconverting it to 60 Hz for distribution, nearby São Paulo City.

73 An important aspect of the process was the simultaneous improvement of the national engineering capacity for designing hydroelectric works, a basis for the future Brazilian consulting and design companies that gradually substituted foreign experts, who had traditionally been in charge of this service before. A distinctive feature of Itaipu is exactly that this great project was designed by a group of Brazilian engineering companies, a fact considered as a "coming of age certificate" for local technology. Those companies later became large national consulting groups, and contributed to the country's economic development also in the petrochemical and industrial projects in general.

74 The great hydroelectric projects of the period, like Itaipu in Paraná State and Ilha Solteira (3.444 million MW) in São Paulo, were constructed with external financing. National and international political decisions resulted in very heavy debt services, while the government's National Economic and Social Development Bank (BNDES) imposed rules that practically turned electric investments prohibitive for the state-owned companies later on. After the military left power in 1985, the "New Republic" aligned itself with the so-called Washington Consensus, decidedly enforcing neoliberal reforms. The decision to privatize the electric sector state companies (fig. 15) was taken by President Fernando Henrique, which privatized also the telecommunications sector, state banks, iron mining, and railroad companies.[42]

75 In terms of electric supply, the effects of deregulation were more immediately and acutely felt in the state of São Paulo. The result was twofold: the sale of the state companies over to private initiative, and secondly the denationalization of the sector, as the biddings were won by foreign investors, mainly American and, later, resold to Chinese. The previous pattern, of almost total control of the electric sector policies by state companies, gave way to another model, one where the vertical business of generation,

39 José Luiz Lima, *Políticas de governo e desenvolvimento do setor de energia elétrica: do Código de Águas à crise dos anos 80* (Rio de Janeiro: Memória da Eletricidade, 1995). Marcelo Silva, *Energia elétrica, Estatização e desenvolvimento, 1956-1967* (São Paulo: Alameda, 2011).

40 Anon. *A energia elétrica no Brasil* (Rio de Janeiro: Biblioteca do Exército, 1977). Francisco de Assis Gomes, "A eletrificação no Brasil", *História & Energia*, vol. 2, 1986. Renato Dias, *Panorama do setor de energia elétrica no Brasil* (Rio de Janeiro: Centro de Memória da Eletricidade, 1988), 198-215.

41 Renato Dias (coord.), *A Eletrobrás e a história do setor de energia elétrica no Brasil* (Rio de Janeiro: Centro de Memória da Eletricidade, 1995). John Cotrim, *A história de Furnas. Das origens à fundação da empresa* (Rio de Janeiro: Furnas Centrais Elétricas, 1994).

42 Lindolfo Paixão, *Memórias do \projeto RE-SEB* (São Paulo: Massao Ohno/ENRON, 2000).

Figure 15: Privatization struck São Paulo State more heavily than the rest of Brazil. These 24 largest hydroelectric power stations in São Paulo State were built by the public sector along 4 major rivers in the second half of the 20th Century, and sold to foreign investors starting in 1998. Source: Electromemory Archive.

transmission, and distribution, previously provided by the same authority, was subdivided and mostly horizontally transferred to different private hands. The price of electric energy, which used to be calculated by a method of historic production costs, became instead a function of market auctions, where energy batches constitute merely a merchandise, and are also subject to the effects of the speculative action of future markets.[43]

76 Table 5 shows the chronological evolution of the 20 largest-capacity hydroelectric stations in Brazil in the last five decades.

77 The average annual electricity consumed by Brazilians is presently 2,578 kWh/inhabitant, a low number even among Latin American countries.[44] The correlation between energy consumed and wealth concentration is well established, and there has been a strong concentration of the use of electricity in the upper layers of society.[45]

78 It is evident that the electricity per capita availability would have to be increased to cope with population growth and a better wealth distribution. However, a new political factor has slowed down the development of hydroelectricity: radical environmentalism mobilization against hydroelectric plants, using even physical violence, by burning construction sites, inciting Indian use

43 Ildo Sauer, "Energia elétrica no Brasil contemporâneo: a reestruturação do setor, questões e alternativas", *in* Adriano Branco (org.), *Política energética e crise de desenvolvimento* (Rio de Janeiro: Paz e Terra, 2002). José Paulo Vieira, *Antivalor. Um estudo da energia elétrica: construída como antimercadoria e reformada pelo mercado nos anos 1990* (Rio de Janeiro: Paz e Terra, 2007).

44 International Energy Agency, Key World Energy Statistics 2016 (data from 2014), access on April 24, 2017, at www.iea.org/publications/freepublications/publication/KeyWorld2016.pdf

45 Antônio Carlos Boa Nova, *Energia e classes sociais no Brasil* (São Paulo: Loyola, 1985).

Plant	Power (MW)	Start
Ilha Solteira	3,444	1973
Jupiá	1,551	1974
Foz do Areia	2,511	1976
Marimbondo	1,814	1977
São Simão	1,710	1978
Paulo Afonso IV	2,850	1979
Água Vermelha	1,380	1979
Salto Santiago	1,420	1980
Itumbiara	2,082	1981
Itaipu	12,600	1982
Tucuruí	8,360	1984
Itaparica (Luiz Gonzaga)	1,480	1988
Xingó	3,162	1994
Serra da Mesa	1,275	1998
Itá	1,450	2000
Porto Primavera	1,430	2000
Santo Antônio	3,568	2012
Jirau	3,300	2012
Teles Pires	1,820	2015
Belo Monte	11, 187	2016

Figure 16: *Table 5 – Chronology of larger capacity hydro-power stations in Brazil*
Source: Data compiled by author (2018)

Source	1966	2016
Hydraulic	73	64.0
Thermal (gas, biomass, oil, coal)	27	30.2
Thermal (nuclear)	0	2.4
Eolic	0	3.4

Figure 17: *Table 6 – Evolution of electric generation sources in Brazil (%)*
Source: EPE – Ministry of Mines and Energy, *National Energetic Balance* (Rio de Janeiro, 2017)

of weapons against engineers and workers, etc. The starting point for this occurred in 1998 during the "Indigenous Peoples' Meeting" of Altamira, in the Amazon region, sponsored by the "Forest Alliance", jointly organized by the World Bank and World Wildlife Foundation, with the support of the World Council of Churches and several Non-Governmental Organizations.[46] This movement was endorsed by President Fernando Henrique Cardoso and by the governments that followed his own, which strongly backed up a position against the construction of new hydroelectric plants, initially in the Amazon region, but they succeeded in barring other initiatives around the country, as well. This reaction created a political mood which defined hydroelectric plants as anti-ecological, and as enemies of local inhabitants, Indians or not, an outlook that has continually weighed on public opinion.[47]

79 These attacks succeeded in delaying or even cancelling already approved projects. Among the plants that suffered significant delays due to this effect, one may cite Tucuruí (8,360 million MW) on the Tocantins River, and the hydroelectric plants on Madeira River: Belo Monte (11,197 million MW), Santo Antônio (3,568 million MW), and Jirau (3,300 million MW). A compromise was reached for some plants, which had to lower their dam height, reducing the projected power capacity, and at the same time to diminish the flooded area corresponding to the artificial lake, thereby affecting the produced energy during the dry seasons.

80 A consequence of those conflicts and the standstill regarding hydraulic power was the decision to generate electricity by means of sources other than water. Wind turbines, besides thermal generation employing gas, especially in the Amazon region, biofuels and coal have all been replacing hydroelectric generation. Taxes on electric bills were imposed to the normal consumer to compensate for the higher cost of thermal plant operation, adding on to the already higher prices that resulted from privatization.

The evolution of electric sources is seen Table 6, 81
which shows a fifty-year interval, indicating the displacement of hydraulic generation by thermal and wind generation.

FINAL REMARKS

The history of energy in Brazil, as in other coun- 82
tries, has also been a history of the battle to become a developed nation. Major cycles of economic development occurred in three distinct phases, and all of them were connected with energetic questions. After preliminary efforts beginning in the second half of the 19th Century, the impacts of World War I contributed to an industrialization wave in São Paulo during the 1920's, which was enhanced and politically used during the 15 year-long first Vargas administration. The main question addressed in this period was electrification and the progressive dominance of hydraulic generation, and a second issue was the existence of oil reserves in Brazil. A nationalist sentiment was solidified, as noted in the discussions about oil prospection and steel production in the country.

The end of World War II also represented an 83
opportunity for an economic impulse, which was signaled by the creation of state companies related to electricity and oil. The petrochemical industry and the automobile plants installed by multinationals in São Paulo challenged the existing foreign electricity concessionaries to produce more energy, and their negative reply made the State gradually enter the electric sector. The military regime made good use of the resulting available infrastructure, and many imported manufactured goods were substituted by nationally produced equivalent products, thus increasing the industrialization in the country. The threat posed by the oil shocks was attenuated by the introduction of ethanol derived from sugarcane as a substitute.

46 Lorenzo Carrasco *et al.*, *Ambientalismo, novo colonialismo* (Rio de Janeiro: Capax Dei, 2005).

47 Lygia Cabral (coord.), *O meio ambiente e o setor de energia elétrica brasileira* (Rio de Janeiro: Memória da Eletricidade, 2009). Carlos Locatelli (org.), *Barragens imaginárias. A construção de hidrelétricas pela comunicação* (Florianópolis: Insular, 2015).

84 The political re-democratization in 1985 also concurred to the adhesion to the neoliberal ideology, which favored the skyrocketing of interest rates and the domination of the economy by speculative financial capital. The privatization of many sectors included the public auctioning of electric generation and transmission lines, and the local distribution networks, as well as significant parts of the oil industry. A shorter economic boom was manifest during President Lula's administration, with the discovery of huge oil and gas deposits in the continental platform under the sea. The electric supply, however, did not follow this trend, radical environmentalism prevented the expansion of hydroelectric and nuclear power plants, and the deregulation of this electric market signified a real increase of rates far above the inflation. The forceful use of thermal electric generation only complicated the situation, with the end of the economic development effort, and the subsequent stagnation, deindustrialization, and high unemployment verified in the country. Social and political tension increased, income concentration returned to previous high levels, and this setback made the country again highly dependent on imported technology.

85 During the energy crises, ideological disputes have questioned whether there is a correlation between energy consuming and economic development. Neo-Malthusian currents have denied such a dependence, arguing for a population control, the curbing of industrialization, and a "greening" of energy sources. However, a truly sustainable economy should provide not only for a necessary control of the quality of air and water, as well as avoiding wastes, but to plan for coming generations the necessary production of enough food, transportation, and public health – all of which demand a growing energetic input. Brazil has sometimes been looked at as a model for these discussions, given national initiatives such as its biofuel policies, and also because it is a large territory comprising the vast reserve of the Amazon forest. All of this suggests a closer attention to how the country's history of energy has developed so far.

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A hitchhiker's guide to quantitative energy studies

Abstract
The increasing digitisation and availability of energy data facilitates their application in research and teaching, but also requires careful source criticism, due to the variety of methodological conventions. This paper introduces the basic principles of quantitative energy studies. After some general remarks on using and interpreting energy data, three open access databases of particular usefulness to energy historians are scrutinized as to their theoretical and methodological approaches. The paper closes with reflections on the value of energy statistics for historical studies, advocating a careful combination of quantitative and qualitative sources.

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The author thanks Ute Hasenöhrl for fruitful discussions and two anonymous referees for their helpful comments on an earlier version of this paper. This paper is based on a comprehensive quantitative cross-country analysis of energy transitions where these three specific datasets have been used (Irene Pallua, "Historische Energietransitionen im Ländervergleich: Energienutzung, Bevölkerung, Wirtschaftliche Entwicklung", *Social Ecology Working Paper* 148, IFF-Social Ecology, 2013).

Plan of the article

ENERGY TRANSITIONS AND QUANTITATIVE DATA

1 Over the last 250 years, Western societies shifted their energy base from traditional non-fossil energy sources such as biomass and hydropower to fossil energy. This protracted process is generally referred to as "energy transition". According to Vaclav Smil, the term "is used most often to describe the change in the composition (structure) of primary energy supply, the gradual shift from a specific pattern of energy provision to a new state of an energy system."[1] In the last three decades, historians as well as scholars from neighbouring disciplines have published a growing number of studies on historical energy transitions, focussing on changes of national energy systems within specific socioeconomic and political contexts. These studies are often based on data on the primary energy consumption of individual nations (or nation groups). This data is utilized to investigate and illustrate quantitative aspects of energy transitions, in particular historical turning points when an energy source gains relative dominance, as depicted in figure 1.[2]

2 For a quantitative history of energy transitions, energy data covering a significant period of time is an indispensable source. While energy data on the post-Second World War period is accessible on websites of various national statistical offices and international organisations (International Energy Agency, the World Bank, the European Union, the OECD or the United Nations), empirically sound data on earlier time periods is not so readily available. Because of this, scholars investigating historical energy transitions have

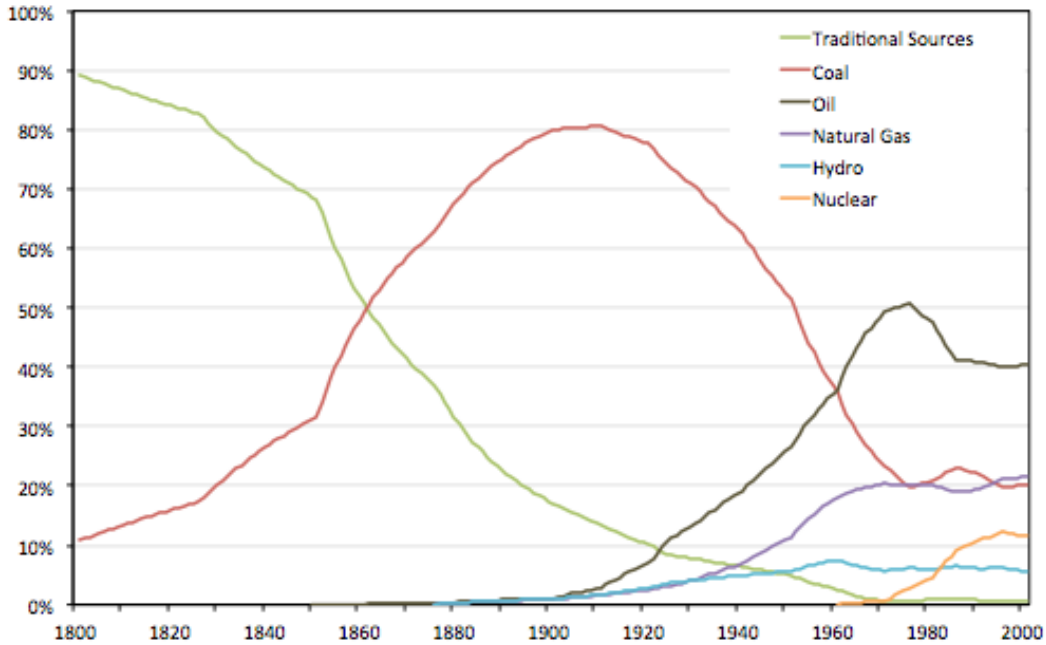

Figure 1: *Energy transitions in OECD countries*
Data from Arnulf Grubler, "Energy Transitions" *in* Cutler J. Cleveland (ed.), *Encyclopedia of Earth* (Washington D.C.: Environmental Information Coalition, National Council for Science and the Environment, 2008, updated 2013, online version, accessed on March 11, 2018.). For a more detailed discussion and interpretation of this data see Arnulf Grubler, "Energy Transitions Research"

1 Vaclav Smil, *Energy Transitions: History, Requirements, Prospects* (Santa Barbara, Calif.: Praeger, 2010), vii. For alternative definitions, see Benjamin K. Sovacool, "How Long Will It Take? Conceptualizing the Temporal Dynamics of Energy Transitions", *Energy Research & Social Science*, vol. 13, 2016, 202-203.

2 E.g. Roger Fouquet, "Historical Energy Transitions. Speed, Prices and System Transformation", *Energy Research & Social Science*, vol. 22, 2016; Arnulf Grubler, "Energy Transitions Research: Insights and Cautionary Tales", *Energy Policy*, vol. 50, 2012; Irene Pallua, *Historische Energietransitionen im Ländervergleich*, 75-104 (cf. note 1).

begun to compile their own datasets, resorting to a variety of sources ranging from official statistical accounts, comprehensive statistical works,[3] information from individual "energy producers" (e.g. coal mines), to primary and secondary literature. Similar to written sources, statistics are contextually produced, reflecting specific spatial and temporal frameworks. More generally speaking, numbers are not at all neutral.[4] Therefore, the retrospective compilation of a database implies correcting (and producing to some extent) different bias.[5]

3 Besides these general problems of historical statistics, working with energy statistics has additional – and very specific – pitfalls, which will be addressed in the first part of this article. The second part then portraits three essential energy databases, which provide data for over 30 countries in total and could be helpful for scholars of energy history, analysing the included countries. Criteria for choosing these databases were unrestricted access, the presence of long-term data, and extensive country coverage. In the concluding remarks of this paper, the overall value of this data for energy history will be assessed.

WORKING WITH ENERGY STATISTICS: PITFALLS AND CAVEATS

4 One of the most important methodological tasks of historical science is source criticism. It is vital to understand the language of the source, its forms, and formulas and their background. This holds true for written sources, images, objects *and* numbers. As medieval historian C.R. Cheney phrased it, they "(...) only speak when they are spoken to, and they will not talk to strangers."[6] Thus, it is often necessary to apply knowledge from other disciplines, to work adequately with specific sources. The following paragraphs present some knowledge from the natural sciences, that is regarded as helpful for understanding energy and, additionally, they address possible pitfalls, such as the level of measurement and the quantification of electricity. Finally, specific energy units, conversion factors and calorific values are discussed.[7]

5 To understand energy and its value for society and the economy, we have to enter the world of physics, or more precisely, thermodynamics. According to the first law of thermodynamics, the total amount of energy in an isolated system is always constant (conservation of energy states). Thus, energy can neither be created, nor can it be destroyed – it can only be converted. The second law of thermodynamics deals with spontaneous change in the energy distribution. Energy can only be converted if the entropy of the system increases. As a result, every conversion is accompanied with "losses" i.e. undirected energy is released (e.g., waste heat) that can no longer be transformed into useful work. The amount of the energy convertible in useful work is named exergy and it decreases when energy is converted. Energy consumption in this sense means that the energy bound in energy carriers is converted into an "inferior" form of energy, an irreversible process. Thus, the second law of thermodynamics imposes physical restrictions to societal utilization of energy – it is not infinitely transformable into useful work.

6 Energy accounting frameworks, such as the energy balances published by international

3 E.g. Brian R. Mitchell, *International Historical Statistics: 1750-2005* (Basingstoke: Palgrave Macmillan, 2007); Bouda Etemad, Jean Luciani, *World Energy Production, 1800-1985: Production mondiale d'énergie, 1800-1985* (Genève: Librairie Droz, 1991).

4 Pat Hudson, Mina Ishizu, *History by Numbers: An Introduction to Quantitative Approaches* (London, Oxford, New York, New Delhi, Sydney: Bloomsbury Academic, 2017), 1.

5 Other issues with historical statistical data include its incompleteness and/or fragmentation, changing definitions or alternating units of measurement. Therefore, they have to be interpreted with care. Such precautionary recommendations can be found e.g. in the introduction of Brian Mitchells seminal compilation of historical statistics (Brian R. Mitchell, *International Historical Statistics*, op. cit., vii-ix).

6 Christopher Robert Cheney, *The Records of Medieval England: An Inaugural Lecture* (Cambridge, UK: Cambridge University Press, 1956), 11.

7 This section makes no claim to completeness. It is only intended to give some insights into the matter of energy statistics. As the section refers to the methodology used by international bodies in particular, it is further strongly recommended to always crosscheck the methodology adopted for compiling the specific energy data that will be used.

bodies like the International Energy Agency (IEA), United Nations, Eurostat[8] or national statistical offices are closely linked to these concepts. They account for "energy flows" in a given unit of time (e.g. a year), which can generally be defined as the throughput of energy required for sustaining a relevant socioeconomic unit of analysis. The unit under study has to be defined and clearly delineated.[9] The main flows are – somewhat simplified – energy production (extraction, capture or manufacturing of fuels or energy in a national territory ready for further transformation or societal use), energy imports (energy flows energy entering the national territory) and energy exports (energy flows leaving the national territory).[10] Energy balances account for these flows and reflect three *levels of measurement*, where the level of exergy decreases from one to another:

- "Primary Energy" refers to all energy in that form as it is extracted from the natural environment, including coal, crude oil, geothermal heat, natural gas, nuclear heat, water, wind power and wood. Adding net imports to domestic extraction, the related and widely used indicator TPES "total primary energy supply" expresses the available amount of "raw energy" for the provision of energy needed in a society. While some primary forms, like natural gas for heating purposes are delivered directly to users, primary energy is usually converted into final energy. As explained above, these conversions are always subject to loss. The lower the loss, the higher the efficiency of the conversion technology, but it cannot be reduced to zero.
- "Final energy" is defined as energy directly reaching end-users such as agriculture, trade, services, public administration, transport and industry, or households, but excluding the energy transformation sector (e.g. power plants, refineries). Examples for final energy are diesel, gasoline or heating oil, coke, town gas and electricity. Final energy can also be imported or exported. Final energy consumption becomes relevant if energy use is investigated at the sectoral level.
- "Useful energy" refers to the energy that becomes effective in the provision of energy services, such as light or heat. In this context, the efficiency of technical engines plays a key role.

When using or interpreting energy data it is very important to consider the level of measurement in which it is given, otherwise this might lead to misinterpretations. Due to the mentioned "losses", the difference, for example, between TPES and final energy is around 30 percent.[11] 7

Another source of ambiguity that needs to be assessed properly when working with energy data is the *quantification of electricity*. Electricity, as a secondary energy form,[12] can be generated from a variety of primary energy sources. In order to avoid double counting, the IEA and the OECD apply the following standardized logic: only the first energy form (primary energy) used to produce electricity is accounted for, rather than the amount of electricity generated by a power plant 8

8 IEA, "Energy Balances Statistics", available at http://www.iea.org/statistics/topics/energybalances/, accessed Dec. 16, 2017, Eurostat, "Energy Balances", available at http://ec.europa.eu/eurostat/web/energy/data/energy-balances, accessed Dec. 16, 2017.

9 In energy history, nation states are often of particular interest, but also other units of analysis are certainly conceivable, depending on the research focus: regions, cities, specific economic sectors, like the building sector, industry, or even a household. Applying a macro perspective, energy flows can be described as energetic exchange between society and the environment. Energy harvested from energy rich raw materials (fossil fuels, biomass, and uranium) and non-combustible "new" renewables (e.g. wind, geothermal heat, solar energy,) enters a socioeconomic system. During and after been "consumed", corresponding outputs, like emissions or waste heat, can provoke several environmental impacts, like global warming.

10 More details can be found in United Nations Statistics Division, "International Recommendations for Energy Statistics (IRES)", available at https://unstats.un.org/unsd/energy/ires/IRES-web.pdf, accessed Dec. 16, 2017, 56-58.

11 According to the IEA, global TPES in 2015 was 13,647 Mtoe, while global final energy consumption was only 9,384 Mtoe (IEA, "World Energy Balances: Overview 2017", available at http://www.iea.org/publications/freepublications/publication/WorldEnerg..., accessed Dec 16, 2017).

12 Secondary energy is transformed primary energy. Apart from electricity, other examples include petrol, gasoline or heating oil, that derive from processing crude oil, or coke and briquettes that are manufactured from coal.

(e.g. the energy input in a fossil-fuelled thermal power plant). That is why only electricity generated from nuclear heat, hydropower, geothermal, or solar heat is taken into account in total primary energy supply and not electricity generated from fossil fuels (see fig. 1, where only the share of nuclear heat and hydropower are depicted). However, data on final energy consumption, for example, includes the total amount of electricity generated from all types of energy. Since various methods for calculating primary electricity from non-combustible sources exist,[13] one should always be aware which convention on the quantification of electricity is used when comparing, interpreting or compiling energy data –these conventions can vary across sources and lead to considerably different outcomes. One method recommended and applied currently by the United Nations Statistics division and the IEA is the "physical energy content method", where the energy content of the primary energy source is accounted for. For electricity production from non-combustible resources, heat input is estimated based on assumed conversion efficiencies of 33% for nuclear and concentrating solar, and 10% for geothermal. Thus, the total energy expenditure required to produce a certain amount of energy from nuclear fission is about three times higher than the energy content of the generated electricity. This method has replaced the "partial substitution method" for calculating primary electricity from non-combustible resources, which was used by IEA in the past.[14]

9 There is another difficulty when working with energy data, especially when compiling them: they can be expressed in *different units*. According to the International system of units, established in 1960, the unit for energy is Joule. However, not all energy data is given in this unit. Alternatives that could be used in energy statistics are, for example, tons of oil equivalent (toe), Kilowatt-hours (Kwh) or British Thermal units (Btu). When confronted with different units it is important to convert data into a common unit, favourably into Joules and its multipliers Megajoule (MJ, 10^6 J), Gigajoule (GJ, 10^9 J), Terajoule (TJ, 10^{12} J) or Petajoule (PJ, 10^{15} J) (see table 1)

	PJ	Mtoe	MBtu	GWh
PJ	1	2.388×10^{-2}	9.478×10^{5}	2.778×10^{2}
Mtoe	4.187×10	1	3.968×10^{7}	1.163×10^{4}
MBtu	1.055×10^{-6}	2.520×10^{-8}	1	2.931×10^{-4}
GWh	3.6×10^{-3}	8.598×10^{-5}	3.412×10^{3}	1

Figure 2 : *Table 1- Conversion factors for energy units*
IEA, *Key World Energy Statistics* (Paris, 2017), 70. A unit converter provided by OECD/Eurostat can be found at http://www.interenerstat.org/converter.asp, accessed on Dec. 16, 2017.

Moreover, sometimes energy is accounted as 10
commodity and values are shown in the original units of measurement, e.g. mass units (kilogramme or tonne) for solid fuels and volume units (e.g. litres –often converted in intermediary units, such as barrels– or cubic metres) for liquids or gaseous fuels. The average conversion factors used to transform this values into Joule only partially reflect the spatial or temporal variability of the calorific value of energy sources[15] and certain flaws can therefore not be ruled out.

Another source of misinterpretations can be the 11
most relevant property of a combustible energy source: its calorific value. There are two conventions used in energy statistics, namely the net (NCV) and the gross calorific values (GCV), where the latter also includes the condensation heat produced during combustion of the fuel measured under laboratory conditions. Generally,

13 E.g. Subhes C. Bhattacharyya, *Energy Economics: Concepts, Issues, markets and governance* (London, New York: Springer, 2011), 27-28; United Nations Statistics Division, *International Recommendations for Energy Statistics (IRES)*, 103-104 (cf. note 12).

14 With this method, the primary energy equivalent was calculated as the hypothetical amount of energy needed in a thermal power plant to generate the same amount of electricity. It was abandoned, however, due to difficulties in calculating the energy balance (*Id.*)

15 Country specific conversion factors, if available in the methodological description of (historical) official energy accounts, should be used. For a general introduction of conversion factors used for compiling energy statistics and balances see United Nations Statistics Division, *International Recommendations for Energy Statistics (IRES)*, 45-54 (cf. note 12), for default calorific values of specific energy sources and products see *ibid.*, 48-50.

NCV is about 5 to 6 percent less than GCV for liquid and solid fossil fuels and about 10 percent for natural gas.[16] Hence, it is vital to know which calorific value is used, when compiling or interpreting energy data.

ENERGY DATABASES

12 As the preceding section has shown, compiling energy datasets is not at all a straightforward task. Fortunately, scholars working on historical energy transitions have compiled databases, which can be of interest for historians working on energy history. In the following paragraphs, three open access databases covering a period of at least 150 years are introduced as sources for research on energy transitions. (1) The Podobnik energy dataset, which covers 27 countries from all continents and was compiled at the end of the 1990s; (2) the data collection elaborated in the Global Energy Project of the Joint Seminar of History and Economics and the MIT Research Group on History, Energy, and Environment covering 11 countries with a regional focus on Europe and the Americas; and (3) the data collection of the Viennese Institute of Social Ecology, focussing on industrialized countries, the city of Vienna as well as on the global level. While Podobniks' energy dataset comprises only modern commercial energy sources, the other two datasets also include biomass as an energy source, but adopt different definitions of societal relevant biomass flows. The basic logic to calculate primary energy consumption applied in all the three datasets is adding up domestic energy production, energy imports and subtracting energy exports.

13 In general, a quality indicator for such databases is a concise but accurate description of sources and methods, allowing users to understand the underlying assumptions and methodologies that largely depend on the research direction and the disciplinary focus of its authors. Such guidelines are provided in (2) and (3), while (1) lacks a comprehensive technical introduction.

The Podobnik Energy Dataset

14 The Podobnik Energy dataset[17] consists of a single Excel-file and was published in 2011 on the website of the Knowledge Network for Energy Transitions by Cutler J. Cleveland. Physical quantities of primary energy production, trade and consumption as well as population and GDP data[18] are presented for 27 selected countries around the globe covering (to varying degrees) the period from 1800 to 1997. This dataset was originally compiled by the sociologist Bruce Podobnik and used in his book "Global Energy Shifts: Fostering Sustainability in a Turbulent Age"[19] as a quantitative background for his analysis on global energy shifts, in correlation with geopolitical rivalry, corporate competition and social conflicts.[20]

15 The database comprises the production of hard and brown coal, oil (in metric tons and tons of oil equivalent (toe)[21]), natural gas (in Terajoules (Tj) and toe) and electricity produced in hydropower plants, as well as in geothermal and nuclear power plants (kilowatt-hours and toe)[22]. Data on trade with fossil fuels and electricity is missing for early years and included from 1925 onwards only. As primary energy consumption is usually calculated as the sum of domestic energy +/– traded energy, energy consumption before

16 OECD, IEA, Eurostat, *Energy Statistics Manual* (Paris, 2005), 20. The Internationals Energy Agency uses the NCV in its energy balances (IEA, *Key World Energy Statistics*, 71 (cf. note 17); IEA, *World Energy Balances* (Paris: IEA, 2017).

17 Data can be retrieved from http://www.digitaluniverse.net/energytransitions/topics/view/51cbfc90f7...

18 GDP and Population are taken from Angus Maddison, *Monitoring the World Economy, 1820-1992* (Paris: OECD Development Centre, 1995). The latest release of this database is available on http://www.ggdc.net/maddison/maddison-project/home.htm accessed on Dec. 12, 2017.

19 Bruce Podobnik, *Global Energy Shifts: Fostering Sustainability in a Turbulent Age* (Philadelphia, Pa.: Temple Univ. Press, 2006). See also Bruce Podobnik, "Toward a Sustainable Energy Regime", *Technological Forecasting and Social Change*, vol. 62/3, 1999 and "Global Energy Inequalities: Exploring the Long-Term Implications", *Journal of World-Systems Research*, vol. VIII/2, 2002.

20 Bruce Podobnik, *Global Energy Shifts*, op. cit., 1-17.

21 One ton of oil equivalent is defined as the amount of energy released by burning one tonne of crude oil.

22 In his book, Podobnik presented data on fuelwood and alternative energy sources that is not included in this dataset.

Region/country	Time period covered	Indicators
Africa		• Energy production (thousand tons of oil equivalent, toe): coal, oil, natural gas, hydro, nuclear energy, geothermal energy • Energy imports (thousand toe): coal, oil and natural gas and its products, electricity imports • Energy exports (thousand toe): coal, oil and natural gas and its products, electricity exports • Total energy consumption = energy production + imports – exports (thousand toe), also given for single energy carries • Per capita energy consumption (GJ/cap) • Energy growth rates (%) • Economic growth rates (%) • Shares of single energy sources in total energy consumption (%) • GDP (million Geary-Khamis 1990 Dollars) • Energy/GDP ratio (TOE Per Thousand GK (1990) $
Nigeria	1915-1997	
South Africa	1884-1997	
Asia		
China	1898-1997	
Hong Kong	1921-1997	
India	1851-2000	
Indonesia	1889-1997	
Iran	1906-1997	
Iraq	1925-1997	
Israel	1949-1997	
Japan	1870-1997	
Kuwait	1935-1997	
Australia and Oceania		
Australia	1848-1997	
Europe		
Austria	1800-1997	
Belgium	1876-1997	
Denmark	1800-1997	
France	1800-1997	
Germany**	1800-1997	
Italy	1846-1997	
Netherlands	1860-1997	
United Kingdom	1800-1997	
USSR	1850-1991	
The Americas		
Brazil	1898-1997	
Canada	1851-1997	
Mexico	1881-1997	
United States	1800-1997	

Figure 3 : *Table 2 - Data Overview: Podobnik Energy Dataset.*
** Data for Germany from 1946 to 1990 can be found in the spreadsheets "East Germany" and "West Germany".

1925 might be underestimated. Additionally, there are data gaps for the period of World War II. The aggregated indicators "total energy consumption" (given in tons of oil equivalent), and "energy consumption per capita" (Gigajoules), percentage of individual energy sources in total energy consumption as well as energy and GDP growth rates and the "Energy/GDP ratio" (toe per Thousand US (1990) $) are provided.

16 The data is based on the following sources:

- For 1800 to 1949, data is mainly retrieved from the statistical reference books published by Bouda Etemad and Jean Luciani on the one hand, and Brian R. Mitchell on the other hand,[23] various publications of Great Britain's Statistical Office and The US Department of Commerce.
- For the period of 1950-1997, data was retrieved from the Energy Statistics Yearbooks published yearly by the United Nations.

17 Podobnik used the method of linear interpolation to close data gaps. To increase the reliability of this database, the author has performed comparisons and crosschecks with other data sources, such the IEA database.[24] However, detailed methodological explanations are missing. Therefore, it is not clear how the data from multiple sources have been harmonised. The following questions arise in particular: Which conversion factors have been applied? How is primary electricity calculated? To be on the

23 Bouda Etemad, Jean Luciani, *World Energy Production, 1800-1985*, op. cit;, Brian R. Mitchell, *British Historical Statistics* (Cambridge: Cambridge University Press, 1988) and International Historical Statistics (different volumes) (Basingstoke: Palgrave Macmillan, 2007) can be regarded as a valuable source for historical statistics on energy production and trade, too.

24 Bruce Podobnik, *Global Energy Shifts*, op. cit., 169–173.

	UK information, year	1800	...	1994	1995	1996	1997
bcoalr	BCOAL Produc, thousand metric tons	0	...				
hcoalr	HCOAL Produc, thousand metric tons	13868	...	47971	52630	51000	50000
oilr	Oil Produc, thousand metric tons		...	119032	121794	129800	127700
ngasr	NGAS Production, thousand Terajoules		...	2703	2958	3098	3266
hydror	Hydro Production, Thousand KWHs.		...	6557000	6836000	6400000	6200000
nucr	Nuclear Energy Production, Thousand KWHs.		...	87382000	88964000	88800000	89000000
geor	Geothermal Energy Production, Thousand KWHs.		...	342000	352000	365000	380000
coaltoe1	COAL Produc, UK, thousand TOE	8339	...	28845	31646	30666	30065
oiltoe1	OIL Produc, UK, thousand TOE		...	121746	124571	132760	130612
ngastoe1	NGAS Produc, UK, thousand TOE		...	61539	68440	73972	77970
hcarbon1	Hcarbon Produc (Coal, Oil, NGAS), UK, thousand TOE	8339	...	212130	224658	237398	238647
hydtoe1	Hydro Produc, UK, thousand TOE		...	564	588	550	533
nuctoe1	Nuclear Produc, UK, thousand TOE		...	22807	23220	23177	23229
geotoe1	Geo Produc, UK, thousand TOE		...	294	303	314	327
toe1	Energy Produc, UK, thousand TOE	8337	...	238771	250948	261428	262726
coaltoe2	Coal Imports, UK, thousand TOE		...	9044	9558	10000	10500
rcoatoe2	Ref Coal Imports, UK, thousand TOE		...	364	433	460	500
oiltoe2	Oil Imports, UK, thousand TOE		...	43674	41855	41000	40500
roiltoe2	Ref Oil Imports, UK, thousand TOE		...	20336	16996	16500	16000
ngastoe2	NGAS Imports, UK, thousand TOE		...	2842	1673	1700	1800
rngstoe2	Ref NGAS Imports, UK, thousand TOE		...				
hcarbon2	Hcarbon Imports (Coal, Oil, NGAS), UK, thousand TOE		...	76260	70514	69660	69300
electoe2	Elec Imports, UK, thousand TOE		...	1452	1404	1430	1460
toe2	Energy Imports, UK, thousand TOE		...	77712	71919	71090	70760
coaltoe3	Coal Exports, UK, thousand TOE		...	737	516	400	300
rcoatoe3	Ref Coal Exports, UK, thousand TOE		...	246	266	286	300
oiltoe3	Oil Exports, UK, thousand TOE		...	80078	81787	82000	82500
roiltoe3	Ref Oil Exports, UK, thousand TOE		...	24708	23597	23000	22500
ngastoe3	NGAS Exports, UK, thousand TOE		...	822	587	600	700
rngstoe3	Ref NGAS Exports, UK, thousand TOE		...	0	0	0	0
hcarbon3	Hcarbon Exports (Coal, Oil, NGAS), UK, thousand TOE		...	106590	106752	106286	106300
electoe3	Elec Exports, UK, thousand TOE		...	1	2	3	4
toe3	Energy Exports, UK, thousand TOE		...	106591	106754	106289	106304
coaltoe5	Coal Consum, UK, thousand TOE		...	48860	45975	39513	39357
oiltoe5	Oil Consum, UK, thousand TOE		...	76941	74434	76631	76416
ngastoe5	NGAS Consum, UK, thousand TOE		...	66808	71847	74971	79040
hcarbon5	Hcarbon Consum (Coal, Oil, NGAS), UK, thousand TOE		...	192610	192256	191115	194813
netoil	Net Oil Imports, thousand TOE. Neg value indicates net exports		...	-44805	-50137	-56129	-54196
electoe5	Energy Consum, UK, thousand TOE		...	25110	25508	25595	25695
toe5	Total Energy Consumption, thousand TOE .		...	214371	216830	219075	220508
toe7	Energy Growth Rates (Annual %), TOE Consumption, UK		...	-2	1	1	1
gdp7	Economic Growth Rates (Annual %), GDP, UK		...	4	2		
percap6	Percapita energy consumption, commercial energy, gigajoules per capita		...	154	155	156	157
coaltoep	Coal as percentage of total commercial energy consumption		...	23	21	18	18
oiltoep	Oil as percentage of total commercial energy consumption		...	36	34	35	35
ngastoep	NGAS as percentage of total commercial energy consumption		...	31	33	34	36
nuctoep	NUC as percentage of total commercial energy consumption		...	11	11	11	11
hydtoep	HYD as percentage of total commercial energy consumption		...				
geotoep	GEO as percentage of total commercial energy consumption		...				
gdp	GDP, million Geary-Khamis 1990 Dollars. Maddison 1995		...				
gdpratio	Energy/GDP Ratio. [TOE Per Thousand US (1990) $]. Maddison 1995. (TOE5/GDP)		...				

Figure 4 : *Table 3. Structure of data tables: Podobnik energy dataset (example United Kingdom)*

safe side, data needs to be compared and cross checked with other sources. Furthermore, due to its multiple content, the dataset is rather unintuitive in its structure and handling.

The Global Energy Project's National Energy Accounts

18 This database[25] covers national energy consumption data for 11 European and American countries. Originally developed within the Energy and Growth group[26] during 2002-2011, data has been added and revised recently. The database is also expected to be supplemented in future. Data was used in several publications to reveal the interrelations between economic development and energy use and the important role technology and efficiency gains played in energy transitions.[27]

19 The database distinguishes not only between modern energy (coal, oil, natural gas) and primary electricity but, in contrast to the Podobnik energy dataset and official energy statistics, also includes biomass (food, fodder, fuelwood) and, for some countries, wind and water power as traditional energy sources. Energy flows are taken into account only when they imply costs or efforts.[28]

20 The data covers the period from 1800 to the first decade of the 21st century and the authors compiled it using a conjoint and largely standardized methodology. However, some small differences exist in calculation methods applied to capture traditional water and wind power as well as biomass, but these slight inconsistencies do not change the overall picture. The data can be downloaded as Excel files containing two spreadsheets, covering (a) total energy consumption (Petajoules) and energy consumption per capita (Gigajoules) and (b) shares of different energy sources in total energy consumption (%). The given shares allow to calculate and compare actual energy flows of different traditional and modern energy sources. Energy imports and exports are not listed separately but can be found in the data appendixes of the related country studies.[29] The data files are organized in a consistent fashion and include a short methodological description. Moreover, data visualisations are provided on the website. This database is methodologically consistent with the IEA energy balances, ensuring comparability and possibilities for further extension of data.[30] Most data on fossil fuel and electricity has been compiled based on official statistics.[31] Primary electricity includes hydro-, geothermal and nuclear power as well as renewable sources, except electricity generated from biomass.

25 Data can be retrieved from https://sites.fas.harvard.edu/~histecon/energyhistory/energydata.html

26 Most members of this group have a disciplinary background in economic history

27 Data has been utilized inter alia in Ben Gales, Astrid Kander, Paolo Malanima, Maria del Mar Rubio, "North Versus South: Energy Transition and Energy Intensity in Europe over 200 Years", *European Revue of Economic History*, vol. 11/02, 2007,; Sofia Henriques, *Energy Transitions, Economic Growth and Structural Change: Portugal in a Long-run Comparative Perspective* (Lund: Lund University, 2011), 54; Sofia Teives Henriques, *Energy Consumption in Portugal: 1856-2006* (Naples: Istituto di Studi sulle Società del Mediterraneo, 2009); Astrid Kander, *Economic Growth, Energy Consumption and CO2 Emissions in Sweden 1800-2000* (Stockholm:Almqvist & Wiksell International , 2002); Astrid Kander Paolo Malanima Paul Warde (eds.), *Power to the People: Energy in Europe over the Last Five Centuries* (Princeton: Princeton University Press, 2013); Paul Warde, *Energy Consumption in England and Wales, 1560-2000* (Naples: Consiglio Nazionale delle Ricerche, 2007).

28 Astrid Kander, Paolo Malanima, Paul Warde, *Power to the People*, op. cit., 18-20.

29 Sofia Henriques, *Energy Transitions, Economic Growth and Structural Change*, op. cit.; Astrid Kander, *Economic Growth, op. cit.; Paolo Malanima, Energy Consumption in Italy in the 19th and 20th Centuries: A Statistical Outline* (Naples: Consiglio Nazionale delle Ricerche, 2006); Paul Warde, *Energy Consumption in England and Wales, 1560 -2000*, op. cit. The group has recently begun to calculate embodied energy in traded goods. For sources and methods, see Paul Warde, "Energy Embodied in Traded Goods for the United Kingdom, 1870-1935. Discussion of Methods and Sources", available at https://histecon.fas.harvard.edu/energyhistory/British_energy_multiplie..., accessed Dec. 12, 2017); Sofia Teives Henriques, Paul Warde, "Fuelling the English Breakfast. Hidden Energy flows in the Anglo-Danish trade 1870–1913", *Regional Environmental Change*, vol. 18/4, 2018, 969-971.

30 Joint Center for History and Economics, Harvard University, "National Energy Accounts: Sources, Methods, and Citations", available at https://sites.fas.harvard.edu/~histecon/energyhistory/sources.html, accessed Dec. 12, 2017.

31 See the sources and methods sections in the publications cited in footnote 31 and 33.

Region/country	Time period covered	Indicators
The Americas		• Total energy consumption (PJ) • Energy consumption per capita (GJ/cap) • Shares of food, fodder, fuelwood, Water/wind, coal, oil, natural gas and primary electricity in total energy consumption (%)
Canada	1800-2010	
Uruguay (shares only)	1882-2000	
Europe		
Czech lands (figures only)	1861-2008	
England and Wales	1800-2008	
France	1800-2008	
Germany	1800-2008	
Italy	1815-2008	
The Netherlands	1861-2008	
Portugal	1800-2008	
Spain	1856-2008	
Sweden	1850-2008	
	1800-2008	

Figure 5 : *Table 4 - Data Overview: National Energy Accounts*

	Total Energy Consumption (Petajoules)	Per capita Energy Consumption (Gigajoules)
1861	464	18
1862	459	17,7
...	...	...
2000	7 164	123,8
2001	7 111	122,7
2002	7 115	122,6
2003	7 395	127,2
2004	7 420	127,5
2005	7 513	129
2006	7 415	127,3
2007	7 246	124,3
2008	7 122	122,2

	Food	Fodder	Fuelwood	Water / Wind	Coal	Oil	Natural Gas	Primary electricity
1861	21,4	18,8	51,3	1	7,5	0	0	0
1862	21,8	18,1	52,3	1	6,8	0	0	0
...	...	...	...	...	...	...	...	...
2000	4,2	0	2,6	0,1	7,2	47,5	33,3	5,1
2001	4,2	0	2,6	0,1	7,8	46,6	33,6	5,1
2002	4,2	0	2,6	0,1	8	46,8	33,4	4,9
2003	4,1	0	2,5	0,1	8,3	44,9	35,5	4,6
2004	4,1	0	2,5	0,1	9,3	42,7	36,7	4,6
2005	4	0	2,4	0,1	9,1	41,1	38,8	4,5
2006	4,1	0	2,7	0,1	9,3	40,8	38,5	4,4
2007	4,2	0	2,7	0,2	9,6	39,3	39,7	4,4
2008	4,2	0	3,1	0,2	9,5	37,9	40,4	4,7

Figure 6 : *Table 5 - Structure of data tables: Global Energy Project's National Energy Accounts (example Italy)*
a) Per capita energy consumption and total consumption in Italy
Source: Malanima Paolo, *Energy consumption in Italy, 1861-2000* (CNR, 2006).
b) Shares of energy consumption in Italy 1861-2008 (%)
Source: Malanima Paolo, *Energy consumption in Italy, 1861-2000* (CNR, 2006).

21 Much effort has been devoted to a re-evaluation of firewood consumption, since it is often underestimated in official statistics.[32] Due to this painstaking work, data is more accurate and reliable here than in official statistics, which usually include only commercially used fuelwood.

22 In contrast to the theoretical framework underlying conventional energy statistics, where only energy convertible by technical artefacts (machines) is included, the contributors' concept of societal energy consumption varies significantly from the one reflected in official energy statistics or other scholarly work.[33] Working animals and human beings are understood as "biological converters" or living machines in this context;[34] they convert chemical energy into mechanical energy, which can be used to perform socio-economically valuable work. Therefore, energy used for human nutrition[35] and food for draught livestock, like oxen and horses, is included in this dataset representing a significant energy flow in preindustrial societies. In order to calculate these energy flows, a consumption-based approach has been used. Based

32 See for example the model on firewood consumption developed for Sweden (Astrid Kander, *Economic Growth*, op. cit., 23-39 and Appendix D).

33 Arnulf Grubler, "Energy Transitions Research", art. cit. and Bruce Podobnik, *Global Energy Shifts*, op. cit.

34 Astrid Kander, Paolo Malanima, Paul Warde, *Power to the People*, op. cit., 37-56.

35 Plant based foods, as well as edible products of animal origin have been included in the calculation of this energy flow. Hence, all edible food that is available in a given year to the population of a country is accounted for as primary energy (e.g. Sofia Teives Henriques, *Energy Consumption in Portugal*, op. cit., 22).

on a "benchmark value" calculated from an average per capita calorie consumption for different years, they extrapolate this value to the entire area using the respective population data.[36] The same approach is applied to calculate feed for working animals: depending on feed requirements of different categories of animals with regard to their height, weight and workload, this energy flow is extrapolated with the total number of the respective working animals.[37]

The Data Collection of the Viennese Institute of Social Ecology (SEC)

23 This data collection[38] includes energy flow data on a global, national and local scale. Krausmann and colleagues compiled the datasets during the last decade[39] covering the period from the 19th to the 21st century. The data is organised in Excel-files in a consistent way, providing an in-depth description of sources and accounting methodologies for each individual data set. Data has been sourced pre-eminently from national statistical offices. In terms of quality and accurateness this database is comparable with the above described National energy accounts, and in principle, also the accounting logic of the two databases, since its originators widely follow the IEA guidelines for energy accounting. However, differences exist in the treatment of biomass and the applied calorific values, which are rooted in the differing theoretical concepts of both "schools".

24 The authors provide data reflecting their background in social ecology, an interdisciplinary field bridging natural sciences with social sciences and the humanities. Its core axiom is that societal and biophysical systems interact, co-evolve and impact upon each other. "Social Metabolism" is a fruitful concept to analyse these interrelations,[40] applicable on every spatial and temporal scale; its related methodology of material and energy flow analysis (MFA[41] and EFA[42]). MFA

36 Astrid Kander, *Economic Growth, Energy Consumption and CO2 Emissions in Sweden 1800-2000*, op. cit., 42; Paul Warde, *Energy Consumption in England and Wales, 1560 -2000*, op. cit., 23-32).

37 Paul Warde, *Energy Consumption in England and Wales, 1560 -2000*, op. cit., 40-45; Astrid Kander, Paul Warde, "Energy Availability from Livestock and Agricultural Productivity in Europe, 1815-1913. A New Comparison", *The Economic History Review*, vol. 64/1, 2011. For a description of sources and the methodology used, see Astrid Kander, Paul Warde, "Number, Size and Energy Consumption of Draught Animals in European Agriculture. Working Paper 2009", available at http://www.histecon.magd.cam.ac.uk/history-sust/files/warde_kander_work..., accessed Dec. 14, 2017.

38 The data is available on http://www.wiso.boku.ac.at/sec/data-download/.

39 Data has been published inter alia in Simron Jit Singh *et al.*, "India's Biophysical Economy, 1961-2008. Sustainability in a National and Global Context", *Ecological Economics*, vol. 76, 2012, 60–69; Fridolin Krausmann, Simone Gingrich, Reza Nourbakhch-Sabet, "The Metabolic Transition in Japan", *Journal of Industrial Ecology*, vol. 15/6, 2011; Helmut Haberl *et al.*, "The Energetic Metabolism of the European Union and the United States. Decadal Energy Input Time-Series with an Emphasis on Biomass", *Journal of Industrial Ecology*, vol. 10/4, 2006; Petra Kuskova, Simone Gingrich, Fridolin Krausmann, "Long Term Changes in Social Metabolism and Land Use in Czechoslovakia, 1830–2000: An Energy Transition under Changing Political Regimes", *Ecological Economics*, vol. 68/1-2, 2008; Fridolin Krausmann, "A City and Its Hinterland: Vienna's Energy Metabolism 1800–2006", *in* Simron Jit Singh *et al.* (eds.), *Long Term Socio-Ecological Research: Studies in Society-Nature Interactions Across Spatial and Temporal Scales* (Dordrecht: Springer Netherlands, 2013); Sylvia Gierlinger, Fridolin Krausmann, "The Physical Economy of the United States of America", *Journal of Industrial Ecology*, vol. 16/3, 2012; Fridolin Krausmann *et al.* "Growth in Global Materials Use, GDP and Population during the 20th Century", *Ecological Economics*, vol. 68/10, 2009.

40 For a theoretical and methodological overview, see Marina Fischer-Kowalski, Helmut Haberl (eds.), *Socioecological Transitions and Global Change: Trajectories of Social Metabolism and Land Use* (Cheltenham, UK, Northampton, MA: Edward Elgar, 2007); Helmut Haberl, Marina Fischer-Kowalski, Fridolin Krausmann, Verena Winiwarter (eds.), *Social Ecology: Society-Nature Relations across Time and Space* (Basel: Springer International Publishing, 2016)

41 The accounting principles of material flow analysis are widely used, for example by Eurostat. A methodological guide was published first in 2001 (Eurostat, *Economy-wide Material Flow Accounts and Derived Indicators: A Methodological Guide* (Luxembourg: Eurostat, 2001)) and complemented with various compilation guides (e.g. Helga Weisz *et al.*, *Economy-Wide Material Flow Accounting. A Compilation Guide* (Luxembourg: Eurostat, European Commission, 2007); Eurostat, *Economy Wide-Material Accounts (EW-MFA)* (Luxembourg: Eurostat, 2013). For a concise methodological description see Nina Eisenmenger, "Method précis: Material Flow Analysis", *in* Helmut Haberl *et al.*, *Social Ecology*, op. cit., 234–238 (cf. note 44).

42 A theoretical and methodological introduction was published by Helmut Haberl, "The Energetic Metabolism of Societies. Part I: Accounting Concepts", *Journal of Industrial Ecology*, vol. 5/1, 2001.

Region/country/city	Time period covered	Indicators
Asia		• Domestic energy extraction (PJ) (coal, oil, natural gas, primary electricity,) • Energy Imports and Exports (PJ) (coal, oil, natural gas and its products, agricultural biomass, wood, electricity) • Domestic energy consumption (PJ)= domestic extraction + energy Imports – energy exports • Per capita energy consumption (GJ/cap) • TPES (PJ)
India	1961-2008	
Japan	1878-2005	
Europe		
EU 15	1960-2001	
Czechoslovakia	1830-2002	
City of Vienna	1800-2006	
The Americas		
USA	1870-2005	
World	1900-2009	

Figure 7 : *Table 6 - Data Overview: SEC Data Collection*

		Year	1878	....	2000	2001	2002	2003	2004	2005
Domestic Extraction (DE)	[PJ/yr]	Agricultural biomass and timber	308	....	962	911	893	869	883	850
	[PJ/yr]	Fuelwood	120	....	1	1	1	1	1	1
	[PJ/yr]	Coal incl. peat	21	....	96	98	41	42	-	-
	[PJ/yr]	Oil	0	....	29	29	28	32	33	36
	[PJ/yr]	Natural Gas	-	....	97	97	100	113	115	125
	[PJ/yr]	Hydropower/Nuclear heat/Other	-	....	4185	4151	3867	3283	3762	3954
		DE	449	....	5370	5288	4930	4341	4794	4966
Imports	[PJ/yr]	Agricultural biomass and timber	0	....	1121	1068	1068	1075	1067	1048
	[PJ/yr]	Fuelwood	-	....	486	462	475	460	497	320
	[PJ/yr]	Coal incl. Peat	1	....	4549	4847	4934	5205	5625	5640
	[PJ/yr]	Oil	2	....	11600	11277	10809	11418	11278	11431
	[PJ/yr]	Natural Gas	-	....	3437	3467	3392	3664	3546	3589
	[PJ/yr]	Electricity	-	....	-	-	-	-	-	-
	[PJ/yr]	Imports	3	....	21193	21121	20678	21822	22013	22028
Exports	[PJ/yr]	Agricultural biomass and timber	2	....	47	70	74	73	89	99
	[PJ/yr]	Fuelwood	-	....	32	31	36	40	42	41
	[PJ/yr]	Coal incl. Peat	6	....	81	76	97	86	67	52
	[PJ/yr]	Oil	-	....	833	858	894	901	987	1179
	[PJ/yr]	Natural Gas	-	....	2	3	4	7	10	8
	[PJ/yr]	Electricity	-	....	-	-	-	-	-	-
	[PJ/yr]	Exports	8	....	996	1039	1106	1106	1194	1378
Domestic Energy Consumption (DEC)	[PJ/yr]	Agricultural biomass and timber	306	....	2036	1909	1886	1871	1861	1800
	[PJ/yr]	Fuelwood	120	....	456	433	440	421	457	280
	[PJ/yr]	Coal incl. Peat	16	....	4564	4868	4877	5161	5558	5588
	[PJ/yr]	Oil	2	....	10795	10448	9944	10549	10324	10288
	[PJ/yr]	Natural Gas	-	....	3532	3561	3487	3771	3651	3706
	[PJ/yr]	Electricity	-	....	4185	4151	3867	3283	3762	3954
	[PJ/yr]	DEC	444	....	25568	25370	24502	25056	25613	25616

Figure 8 : *Table 7 - Structure of data tables: SEC Data Collection (example Japan)*
Primary energy flows by main energy types, 1878 to 2005
Methods and sources: see technical notes and Krausmann *et al.* 2011
Unit: PJ/yrs

and EFA allows taking into account all material / energy flows extracted from the biophysical environment that enter a defined socioeconomic system as an input. All material and energetic inputs are transformed and used within the socioeconomic system to build up or maintain its biophysical stocks (human population, livestock, infrastructure and long living artefacts). The residues are crossing the border between the socioeconomic system and the biophysical environment again as unwanted "output" in form of wastes and emissions.[43]

25 The provided data collection includes coal, oil, natural gas given as gross calorific value (GCV) and primary electricity[44] in Joules and additionally, biomass flows that are considered as societal relevant energy flows. Biomass in the socioecological understanding does not only comprise biomass used for building and maintenance of infrastructure and artefacts, but also for human and livestock reproduction. The inclusion of biomass flows might be regarded as a similarity with the Global Energy Project's National energy accounts. However, the accounting concept is based on different theoretical assumptions and, in consequence, a different methodology. While the national accounts include only biomass used for energetic purposes (food, fodder, and fuelwood), biomass flows covered in EFA are more comprehensive. In analogy to the accounting concept of energy balances, all biomass flows through a socioeconomic system are regarded as primary energy. Moreover, biomass used for human nutrition is understood as final energy.[45] Therefore, primary energy includes the total amount of harvested biomass as well as grazed biomass.[46] This comprehensive and harmonized accounting scheme and its derived indicator *domestic energy consumption* (DEC) allows to go beyond the spatial or temporal scale of an industrialised society, which is certainly a shared asset with the National energy accounts described above. Hence, it can be applied for analysing transitions from a biomass-based and predominant agrarian to fossil fuel based industrial socioeconomic system. While this indicator measures energy use in a defined socioeconomic system, it can also be interpreted as its emission potential. Generally, it can be linked to socioecological indicators (e.g. human appropriation of net primary production, HANPP)[47], resource efficiency indicators, as well as to economic and demographic indicators.

CONCLUDING REMARKS

26 The paper introduced some basic concepts of energy and energy accounting, drawing attention on possible uncertainties. Awareness of different conceptual and accounting methodologies helps energy historians to utilize or interpret historical energy data or to compile their own datasets. The following questions are important for an appropriate treatment of such sources: Which level of measurement (primary energy, final energy, useful energy) is reflected in the data? What is the basic convention for accounting of electricity? Which conversion factors have been used? Shedding light on these pitfalls is

43 Marina Fischer-Kowalski, *et al.*, "Methodology and Indicators of Economy-Wide Material Flow Accounting", *Journal of Industrial Ecology*, vol. 15/6, 2011.

44 The calculation of primary electricity is based on the following conversion efficiencies: 33 %for nuclear heat, 95 % for hydropower and 10 % for geothermal energy (Helmut Haberl, "Economy-Wide Energy Flow Accounting", *in* Heinz Schandl, Clemens M. Grünbühel, Helmut Haberl, Helga Weisz (eds.), *Handbook of Physical Accounting.: Measuring Bio-Physical Dimensions of Socio Economic Activities. MFA - EFA - HANPP* (Vienna: Federal Ministry of Agriculture and Forestry, Environment and Water Management, 2002) See also United Nations Statistics Division, *International Recommendations for Energy Statistics (IRES)*, 103-104 (cf. note 12).

45 Helmut Haberl, "The Energetic Metabolism of Societies" (cf. note 46).

46 For a detailed description of the accounting methodology see Fridolin Krausmann, *et al.*, "Global Patterns of Socioeconomic Biomass Flows in the Year 2000: A Comprehensive Assessment of Supply, Consumption and Constraints", *Ecological Economics*, vol. 65/3, 2008; Fridolin Krausmann, *et al.*, "Global Human Appropriation of Net Primary Production Doubled in the 20th Century", *Proceedings of the National Academy of Sciences of the United States of America*, vol. 110/25, 2013.

47 Helmut Haberl, "Human Appropriation of Net Primary Production", *in* Helmut Geist (ed.), *Our Earth's Changing Land: An Encyclopedia of Land-Use and Land-Cover Change* (Westport, Conn.: Greenwood Press, 2006), 292–294.

vital, and will facilitate the analysis of the data and prevents misinterpretations. One should keep in mind that, in general, historical statistics have their limitations, such as reliability, varying definitions of indicators over time, or changes of national borders, which might not always be reflected in the choice of data.

27 Nevertheless, compiling databases, as the ones described in the second part of this paper, and publishing them online, thus allowing access to interested scholars is an important effort that deserves immense recognition. However, an in depth knowledge of the content and quality of the applied datasets is needed, when utilizing them. The Podobnik energy dataset includes only modern energy sources, like fossil fuels and primary electricity generated from hydropower, nuclear and geothermal heat, and is only suitable for analysing "modern" energy transitions, e.g. from coal to oil. The dataset provided by the Global Energy Project and the data collection of the Institute of Social Ecology are more comprehensive and include also biomass as a traditional energy source, but applied methodologies differing from each other. Nevertheless, with this data it is possible to delineate the historical energy transition from biomass to fossil fuels and electricity.

28 Quantitative data can be used as a valuable source for historical energy studies, especially if they are intended to describe historical trends on an aggregate level. Studies of this kind mostly choose a macro perspective: focussing on the timing of energy transitions, correlating the energy data with economic data and/or technological change[48] or data on social upheavals and geopolitical changes[49] or analysing sustainability problems of past and present energy systems.[50] These datasets are especially useful for describing structural changes in energy systems; they show clearly when they occured but not *how*. As data alone can never tell the whole story, it is recommended to combine it with qualitative sources to expand the overall picture – especially to trace the histories and roles of actors involved in energy transitions, in order to assess the multiple dimensions of energy history.

48 E.g. Astrid Kander, Paolo Malanima, Paul Warde, *Power to the People* (cf. note 31).

49 E.g. Bruce Podobnik, *Global Energy Shifts*, (cf. note 23), Bruce Podobnik, "Global Energy Inequalities" (cf. note 23).

50 E.g. Arnulf Grubler, "Energy Transitions Research" (cf. note 3); Sofia Teives Henriques, Karol J. Borowiecki, "The Drivers of Long-Run CO 2 Emissions in Europe, North America and Japan since 1800", *Energy Policy*, vol. 101, 2017, 537–549; Fridolin Krausmann, Marina Fischer-Kowalski, Heinz Schandl, Nina Eisenmenger, "The Global Sociometabolic Transition: Past and Present Metabolic Profiles and their Future Trajectories", *Journal of Industrial Ecology*, vol. 12/5-6, 2008,.

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Abstract

Energy and Civilization is a journey through the world history of energy from the discovery of fire to the latest energy transition. Smil reviews the evolution and differentiation of energy's uses and transformations, and energy's role in shaping economies. Furthermore, he evaluates energy's many benefits and problematic aspects. However, the book presents some epistemic and methodological challenges.

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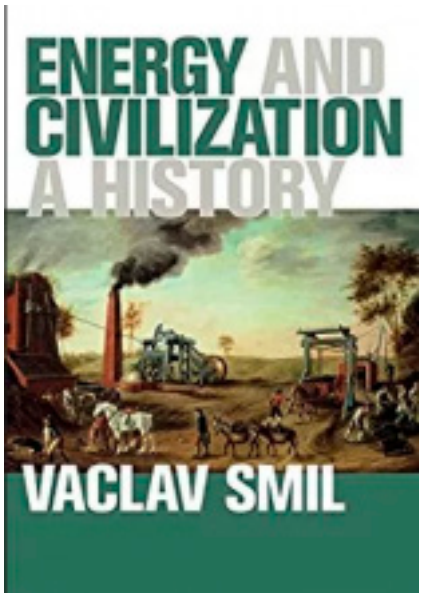

A GRAND EDIFICE

1 Vaclav Smil's *Energy and Civilization* is a monumental attempt at reconstructing the history of energy from prehistory to the contemporary era: energy's uses and transformations; its effects on the shaping of societies; the achievements it made possible, as well as its problematic aspects. This book is the latest step in a long series of works on energy that the author has been publishing in the last decades: a fecundity that, together with the author's meticulousness in data mining, and scrupulous research for adequate sources to support his claims, has made him into "the man who has quietly shaped how the world thinks about energy", as well as a favorite reading of America's technical, political, and financial elite (back in the 1980s and 1990s he collaborated as a consultant with the World Bank and the CIA, but also, more recently, with a number of Swiss banks. Microsoft's cofounder, Bill Gates, has also praised his works).[1]

2 The temporal, geographical, and disciplinary breadth of this work is remarkable: Smil's sources, both primary and secondary, range from prehistoric times to contemporary biofuels; from the history of technology to farm economy; and from China to Latin America. These hundreds of sources are harmonized to form a grand narrative edifice. The book is enriched by both a lavish iconographic apparatus, illustrating technological artefacts produced in different cultures and historical epochs, and tables and graphs synoptically presenting data, the painstaking collection of which must have involved a major research effort. It would be hard to find a work as broadly conceived as this one amongst scholarly monographs on the history of energy. The very task of setting off to produce a world history of energy from the emergence of human beings on Earth would be dismissed as unfeasible even by a team of professional historians. Smil, whose expertise ranges from environmental science to policy analysis, to nutrition and risk assessment, but does not include history, happily faced the challenge: his prolific production is the clearest witness to his polymath spirit. Such breadth, however, comes at a cost: while the book is longer than the average academic book, it still faces the problem of condensing millennia of world history in 450 pages.

AN ECONO-PHYSICAL VIEW OF ENERGY

3 The book includes six chronologically ordered, empirical chapters, preceded by an introduction and followed by a summarizing chapter that also includes concluding remarks. The empirical chapters cover: a) energy in prehistory, b) traditional farming, c) preindustrial prime movers and fuels, d) fossil fuels, primary electricity and renewables, and e) fossil-fueled civilization. From the very introduction the reader can get an idea of the main view of energy that underlies Smil's arguments throughout the book. To pinpoint it, we can refer to a tetrapartite distinction outlined in 1984 by the US National Research Council's Committee on Behavioral and Social Aspects of Energy Consumption and Production, a committee of social scientists charged with exploring the 'human dimension' of energy.[2] I believe that distinction is still valid today. The Committee

1 Quoted from: Paul Voosen, "Meet Vaclav Smil, the man who has quietly shaped how the world thinks about energy", *sciencemag.org*, 21 March 2018, https://doi.org/10.1126/science.aat6429.

2 Paul C. Stern, Elliot Aronson (eds.), *Energy Use. The Human Dimension* (New York: W.H. Freeman and Co., 1984), 14 ff.

identified four views of energy as: commodity (dominant in the US), ecological resource, social necessity, and strategic material. Each of these visions focuses on a different aspect of energy: respectively, the value of choice for present-day consumers and producers; energy in the context of biospheric systems; energy as a right—for home heating, cooling, lighting, cooking, transportation, etc.; energy as a geopolitical tool, mostly in terms of supply security.

4 Throughout the great majority of the book, it is the view of energy as commodity that predominates: the interests of energy producers and consumers take center stage. Only the very last section in the book changes its focus from the commodity to the ecological resource and strategic views. However, there is probably a fifth view of energy that is not mentioned in the NRC report: energy as a physical, all-encompassing parameter through which one can quantitatively evaluate human activities. Together with the commodity view, this is also Smil's favorite, to the extent that: "To talk about energy and the economy is a tautology: every economic activity is fundamentally nothing but a conversion of one kind of energy to another, and monies are just a convenient [...] proxy for valuing energy flows." (p. 344) That is, admittedly, a markedly reductionist view of economics, which, contrarily to what Smil argues, also includes historical and political contexts, and the NRC's 'human dimension'. These aspects seem to go missing in Smil's account. It is then not surprising that actions that most readers would never associate with energy balances (the 'energy cost of pregnancy', for example, p. 125) are treated by Smil as acts of energy generation, consumption, and savings.

TECHNOLOGICAL ANACHRONISM AND EVOLUTIONISM

5 In the book's last chapter, Smil spends quite some time warning against the indiscriminate use of energy in historical explanations: not everything that has happened in history, he says, can be explained by means of energy savings. While that sounds as a truism when one looks at energy from the standpoint of social or human sciences, when energy is approached with a reductionist mind set, Smil's is a providential caveat. However, in most of his book the author does not appear to practice what he preaches: he mostly adopts an energy-based, calculative approach to explain why, for example, a certain prehistoric society may have switched between different kinds of crops; he refers to amounts of chemical nutrients to assess the preference of certain kinds of fertilizers in traditional societies. That is as close to anachronism as one can get. It is perfectly fine, of course, to try and calculate the amount of proteins contained in a prehistoric meal: what is less historically justifiable, is to interpret past processes by attributing to historical actors ways of thinking and categories of analysis belonging to later times.

6 A further troubling point concerns Smil's argumentative lines to justify the preference of a supposedly more innovative technology over one that has ended up being dismissed. These are deeply indebted to a rational actor perspective that has been repeatedly challenged in works on societal aspects of energy. These works, however, are absent from Smil's references: as a consequence, readers are presented with a teleological discourse on the continuous evolution and improvements of technology, described in a parallel to the improvement of humankind. Smil is aware that the equation 'more refined energy flux coupling = more refined cultural mechanism' does not hold, and he criticizes Ronald Fox for his energy determinism (p. 431). Avoiding the trap of energy determinism, however, did not prevent him from falling into the parallel trap of technological teleologism, according to which for every new invention, there has been an improvement in the living conditions of humankind. By the yardstick of STS scholarship, this sort of technological evolutionism has a distinctive whiggish smack. Smil's non-nuanced references to works by George Basalla, a historian of science whose diffusionist approach has long been considered as analytically unsatisfactory, are also problematic.

TO TRANSITION OR NOT TO TRANSITION?

7 A second issue worthy of reflection is Smil's position on the relationship between economic growth, energy consumption growth, and energy transition. Also in this case, *Energy and Civilisation* is characterized by an ambiguous narrative, which may be interpreted as the consequence of a lack of reflexivity *vis-à-vis* the currently predominant economic system. In the book's ten final pages Smil casts some doubts on the possibility of perennial growth, it does so unconvincingly: readers feel that he would like to challenge the growth argument (as on p. 362, or where he mentions works on steady-state economy by Nicholas Georgescu-Roegen and on energy equity by Ivan Illich, for example), but that he is not entirely convinced that it can really be challenged. Smil believes that human beings should be concerned about the impact of our reliance on fossil fuels on the habitability of the biosphere (p. 425), yet he is extremely skeptical of renewable energy sources. On the one hand he approaches the problems of energy expansion (p. 295-6), but on the other hand he sees in US shale gas "enormous opportunities that remain to be fully exploited" (p. 424). How these apparently opposite views are supposed to harmonize with each other, it is unclear.

8 Smil's skepticism *vis-à-vis* renewables can also be noticed from his chapter on fossil fuel, primary electricity, and renewables, in which the focus is preponderantly on the first two (renewables are dedicated six pages out of the chapter's 69), as well as by his cursory dismissal of the German solar energy policies as the outcome of state subsidies, as opposed to what he defines as "a gradual, organic process" (p. 287). What he would like such an organic process to be based on, is left unspecified: arguably, market forces. So, while he argues energy transition to renewables will be extremely slow, by advocating the non-intervention of governments in this matter, he appears as prompting the self-fulfillment of his own bleak prophecy. In an interview with *Science*,[3] Smil mentioned that in 2000 fossil fuels provided 84% of Germany's energy, while after the implementation of the country's huge solar program, the share has barely dropped to 80%. He argued that, as a consequence, the program only benefited German industrialists, not the environment. What he seemed to forget is that, after the Fukushima accident, the German government implemented a major turnaround on its energy policies, by making the decision of gradually shutting down all of the country's nuclear plants. In the short-term, that meant an increase in the use of coal-burning power plants.

9 Contradictions similar to the ones mentioned with regard to energy transition are also to be found in Smil's attitude toward nuclear energy: on the one hand, he acknowledges problems of waste disposal, technical weakness, and high construction costs; on the other, however, he feels sorry that Europe and North America have left the initiative in "this clean, carbon-free way of electricity generation" to India and China (p. 284). How can a source of energy characterized by a major problem with waste disposal be considered as 'clean'? Smil is equally dismissive of wind energy, especially when applied to the US case: however, he acknowledges the recent growth of this market in Europe. His criticism of wind turbines on grounds that oil is needed to drill the ground for their foundations, gas for kilns to bake concrete, and coal for steel towers, appears as a straw man.[4] No advocate of renewables has ever argued that these sources will bring fossil fuel consumption to zero. What is rather discomforting, in Smil's account of the future role of renewables, is that he never mentions the importance of political decisions in the energy transition, nor does he ever consider social factors in the evaluations of these technologies, such as public perceptions, political beliefs, or the distribution of decision-making power. Renewables will not work in the short- to medium- term, according to Smil, just because in terms of cost-benefit analyses it makes little sense to replace more energy-dense sources of energy (fossil fuels) with less energy-dense ones. This is a very rational approach to reality,

3 Paul Voosen, "Meet Vaclav Smil", op. cit., (cf. note 1).

4 Paul Voosen, "Meet Vaclav Smil", op. cit., (cf. note 1).

but that is not how energy choices are generally made even today, let alone before the empowerment of accounting disciplines.

WHAT DRIVES TECHNOLOGY?

10 One of the most frequently debated questions in the STS has long been: does technology drive history? Does it drive society? And what is it that drives technology? These questions are connected to the question of agency. Questioning agency leads to a third problematic element in Smil's narration: the lack of it. Incidentally, lack of agency is perfectly in tune with Smil's pessimism regarding energy transitions: obviously energy transitions take longer if technologies are considered as disembodied tools. Quite often in *Energy and Civilization* are we presented with lists of inventions, one following another, introduced in this or that civilization, at this or that time, in what appears as a splendid edifice of rationalization of efforts, only tainted here and there by some passing failure. In fact, technological failure is almost never mentioned: when it is, the abandonment of a certain technology is justified on account of lesser efficiency. Technologies 'appear'; technologies perform acts ("Multitube planting drills reduced seed waste", p. 90), but what externalist historians would rather like to see here is perhaps fewer technical detail of moldboard ploughs or animal yokes, less namedropping of famous scientists and their inventions, and more on what social and political processes may have led to the adaptation and adoption of a certain technology. For example, when Smil mentions the evolution of the safety bicycle (p. 187), one would expect to find a reference to Wiebe Bijker's *Of Bicycles, Bakelites, and Bulbs*, a foundational work in the STS, in which the author convincingly argued that the final design of the safety bicycle did not ultimately win because of some intrinsically superior design. Some users felt that other early bicycle variants represented superior designs.[5]

11 To do justice to Smil, one needs to acknowledge that information on agency is sometimes impossible, or extremely hard to obtain for most of the time of the Homo sapiens sapiens era, in the almost total absence of written sources. And Smil honestly admits that (p. 42). But one may then legitimately ask: considering the multiplicity of activities in which energy is employed, the complexity of their interactions, and the difficulty in identifying agency until recently in history, is a history of energy possible at all? Isn't it too pretentious a task for an individual researcher? Imagine you want to write a book on the history of water and civilization. Multiply that for all possible energy sources, and you are more likely to require the work of a team of historians and archaeologists with varied language expertise for a decade, in order to come up with a historically meaningful account.

12 Even when he deals with more recent technological developments concerning energy, Smil does not seem too concerned with providing socio-political contexts: he is more interested in showing technical details of a particular furnace and the energy savings it allowed. Unfortunately, this unproblematized approach to the history of technology does not do justice to decades of social constructivism. One of the consequences is that Smil contributes to a history of technology that is marked by a linear view, where energy is constantly entangled with "evolutionary and modernist ways of thinking" that have been broadly criticized by contemporary historians of technology.[6] Sentences such as "without sickle and plow there would be no cathedrals" (p. 52) are debatable to say the least: since historical processes are not predetermined, we may have had cathedrals even without ploughs and sickles (or we may have had sickles and ploughs but no cathedrals, for that matter).

13 The introductory chapter is called "Energy and Society", but society is conspicuous by its absence throughout this work (including the

5 Wiebe Bijker, *Of Bicycles, Bakelites, and Bulbs. Toward a Theory of Sociotechnical Change* (Cambridge, MA: MIT Press, 1995).

6 Quoted from: Anna Szolucha (ed.), *Energy, Resource Extraction and Society. Impacts and Contested Futures* (London: Routledge, forthcoming in 2018), Introduction.

introduction itself). To be fair, Smil does produce some cameos of society here and there, as when he mentions the miserable working conditions of women and children in Scottish mines (p. 230). But that is a rather isolated remark until the last ten pages of the book, when issues of energy equity are mentioned and consumerist society is heavily criticized (although the political-economic system generating it is not). One would be deceived if one were to browse *Energy and Civilization* for a reflection on the catastrophic human consequences of centuries of resource extraction: little mention is made of the colonial era and the attendant slaves' role in producing resources (except in terms of energy cost needed in the building effort, p. 203), or of the inequity characterizing the production of energy in capitalist, 'anthropocenic' societies. We found only a brief reference to the fact that energy decoupling in Western societies is occurring at the cost of displacement of greenhouse gas emissions to poorer countries (p. 348), and while Smil sometimes mentions environmental consequences of overexploitation of resources, two lines later he is back on the exaltation of energy consumption as a universal measure of economic growth.

HISTORY FOR THE ELITES

14 This work is very likely to please the world's technopolitical elites: it hardly summons issues of power and equity; it advocates a developmentalist and incremental view of innovation; it affirms that the world needs switching to less carbonated energy sources but also that that will only happen in an extremely distant future, and that fossil fuels will dominate for time immemorial. In line with the neoliberal doctrine, Smil argues that the only remedy people can take are individual ones, such as consuming less meat or insulating their houses better. The body politic is nowhere to be found; collective action is not contemplated. In terms of societal action, this is a view that overemphasizes linearity and continuity, while running the risk of being interpreted as self-absolutory. When one turns over the last page of the book, in spite of the glimmer of hope that Smil provides in the final paragraph on the limits of energy explanations, one is left with the bitter aftertaste that only what has already happened in history, can happen again; what has not yet happened, cannot and will not happen.

POTENTIAL AUDIENCE

Ultimately, the richness of data this book presents can hardly be overrated, its cohesiveness and its plain—although at times excessively dry—language, make it a compact compendium of energy and technology (and much less, society). While historians of science and technology—especially those oriented towards social history—may find it desperately lacking in human agency and *passé* in its teleological narrative, the book will definitely stimulate the curiosity of readers versed in natural sciences or engineering that may have an interest in a well-structured, introductory smattering on the history of energy. Economic historians and energy historians may also find it useful as it provides a grand and detailed synoptic picture of the effort deployed by human beings in harnessing energy for the production of material benefits. 15

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Jean-Claude Debeir, Jean-Paul Deléage, Daniel Hémery, *Une Histoire de l'énergie. Les servitudes de la puissance* (Paris: Flammarion, 2013 [1986])

Abstract

Une Histoire de l'énergie. Les servitudes de la puissance is a long-term analysis of the energy systems that have shaped our societies since pre-historic times. This cognitive map depicts the continuities and transitions of the relationship between man and nature till our modern society and its democratic challenges.

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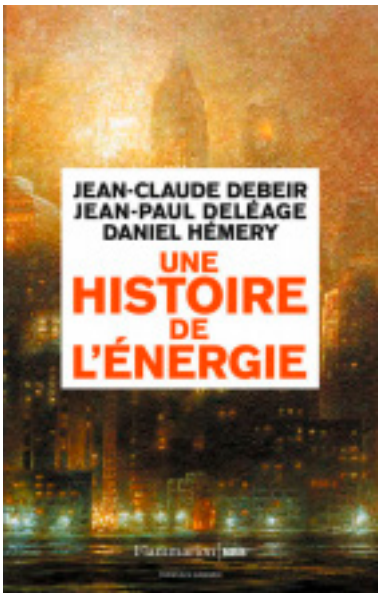
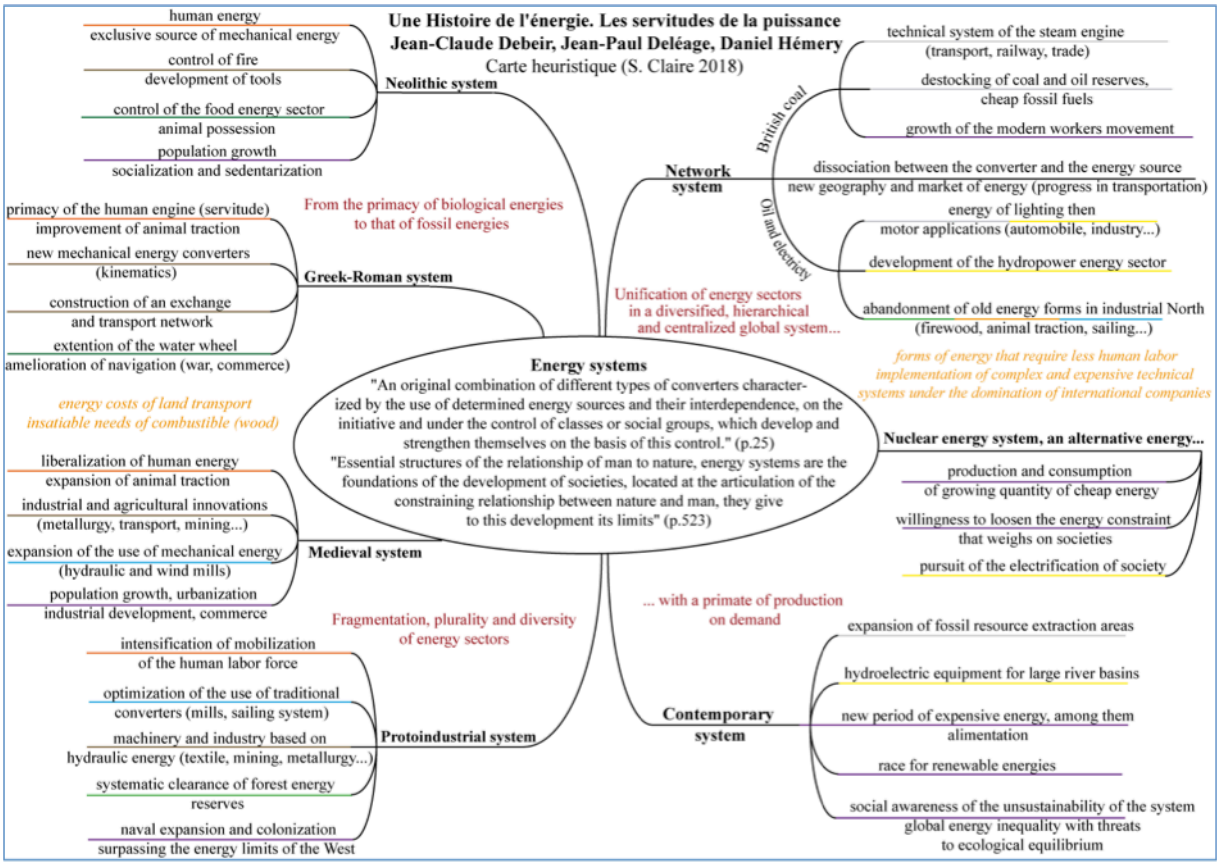


1 This cognitive map of *Une Histoire de l'énergie. Les servitudes de la puissance* written by Jean-Claude Debeir, Jean-Paul Deléage and Daniel Hémery, attempts to reconstruct the two main perspectives developed by the authors, which constitute the major contributions of this book. The first perspective is conceptual: it constructs the analytic notion of "energy systems". The second perspective is a *longue durée* approach that enables to think about the society we are building. A cognitive map, that is a visual representation of a thought pattern, reproduce the authors' argument in its entirety and complexity, and invites a synthetic and in-depth analysis. In the center of the book and the map is the notion of "energy system" surrounded by his historical translations: the preindustrial systems on the right and industrial systems on the left, in chronological order from bottom to top. The different branches of the systems (orange: human labor and animal traction, blue: hydraulic and wind resource, green: biomass, grey: fossil energy, yellow: electricity, purple and brown: social and technic considerations) bring out the different energy sources within each system and point out the rupture or continuity in their exploitation by the different social models.

2 Throughout the book, the authors reconstruct the characteristics of the main energy systems developed by western and Chinese societies, highlighting their issues, constraints and



dependencies. The notion of "constraint", central in the authors' analysis to explain the development and decline of energy systems, appears to be both related to the physical characteristics of the resource but also to the exploitation form put in place by the various forms of social organization, thus modelling a socio-energetic system. The authors shed light on the persistence of the constraint of transportation and the insatiable needs of wood encountered by the Neolithic, Greco-Roman, medieval and protoindustrial systems all based on the extraction of organic energy. The diversity of energy sectors inside preindustrial systems is gradually being replaced by the creation of global and centralized energy networks within nascent capitalism: the era of coal, oil and electricity networks is ushering in a new period the relationship of man to nature by breaking the previous constraint of transportation. The newly formed energy sector in the hands of a few global companies offers energy that tends to precede demand. The alternative of nuclear energy as a way out of global energy inequalities, climate and environmental crisis is no longer as promising and is not adequate to loosen the energetic constraint, which weighs on capitalist societies.

With this invitation to think about the long term, the authors show the succession of energy paradigms, the last of which being the energy transition, and the complexity of the passage from one to the other, often much less radical than one might think, in the manner of the evolution of human societies. They show that no energy system exists without constraints and that we must rethink ours as a whole, starting first by questioning its capitalist structure and our weakened democracy. Energy model and society are thus thought together with their mutual determination. The authors' desire to think of energy in its social, economic, environmental and political roots, as this map tried to represent, should thus continuously animate any history of energy so that it remains a history of humanity.

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Carbon Democracy: Political Power in the Age of Oil (Timothy Mitchell, 2011)

Bibliographic reference

Timothy Mitchell, *Carbon Democracy: Political Power in the Age of Oil* (London: Verso, 2011)

Abstract

Carbon Democracy is an inquiry into the relations between fossil fuels and political power. Timothy Mitchell analyses energy systems as political machineries that need to be consider in histories of democracy. To do so, he follows the connections and conversion that were engineered to extract, produce and distribute coal and oil, drawing together materialities, politics, and ideas.

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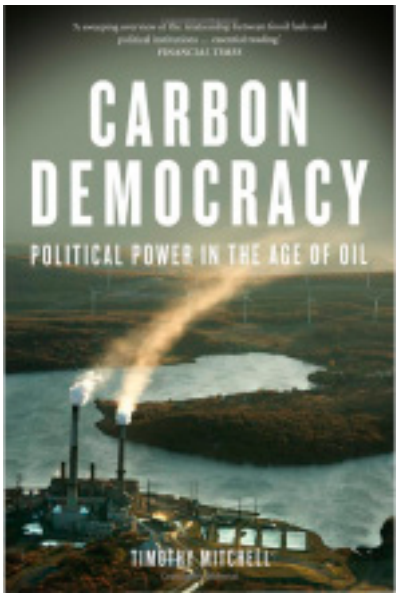

1 The intention of Timothy Mitchell in *Carbon Democracy* is quite straightforward, even though its subject matter is not: to investigate how democracy relates to fossil fuels. The book starts from a seemingly simple question: by retracing the history of the exploitation of oil and contrasting it with that of coal, what do we learn about the organisation of political and economic power? Mitchell answers with an invitation to revisit our conception of democracy, opening his book on the strong claim that "Fossil fuels helped create both the possibility of modern democracy and its limits" (p. 1). The implication is that the history of democracy and of its transformations during the 20th C. is inseparable from the history of fossil fuels -and, in particular, of oil. This does not mean that oil explains everything about the organisation of political power -indeed, Mitchell shuns technological determinism-, but rather that oil cannot be left out of the equation.

2 Mitchell's account of the history of the intricate connections between oil and political power is too detailed to be summarized here—it spans a whole century, travelling from the Persian Gulf to Bretton Woods. Instead, the review focuses on how oil is included in the equation: how does Mitchell analyse "democracy *as* oil" (p. 5), and what does he say from there? I will first discuss the distinct perspective on energy history that Mitchell adopts, and then draw on his key arguments to show how he puts it to work.

THE MAKING OF POWER

Carbon Democracy is a striking demonstration 3
that the history of energy is about much more than a history of resources and technologies: it shows how energy is intimately, crucially, linked to the making of political and economic power. Mitchell adds a layer to this argument: to deploy the full potential of such histories, we *need* to take resources and technologies seriously. The core ambition of the book is to follow oil and the sets of connections that were engineered in the process of extracting and distributing it. Mitchell looks into the very physical properties of oil and into how it is measured, extracted, shipped, consumed, and converted into money and power. Such things, he argues, are generally glossed over in traditional accounts about oil and power: they focus on oil money, ignoring the whole equipment and operations that went into converting oil into monetary flows. The argument extends to democracy, which Mitchell does not approach as a set of principles and ideals (or as, in his own words, an idea, that is something that stays the same, regardless of space), but as the engineered result of specific socio-technical arrangements. "Carbon democracy", then, refers to the forms of politics that emerged from arrangements connecting fossil fuels, finance, and political power.

The book is thus about connections and con- 4
versions. Its strength lies in how it interweaves descriptions of the material (resources, infrastructures, technical devices), the political (imperial power, geopolitics, the constitution of Middle-Eastern states, contestations) and the history of ideas. This quality runs through Mitchell's bibliography, and is a testimony to the contribution that actor-network theory and performativity studies can make to the study of energy (see Box below).

ACTOR-NETWORK THEORY AND PERFORMATIVITY

Mitchell introduces himself as a political the- 5
orist and historian, but his work takes part in Science and Technology Studies, and falls in line

with actor-network theory and performativity studies. *Carbon Democracy* builds on the work of Bruno Latour and Michel Callon who, as leading proponents of actor-network theory, have developed methods to bring nature and technology within the realm of social sciences and humanities and, thereby, to question the divide between nature and politics. Actor-network theory is characterized by its relational take on social processes, its inclusion of the non-human as social actors, and its attention to situations of controversies in which "sociotechnical arrangements" are put to the test and negotiated. It has also contributed to the study of economics and markets, with two major interests: first, the "performativity" of economics, that is to say, the distinctive ways in which economics knowledge relates to its objects and takes part in constituting the economy; and second, descriptions of the functioning of the economy and of markets focused on "market devices", that is the sociotechnical devices, both material and conceptual, that organise it.

6 The influence of these perspectives notably shows in the way Mitchell interrogates the making and maintenance of the divide between the "natural" and the "political"[1] and of the particular domain of the "economy", whose constitution in the mid-century is one crux in the series of events analysed in the book. These interrogations are formulated by considering the history of oil and power in terms of what scholars in actor-network theory have called "socio-technical arrangements"[2] (or *agencements)* -in other words, by analysing the relations between humans and non-humans, materials and ideas, or calculations and objects of calculation. And it is precisely the attention to these connections and assemblages which enables Mitchell to address the constitution of such large entities as democracy, the economy or the market. These, Mitchell shows, are made of abstractions (calculations, theories, discourses) as much as of concrete, massive objects—pipelines, refineries, ships, weapons. The book moves seamlessly between detailed historical and geopolitical accounts of events related to oil and reflections on the making of doctrines and objects of government.

7 Tackling an issue so broad in scope and so fraught with power and violence as the history of oil is, at the same time, a challenge to actor-network theory, however well-equipped it is to disentangle situations of controversies and uncertainty. Mitchell faces giants—the oil infrastructure is massive and democracy is not the most easily circumscribed of notions. The vast and precise panorama he draws to tame them contrasts with the narrowly empirical perspective of most actor-network theory studies. It is a challenge to scrutinize the intricacies of socio-technical arrangements over a century, and across most of the globe, and the entities tackled sometimes remain hard to grasp. Despite the promise of the title and earlier chapters, democracy, for instance, is not seen at work consistently throughout the book, and in some parts it tends to retain a somewhat nebulous character. Other entities such as the economy, on the contrary, are deployed and dissected in great and powerful detail.

8 Two main threads of inquiry run through the book to build up the argument that equipping energy production is also, to varying degrees, equipping political power: the analysis of energy systems as political machines and that of the calculation techniques developed around coal and oil production. Two key chapters deserve closer attention as they lay out the bases for these two lines of reflection: Chapter 1, which analyses coal extraction as a political machine that equipped mass democracy and contrasts it with the oil industry; and Chapter 5, which is an account of the emergence of the "economy" as a governable entity and a central object of government.

1 Bruno Latour, *Politics of Nature* (Cambridge, MA: Harvard University Press, 2004).

2 Andrew Barry, "Technological Zones", *European Journal of Social Theory*, vol. 9/2, 2006, 239-253; Andrew Barry, *Political Machines: Governing a Technological Society* (London: Athlone Press, 2001); Koray Çaliskan, Michel Callon "Economization, Part 2: A Research Program for the Study of Markets", *Economy and Society*, vol. 39/1, 2010, 1-32.

COAL AND THE POSSIBILITY OF MODERN DEMOCRACY

9 Coal, Mitchell demonstrates in Chapter 1, was instrumental in the development of industrial democracy at the turn of the 20th C. The first step undertaken in *Carbon Democracy* is to introduce coal as a player in the history of modern democratic politics, to provide an account of how it played, and to contrast it with oil. The argument is not that democratic demands were a product of the increased use of coal as fuel, and much less that the extension of democratic rights was a necessary consequence of building energy systems based on coal. Far from positing that specific energy resources foster specific forms of politics, Mitchell describes how political agencies and demands pushing for mass democracy were assembled with, and within, the production and use of coal. To do so, he is particularly attentive to the material properties of coal and of the networks through which it circulated through industrial societies. These material properties go from the unprecedented quantity of energy concentrated in coal to the organisation of labour, expertise and distribution networks organised around coal. For instance, Mitchell shows how the increase in available energy transformed industries, trade and the spatial organisation of societies. However, his main contribution lies in his analysis of the forms of collective organisation that developed around coal flows: in his account, the coal industry appears as an equipment for political demands—a "political machine", in Mitchell's words (p. 12). The circulation of coal as the fuel of the burgeoning industrial society connected workers in different places and sectors. Collectively, coal workers—the miners, but also all those involved in the circulation of coal—could turn the "machine" they operated into a very powerful tool for political leverage. By exploiting coal dependencies and the vulnerabilities of coal extraction (dependent on underground expertise) and distribution (organised in large part around railways), coal workers were able to gain some control over energy flows, and, with this, political power that carried forward labour parties and drove a gradual expansion of democratic rights.

OIL AND THE LIMITS OF MODERN DEMOCRACY

10 This exploration of the links between coal and democracy provides the basis for the rest of the book. How did the "political machines" of oil contrast with those of coal? First, they connected the politics of industrialised countries with those of oil producing countries, and, second, to a large extent, they enabled limitations of democratic aspirations in both. To understand how that happened requires analysing how control over resources is gained, as the section on coal demonstrates. And controlling a resource implies controlling extraction, workforce, supply, flows, prices and demand.

11 The development of oil took shape in very different control patterns from that of coal. It occurred in regions remote from large populations and far from the industrialised places were oil would be used. It was much less work-intensive than coal, and work was above ground. Workers were imported and racially segregated, hindering collective organisation. Oil, as a liquid, was relatively light and transited in pipelines and on ships, travelling large distances on dendritic networks—meaning that two points could be connected by several routes. In the sociotechnical arrangements of oil production, firms held most of the control. They used it not as a tool to promote political demands, but to maintain scarcity. The mechanisms set up to produce scarcity acted on resources (securing access slowing down production), on distribution channels (controlling flows, restricting the development of alternative channels), and on demand (encouraging a shift from coal to oil, producing lifestyles relying on heavy oil consumption).

12 Mitchell then investigates the engineering and transformations of the mechanisms arranged to grasp and hold control over oil, as well as of the forms of politics and power that they enabled and maintained throughout the 20th century, with a focus on the Middle East.[3] *Carbon*

3 Oil producing countries in South America are mentioned but not covered in as much detail as those in the Middle East. The book does not consider the arrangement of oil production in countries such as Norway and Scotland, leaving one to wonder to what extent they would constitute examples of alternative ways to assemble fossil fuels and democracy.

Democracy covers the seizing of Middle-Eastern oil resources by American and European firms in the early 20th C. and the strategies to contain production (Chapter 2); the mechanisms designed to keep control over oil in the transition from imperialism to self-determination and the links between the oil industry and democratic demands in newly independent Middle Eastern States (Chapters 3 and 4); the political struggles of these States to reappropriate their oil resources, the resistance of oil firms, and the doctrines and financial mechanisms set up to keep control over oil (Chapter 6); the contemporary imbrications between oil capitalism and political Islamism, labelled as "MacDjihad" (Chapter 8).

CRAFTING THE ECONOMY

13 A second thread runs through the book: that of the interrelations between fossil fuel production and economic life. It leads to some of the most original and convincing propositions of *Carbon Democracy.* Fossil fuels, Mitchell argues, did not only contribute to shape modern democracies; they also underlay the coining of a new entity, the "economy". In Chapter 5, Mitchell demonstrates that the economy as it is understood today did not exist until the 20th C., when it gradually became an object of study for economists, and a key organising principle and object of government. He thus describes the crafting of this new space of intervention between nature and politics as another way in which fossil fuels were embedded in the organisation of democracy.

14 Mitchell's take on the economy builds on his previous work. Throughout his career, Mitchell has investigated the production of the economy as an autonomous domain of expertise and policy.[4] He has also explored how economics as a discipline "makes its world",[5] and how it relates to the objects it studies. Economic knowledge, he has shown, is not so much about representation as about intervention: it takes part in constituting its objects, and produces arrangements that organise the world *and* establish economic facts.[6] Following this line of thought, *Carbon Democracy* retraces how fossil fuels were incorporated in the economic system, that is to say in the very organisation of economic and financial life but also in the conceptual apparatus of economics. The strength of the account lies in its capacity to display the complexities and intricacies of the systems analysed, making them legible without simplifying them. Large parts of the book analyse calculation in the ages of coal and oil, and its links to the abundance of energy concentrated in fossil fuels and to the practical arrangements of economic, financial and political life that were engineered around coal, then oil.

15 The most elaborate analysis is that of the "Fuel Economy" in Chapter 5. Mitchell details the role of fossil fuels in the conceptualisation and organisation of national economies as measurable and governable entities liable to grow without material limits. He also situates this evolution in the history of economic thought. While the rearrangement of the international financial system after the Second World War (notably the end of the Gold Standard) based it upon the flow of oil, the discipline of economics abstracted its object from concerns over natural resources. As fossil fuels constituted seemingly inexhaustible amounts of energy, Keynesian economics were the first to consider that the availability of resources was no longer a threat, and that what mattered was the circulation of money. Economics became the science of monetary flows, whose main object was an aggregate of all monetary transactions within a given space, the "economy". This new object, that statistical techniques developed in the age of coal helped measure, became a crucial focus of policy. The calculation techniques used to define the economy excluded nature and resources from economics and politics. They also limited democratic debate, because they defined the

4 Timothy Mitchell, "Fixing the Economy", *Cultural Studies*, 12/1, 1998, 82-101.

5 Timothy Mitchell, "The work of economics: how a discipline makes its world", *European Journal of Sociology*, vol. 46/2, 2005, 297-320.

6 Timothy Mitchell, "Rethinking economy", *Geoforum*, vol. 39, 2008, 1116-1121.

object of politics as something to steer using economic expertise. Last, by coining the economy as something that could grow indefinitely, they contributed to orienting democratic politics towards the future as a limitless horizon of growth.

RE-OPENING ENERGY SYSTEMS

16 Like the analysis of coal production as a political machine in the first chapter, the account of the production of the economy provides a basis for further discussions of subsequent developments in the history of oil, energy expertise and democracy. Chapter 7 focuses on the multiple transformations that were bundled up under the "oil crisis" of 1973-74. Unravelling the so-called crisis, Mitchell encounters and opens up several entities that have now become self-evident in debates around energy – much like the economy has become an evident concern in politics: the environment, the oil crisis, limits, energy as a new domain of public intervention, or the market. In particular, he shows how the market as conceived by neoliberals came to supersede the Keynesian economy as a device for organising and regulating economic life. The very notion of the "oil crisis", and more specifically the idea that the sudden increase in oil prices was a textbook example of the laws of supply and demand—hence that it was an issue of market regulation—then appears as related to the work devoted to pushing the market as a new principle of political organisation and regulation—and as a new set of techniques to contain democracy.

17 The concluding chapter pursues the investigation of the calculation techniques that take part in constituting the worlds of oil. It posits that more transformations are underway with the end of the fossil fuel era on the horizon. Two related issues make it increasingly difficult to consider that oil does not count and does not need to be counted: the dwindling pace of discovery of new resources, and climate change. Oil can no longer be so easily extracted from the ground—in conceptual as well as in physical terms (tar sands or shale oil are much harder to extract than conventional oil and require direct intervention in the rocks). *Carbon Democracy* then ends on a note of cautious hope: the current situation, in which the uncertainties around oil production are becoming more visible, is an opportunity to reclaim the territory that calculative techniques of economics have established between nature and politics.[7] The future of energy politics will not be determined by the forms of energy used; it will depend on how the connections between resources, politics, technologies, society and finance are arranged. Ultimately, *Carbon Democracy* is an invitation to continue opening up these arrangements and following these connections. In so doing, we can redefine energy as a sociotechnical matter that can be acted upon in more or less democratic ways, depending on how it is collectively seized. This claim makes *Carbon Democracy* a manifesto for the relevance of energy studies that do not shy away from analysing the making of power in every sense of the word.

7 Mitchell has discussed this further in an episode of the Cultures of Energy Podcast, produced by the Center for Energy and Environmental Research in the Human Sciences at Rice University. Cultures of Energy Podcast, Episode 57, http://culturesofenergy.com/ep-57-timothy-mitchell/ (accessed 11/05/2018)

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Power to the People: Energy in Europe over the Last Five Centuries (Astrid Kander, Paolo Malanima and Paul Warde, 2013)

Bibliographic reference

Astrid Kander, Paolo Malanima and Paul Warde, *Power to the People: Energy in Europe over the Last Five Centuries* (Princeton: Princeton University Press, 2013)

Abstract

Kander, Malanima and Warde's book aims to demonstrate the potential of energy statistics to understand the historical and economic evolutions of European countries since the Renaissance. During the last five centuries, successive energy transitions allowed an unequaled expansion of energy consumption, leading to our current dependence on fossil fuels. According to the authors, rises in energy consumption and economic growth seem strongly intertwined. Nevertheless, the authors' tendency to limit their analysis to neoclassical economic patterns represents the major questionable point of this book.

Plan of the article

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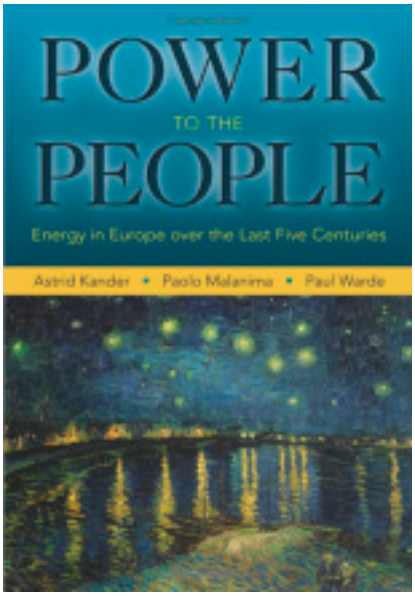

1 The economic history of Europe since the sixteenth century has already led to extensive historical research coverage with divergent analytical viewpoints. Kander, Malanima and Warde do not attempt to summarize this research. More precisely, they aim to offer a new narrative of the history of modernity through the lens of energy consumption. According to them, historians and economists did not sufficiently put the stress on the historical role of energy in the shaping of our modern economies. Yet "all things need energy, and all actions are transformation of energy" (p.1). This statement illustrates clearly the intellectual approach of this book. Inasmuch as energy is at the heart of every human activity and natural process, any economic production in a specific historical society takes place within a broader energy economy that characterizes this society. From this point of view, the history of human economies can be studied as a history of energy dependence. This book concentrates on modern times, since this short period in history represented a very specific moment in terms of energy consumption.

2 *Power to the People* is the result of an important work of data compilation achieved by the Long-Term Energy and Growth (LEG), an international research network dedicated to the production of comparable historical assets of energy consumption around the world (principally Western European countries). The database that served as a reference for this book is freely accessible online on www.energyhistory.com. It represents a very impressive and useful work for historians, since the compilation of such quantitative data allowing international comparisons over several centuries is always a tricky (and sometimes hazardous) task. With these data, the authors wish to illustrate the decisive role played by the energy factor in the evolution of European economies in the last five centuries.

3 The major center of interest of this book is to understand the links between energy consumption and economic growth since the beginning of modern times. The main argument of the authors is that modern development would not have been possible without successive historical changes in the energy model of European economies. As argued by Edward Anthony Wrigley,[1] the industrialization of Europe meant a structural shift from an "*organic dependent*" to a "*fossil fuel dependent*" economy. But as the title suggests, the authors also show an interest in the links between the last centuries' energy transformations and people's rising "*empowerment*". Following Timothy Mitchell's analysis,[2] Kander, Malanima and Warde suggest that the increase of energy consumption participated in people's emancipation over time. This went mainly through the political power brought to energy workers by the first industrial revolution, and also through the reduction of working time supposedly brought by the consumer society.

4 The book is divided into three sections, in accordance with the traditional chronology of economic modernity: pre-industrial economies (from 1500 to 1800), the first industrial revolution (from 1800 to 1900), and the second and third industrial revolutions (twentieth century). Each part was written by one of the authors, depending on their historical expertise: Paolo Malanima on pre-industrial times, Paul Warde on the first industrial revolution, and Astrid Kander on the

1 Edward A. Wrigley, *Energy and the English Industrial Revolution* (Cambridge - New York: Cambridge University Press, 2010).

2 Timothy Mitchell, *Carbon Democracy: Political Power in the Age of Oil* (London - New York: Verso, 2011).

twentieth century. In each historical phase, the authors try to identify what were the scale and the economic drivers (mainly technological breakthroughs) of the energy transitions that participated in reshaping the world.

AN ENERGY HISTORY OF EUROPEAN ECONOMIES OR AN ECONOMIC HISTORY OF EUROPEAN ENERGY?

5 This question could seem rhetorical, but it is worth raising. In order to well understand Kandler, Malanima and Warde's book, whose economic reasoning is sometimes complicated to follow, it is important to identify their fundamental concern. And one could argue that the latter is more of an economic nature than an historical one. Of course, the authors do not forget to mention the multiple changes that accompanied the energy transitions in European ways of living and in social relations, but this is not the core of their questioning. Their concern is to understand how the energy resources and devices participated in the successive phases of economic growth. In order to do so, they borrow several economic concepts that allow them to write their narrative of the energy revolutions.

6 The most important of these notions is the "*development blocks*" as conceptualized by the Swedish economist Erik Dahmén.[3] It refers to a set of industrial products and technologies that are strongly interconnected in their economic development. They form a block in the sense that their economic path is codependent. For example, coal, steam engines and steel formed a major development block during the first industrial revolution because coal's success would not have happened without the steam engines' needs in coal. Those engines themselves needed cheap steel in order to be manufactured, and that would have been impossible without the new forging techniques using cheap coal. In order to follow the reciprocal influences of the products and techniques inside one development block, the authors study their reciprocal price dynamics over time.

7 Following the very classic narrative of industrial history, inventions and innovations play a major role in Kandler, Malanima and Warde's story. The rise of coal, oil and electricity relied on major technical and scientific breakthroughs such as steam and petrol engines, that the authors call "*macro-inventions*". But they also attach importance to more local, daily and small-scale innovations in the overall process of industrial revolution, in accordance with the research of historians like Joel Mokyr[4] or David Edgerton[5] pointing out the economic role of "*micro-inventions*" and the persistence of old techniques in the new world. The numerous micro-inventions that made it possible to adapt the steam engine to factory machines where almost historically as important as the invention of the steam engine itself.

8 As the intellectual reasoning of Kander, Malanima and Warde is of an economic nature, they use several concepts that enable them to illustrate the classical laws of the market. These are mainly the "*market suction*" and "*market widening*" notions. While the former allows us to understand the rise in price of a good that is necessary for a specific production process (for example oil required by engines), the latter explains how low costs of a resource or a technical device can stimulate the use of new energy forms.

9 Finally, in order to write their quantitative history of energy, the authors created several markers that allow them to link the historical energy consumption to economic figures. The most important of these markers probably is "*energy intensity*", defined as the ratio between the total energy consumption of a country and its gross domestic product (GDP). It is then a useful way to quantify how much energy was

3 Erik Dahmén, "'Development Blocks' in Industrial Economics", *Industrial Dynamics*, vol. 10, 1989, 109–21.

4 Joel Mokyr, *The Lever of Riches: Technological Creativity and Economic Progress* (New York: Oxford University Press, 1990).

5 David Edgerton, *The Shock of the Old: Technology and Global History* (New York: Oxford University Press, 2006).

necessary to produce an amount of growth at a given time and also to evaluate the evolution of the dependency of growth in energy consumption. The smaller this number is, the less energy is needed to produce the same amount of riches.

PRE-INDUSTRIAL ECONOMIES AND THE "PHOTOSYNTHETIC CONSTRAINT"

10 The particularity of Malanima's approach is to consider food as a primary energy source. This allows him to illustrate what he considers to be the economic limit of the energy systems of the pre-industrial agrarian societies. The majority of economic production was performed by human and animal muscles, themselves principally assigned to energy production. Indeed, most of working time was used in order to produce daily energy supplies: agricultural products for human nutrition, fodder for working animals, and firewood for heating. Moreover, the low fertility of European soils required the cultivation of bigger areas compared to other parts of the world. Wind and water-mills were very important as the only sources of non-muscular mechanical energy. They played an important role in the daily life of village communities. But quantitatively speaking compared to cereals, fodder and wood, wind and water represented only a very small amount of the total energy consumption.

11 Pre-industrial societies were characterized by their predominant use of reproducible energy sources. Until the 18thC. coal represented an insignificant energy source for heating in European countries, except in England where land-scarcity led to a growing consumption of coal from the sixteenth century onwards. According to Malanima, this predominance of vegetal energy systems in pre-industrial societies was a major barrier to economic growth. There were physiological limitations to the increase of human and animal work yield – also implying severe constraints on transport capacities –, and the possibilities of increasing the agricultural productivity were very limited. As a consequence, pre-industrial economies were very sensitive to temperature and climate variations. Nevertheless, the introduction of new crop varieties from America (potatoes, maize, etc.) and the generalization of crop rotation techniques made it possible to compensate population growth from 1500 to 1800.

12 Malanima's account draws a very rigid or static picture of these three centuries of economic and technical history. For him, "*the agricultural energy basis of past civilizations was the main obstacle to their economic progress*" (80). The inelastic availability of cultivable lands, and the competition between agriculture, pasture and forest activities almost made economic growth impossible.

COAL AND THE FIRST INDUSTRIAL REVOLUTION

13 According to the authors, coal was what allowed European economies to free themselves from the organic energy constraint. The majority of wealth created was no longer the result of the work of muscles, but of machines. Warde puts the stress on a particularity of this new energy system centered on coal, steam power and steel: steam engines made it possible to deploy an amount of power that no previous organic energy converter was able to give. Then steam engines did not only replace human and animal work, they multiplied the production capacities of industrial economies, bringing growth possibilities unknown until then. This growth was also supported by the "*transport revolution*" brought about by steam ships and locomotives. And this new economic growth implied an important increase in the European energy consumption in return.

14 Britain appears at the heart of these dynamics. For the authors, this is mainly because of her historical advantage in coal consumption. The technical innovations that led to industrial steam engines were firstly developed there because of her needs in deeper mine digging. The development block formed by coal, steam engines and steel progressively opened the way to easy availability of cheap energy for countries with sufficient coal deposits. This radically transformed the geography of wealth production on global and national scales. Inside countries, industrial cities with high concentrations of workers became the

core of the production of riches. At an international level Britain, as the most industrialized country and the first European coal producer, clearly played the leading role in the nineteenth century economy. National differences in coal deposits and in the transition dynamics to an industrial economy led to an international and combined division of labor. Even if there were no close links between total energy consumption and income in a cross-country comparison for this period, it appears that the income of a country was clearly linked to the share of coal in its total energy consumption. In other words: nations seeking important growth rates had to go through a coal transition for their industrial and/or transport development.

15 Warde insists on both the positive and negative side effects of this energy revolution, in terms of pollution and social changes. In particular it implied a major reorganization of productive processes, with the imposition of a strong discipline on workers, no longer useful for their muscular strength but for their ability in monitoring machines. For the authors, this could be characterized as a "*labor saving*" process. In return, with their new and vital economic role, coal workers were able to gain new social rights and to impulse the emergence of workers' organizations.

16 Warde also puts the stress on the fact that this coal revolution like the following energy revolutions did not imply the end of the organic energy system. Agriculture was even able to win important productivity rates at the end of the nineteenth century with the development of synthetic fertilizers. And animals still played a vital role for short-distance transport on agricultural fields and in cities. But from a quantitative point of view, organic forms of energy had become insignificant during the nineteenth century.

OIL, ELECTRICITY AND THE INFORMATION AND COMMUNICATION TECHNOLOGIES IN THE 20TH C.

17 The twentieth century was characterized by two industrial revolutions and new development blocks studied by Kander. Like the previous ones, they strongly contributed to the rise in energy consumption and the change in the positioning of the countries. Quantitatively speaking, coal continued to represent an important part of European growth during the whole of the twentieth century. But oil and electricity made it possible to diversify energy sources and brought new domestic and industrial usages.

18 The development block formed by oil and the internal combustion motor radically transformed the geography of energy supply on a global scale, with the economic emergence of the USA. The liquid nature of oil also allowed more flexibility in its provision. For the authors, the oil development block is centered on the transport domain. It made a new transport revolution possible with cars, fuel ships, and planes. Internal combustion engines created a market suction for oil, that finally ended in a market widening dynamics with the necessity to find other outlets than petrol for crude oil (chemistry, heating, etc.).

19 According to Kander, the electricity and electric engines development block was revolutionary because of the "*modularity*" of electric power: it can be produced by many primary sources of energy (water, coal, nuclear, etc.) and electric motors can perform a great diversity of tasks from factories to houses. The fluidity of the new energy system can be illustrated by the reaction of the European countries after the two 1970 s' oil shocks: they witnessed a diversification of their energy primary sources with a relative decline in oil consumption and a rise in nuclear electricity and natural gas consumption.

20 Like the coal development, the oil and electricity emergence required many technical inventions and innovations that led to major efficiency gains in terms of energy use. But as during the nineteenth century, the total energy consumption did not stop rising. From 1800 to 1970 innovations in energy savings always meant more energy consumption. But according to Kander the period after 1970, characterized by the Information and Communication Technologies (ICT) development block, is historically remarkable in the sense that it witnessed a reduction of energy intensity and a stabilization of energy consumption per capita.

This point is probably the most interesting and groundbreaking argument of the book. Kander rejects any interpretation of this energy intensity reduction in terms of "dematerialization" of Western economies. For the author, this phenomenon must be understood as the power-saving effect of the generalization of microelectronic devices in industrial and domestic uses. These devices would have permitted a reorganization and a rationalization of production processes that strongly helped to save energy. Furthermore, the growing specialization of European industry in light manufacturing rather than raw industry would also have permitted to reduce the amount of energy needed to produce the same amount of riches.

A (NEO)CLASSIC NARRATIVE OF EUROPEAN INDUSTRIAL HISTORY?

21 Kander, Malanima and Warde's book represents both an impressive overview of the most important research work on history of energy in Europe, and a challenging attempt to re-inject the energy factor into the historical economic analysis. Not only do the authors propose a quantified history of energy consumption and dependence in the European countries. They most importantly offer an economic framework of interpretation (development blocks, market suction and widening, energy intensity) that allows them to link their quantitative energy data to growth figures. But behind this original approach, the narrative of modernity offered by the author follows the most classic historiography on industrial revolution. Modern economies were profoundly reshaped by a series of technical revolutions in the energy domain that inevitably led to the emergence of our industrial world.

22 At first, it may seem difficult to characterize the authors' framework in terms of economic analysis: development blocks and the role of innovations evoke Schumpeter's economics, while the interpretations in terms of market suction and widening look more like classical Smithian economics. But in the end, the authors clearly opt for a neoclassical analysis. Price dynamics are the main factor of the evolution of the last centuries' economies. Path-breaking innovations and micro-inventions in the energy domain were historically important because they made it possible to impulse the new market dynamics (widening of demand, price fall, etc.) that radically transformed our modern societies. According to the authors, the basic laws of the market were the real agents of the historical energy transitions. This represents an important limit of this book, because its narrative strongly tends to depoliticize and naturalize energy history over the last centuries, as if there were no winner and loser of these transitions. Yet for several decades now, important works on social history of science and technology put the stress on the fact that no technical evolution ever went without protests and the reinforcement of political and economic interest for some people.[6]

23 Another limit of this book is its restriction to a West European geographical scope. This would not be a problem if the author only intended to produce a statistical survey. But the point here is to make a whole analysis of European economies in the chosen historical period. Even in the sixteenth century, European economies had begun to be integrated into global networks of trade and production. Is it really meaningful then, to link European countries growth rates (a more and more international phenomena since the sixteenth century) to national energy consumption data? For example, the authors did not take into account the food consumption of slaves on the American continent, while their work in cotton production strongly participated in shaping the West European economies from 1600 to 1800. And for the current period, the authors' interpretation of the power saving phenomena in European countries is strongly questionable. With the current globalization of industrial production, the international division of labor and the strong co-dependency between every national economy, does it really make sense to attempt to link national growth products with national energy consumption data?

6 Langdon Winner, "Do Artifacts Have Politics?", *Daedalus*, vol. 109/1, 1980, 121–36; François Jarrige, *Technocritiques : Du refus des machines à la contestation des technosciences* (Paris : La Découverte, 2014).

On a global scale, energy consumption has not stopped growing since 1970. And would it be possible for European countries to currently experience such an energy saving phenomena, if Asian energy consumption had not risen remarkably since 1970?

OTHER POSSIBLE NARRATIVES FOR THE ENERGY HISTORY OF EUROPE

24 The Kander, Malanima and Warde's limitation to a classical economics analysis too strongly restrains the understanding of the relations between energy and economic transformations since the sixteenth century. Some research tracks will here be suggested in order to diversify the narratives that can be drawn from the data compiled by the authors. These proposals are inspired by recent research in critical history of science and technology, such as Christophe Bonneuil and Jean-Baptiste Fressoz's work on the Anthropocene.[7] Each of these narratives shares the same approach: they do not analyze energy transitions as the achievement of an inevitable economic process opened by technical innovations. On the contrary, they believe that energy transitions were the result of political choices and very individual economic interests.

25 Firstly, we could think of another reading of the relations between emancipation and energy. This story would then be centered on the historical struggles against and for energy transformations. For example, it seems obvious for the authors to consider firewood as a commodity since the sixteenth century. However, research in social history such as Edward Palmer Thompson's on forest-wood in Britain[8] clearly demonstrated that the emergence of wood as an economic commodity was the result of several decades of social struggles about the imposition of a wood market. This was rendered possible with the strengthening of the repressive modern states. Land and wood scarcity "for the people" in England was the result of a long process of land and forest appropriation and enclosure with state support. Coal emergence and the industrialization of European economies would have been impossible without these severe political measures, that allowed the making of the urban working class. If energy transitions had always meant empowerment for the people, there would have been no Luddite movements in the nineteenth century, nor current struggles for environmental justice. Furthermore, one could argue that the energy intensity reduction phenomena described by Kander at the end of the book are much more related to the emergence of ecological struggles in the years 1970 than it is to ICT devices. Confronted with growing concerns about environmental destruction and climate change, European countries have been progressively pushed into presenting a lower carbon dioxide emission profile.

26 Another way to reinterpret the history of energy in Europe since 1500 would be an attempt to link the long term energy series provided by Kander, Malanima and Warde to the question of the emergence of the modern states. As many works in economic history or in history of science and technology demonstrated, those modern states were strongly involved in pushing technological development as a way of increasing their power.[9] From this point of view, economic markets are not just abstract entities but they result from very concrete state economic policies. During the last five centuries energy resources were not only commodities but also a central means for European states in order to affirm their economic and military superiority. The cheapness of coal in nineteenth century England had a lot to do with canal construction by the state in order to allow coal transport. And European electricity would not have proved profitable

7 Christophe Bonneuil, Jean-Baptiste Fressoz, *The Shock of the Anthropocene: The Earth, History and Us* (London, New York: Verso, 2017).

8 Douglas Hay, Peter Linebaugh, John G. Rule, Edward P. Thompson, Cal Winslow, *Albion's Fatal Tree: Crime and Society in Eighteenth-Century England* (London, New York: Verso, 2011 [1975]).

9 As examples for the British and French cases, see Eric H. Ash, *Power, Knowledge, and Expertise in Elizabethan England* (Baltimore, London: Johns Hopkins University Press, 2004). Philippe Minard, *La Fortune du colbertisme. Etat et industrie dans la France des Lumières* (Paris: Fayard, 1998).

without the huge state investments in electrical infrastructure and nuclear devices. And the control of energy resources was one of the priorities of European countries' imperialistic policies throughout the nineteenth and twentieth
27 centuries.

Many other narratives could be drawn from Kander, Malanima and Warde's book. One of these would be to follow the evolution of the concept of energy during the historical period chosen by the authors. The latter do not examine as historians the scientific notion that they use to construct their data, as if it was obvious that firewood of the sixteenth century, muscle-work from seventeenth century horses, coal of the nineteenth century and electricity from a twentieth century nuclear plant were commensurable things. This in fact is the result of a long-time evolution in the history of ideas, that was strongly linked to the technical evolutions that the authors describe in their book. Nevertheless, those possible alternatives in the reading of the last five centuries' energy history do not invalidate the serious work of Kander Malanima and Warde. They just remind the readers about the necessity of not restraining the understanding of energy consumption history to a market dynamics. In any case, *Power to the People* and its numerous figures and graphs remain a very useful reference for anyone interested in the history of energy consumption over the last five centuries.

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The Shock of the Anthropocene (Christophe Bonneuil and Jean-Baptiste Fressoz, 2017)

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Christophe Bonneuil and Jean-Baptiste Fressoz, *The Shock of the Anthropocene* (London - New York: Verso, 2017) Translator, David Fernbach

Abstract

Christophe Bonneuil and Jean-Baptiste Fressoz offer a provocative programme for history in the Anthropocene. They propose a form of minoritarian environmental history. Within this argument, they take aim at energy history "as currently practised". This essay addresses the author's proposed reforms.

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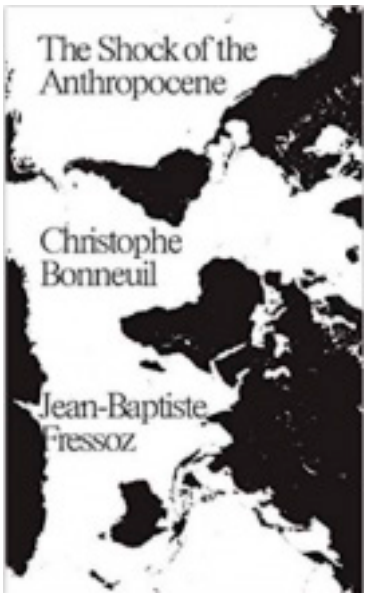

1 In this English translation of a French text first published in 2013, and in an expanded form in 2016, historians Christophe Bonneuil and Jean-Baptiste Fressoz offer a provocative programme for history in the Anthropocene.[1] Their book is a work of synthesis that addresses the consequences of this contentious new epoch from a distinct Francophone perspective. In a wide-ranging argument they propose seven registers for thinking about the past in light of this possible new future. These range from the *Thanatocene,* the age of "deadlier and more frequent" war, to the *Polemocene,* the marginalised histories of opposition to the ecologically misguided tenets of free market economics.[2] In this vein, they propose a form of minoritarian environmental history "to guard against the scientistic illusion that ecological awareness and 'salvation' can only come from scientists and not also from the struggles and initiatives of other Earthlings and citizens of the planet".[3] Within this argument, they take aim at energy history "as currently practised", and their proposed reforms to this discipline should be of particular interest to readers of this journal.[4] This essay addresses the author's proposed reforms, though it begins with more general questions regarding energy history as a discipline.

2 Exactly what is energy history? Does it involve the natural history of energy or the history of human awareness of energy's historical agency, or both? Should it begin from the Big Bang, the human use of fire, the discovery of laws of thermodynamics, industrialisation, or the energy crises of the 1970s?[5] That last event led historian of chemistry Arthur Donovan, then editor of *Materials and Society,* to dedicate a 1983 issue of the journal to this new speciality. The journal before you is not the first time energy historians have pronounced the need for their own discipline. The 1970's crisis had affirmed energy's historical agency, but for the analysis of this relation to succeed, Donovan wrote, "the history of energy must be defined and guided by a clear conception of its proper range and purpose".[6] And again, in the wake of the 1992 United Nations Climate Change Agreement for example, a special issue of the *British Journal of the History of Science,* historian of biology Robert Olby editorialised that "triumphalist" narratives of progressive mastery over the physical world "no longer continues unquestioned in energy history".[7] Clearly the range and purpose of our field is constantly altered by our changing relation to energy.

3 Does the way we formulate our discipline matter? *Energy history*, like environmental history, emphasises the agency of energy, perhaps even implying energy determinism. Whilst *the history of energy* (or should that be *histories* of energy?), indicate the object of inquiry will be historicised, as it is in the history of physics.

1 Christophe Bonneuil, Jean-Baptiste Fressoz, *L'Événement Anthropocene: La Terre, l'histoire et nous* (Paris: Éditions du Seuil, 2016 [2013]).

2 Christophe Bonneuil, Jean-Baptiste Fressoz, *The Shock of the Anthropocene*, trans. David Fernbach (London - New York: Verso, 2017), 122, 253.

3 *Ibid*., 287.

4 *Ibid*., 100.

5 So-called "big" histories often claim the formation of the universe is the rightful starting point of history, see Yuval Harari, *Sapiens: A Brief History of Humankind* (New York: Harper, 2015).

6 Arthur Donovan, "Preface", *Materials and Society*, vol. 7, no 3-4, 1983, 243-245.

7 Robert Olby, "Introduction", *British Journal for the History of Science*, vol. 26, no 1, 1993, 1-3.

This is not word play, such considerations are central to defining disciplinary range and purpose. Yet again, there are antecedents. In 1908 chemist-philosopher Émile Meyerson considered energy merely a special example of a general "causal postulate", a human propensity to explain change in relation to unchanging metaphysical quantities.[8] In which case, isolating energy over other aspects of causation would be strange. By contrast, in 1910 historian Henry Adams argued that if you took the laws of energy to their ultimate conclusion then the inescapable dynamic of entropy, the dissipation of useful energy, explained everything: all history was energy history.[9] Written soon after Wilhelm Ostwald's theory of energetics, which reduced history to "man's advancing control over energy", one suggestion is that Adams's argument was an elaborate joke, a *reductio ad absurdum* critique of scientific modes of historical explanation.[10] The jurisdiction of energy history surely lies somewhere between these two extremes? Of course the human use of energy has been historically consequent, but it would be absurd to offer over-essentialised explanations that ignore the role of knowledge, technology, and society, *inter alia*, as co-determinant aspects of that history.

4 In their book, Bonneuil and Fressoz argue that evidence of the extent of human environmental impact should be cause for a reformation in energy history. In their view the Anthropocene, an event "characterized by an unprecedented upsurge in energy mobilization" offers a opportunity to explain how historical change can be both energetically and socially determined.[11] The idea's principle advocates, atmospheric chemist Paul Crutzen and biologist Eugene Stoermer argue that human action has created a new epoch in Earth's geochronology. To understand the gravity of this claim it should be appreciated that the last epoch, the Holocene, began eleven-thousand years ago when the last ice age ended. They first suggested this new epoch began in 1784 with James Watt's invention of the steam engine, which meant vast reserves of fossil energy could now be exploited. Over the next 250 years a forty-fold increase in energy consumption occurred. The agency afforded by this unprecedented combustion transformed Earth's ecological, climatological, and geological systems, with possibly deleterious and certainly transformative consequences for humankind. On this basis, Bonneuil and Fressoz argue the availability of energy partly dictated the scale and properties of human history whilst humans expanded this availability by prospecting and inventing new modes of exploitation. This reciprocity, they argue, transformed human and environmental history, and perhaps now even geological time. If energy historians are to appropriately explain their subject of inquiry in this new epoch, the author's argue, they must develop an 'understanding of the energy and matter metabolism operated in and by the social system that is as fine-grained as the analysis of biogeochemical flows in the Earth system'.[12]

5 Rather than advocating a fusion of earth systems science and cliometrics as one might imagine, Bonneuil and Fressoz suggest that energy history must do two things: apportion blame for our current predicament, and study the history of divergences from this trajectory rather than those actions that led us here. Borrowing a term from French radical ecologists, they term this *Thermocene* history. Without this more radical stance they fear current mitigation proposals that involve geo-engineering and will be overseen by the world's leading scientists provide only a 'new modernist fable', a reaffirmation of our assumed mastery of nature.[13] Worse yet, a response diffuses blame over an undifferentiated humanity, failing to consider changing the specific "actors, institutions, and decisions that

8 Philip Mirowski, *More Heat than Light: Economics as Social Physics, Physics as Nature's Economics* (Cambridge: Cambridge University Press, 1989), 5-7.

9 Henry Adams, *A letter to American teachers of history* (Washington: J.H Furst Co., 1910).

10 Wilhelm Ostwald, "The Modern Theory of Energetics", *The Monist*, vol. 17, no 4, 1907, 481-515; Howard Munford, "Henry Adams and the Tendency of History", *The New England Quarterly*, vol. 32, no 1, 1959, 79-90.

11 Christophe Bonneuil, Jean-Baptiste Fressoz, *The Shock of the Anthropocene*, op. cit., 9 (cf. note 2).

12 *Ibid*., 35.

13 *Ibid*., 79.

have produced these effects".[14] So as part of a larger aim of identifying "Who is the Anthropos?" in the author's proposed reforms we energy historians are tasked with writing political histories of carbon dioxide, accounts that ask: who burnt all the hydrocarbons?

6 To make this point, the authors take 'energy history as currently practised' to task. Current practitioners, they argue, place too high expectations on the study of past energy transitions as means to inform a low-carbon transition. They warn such "energy history with a managerial approach" misdirects attention to a misleading notion. What look like segues between fuels are perspectival or scalar tricks that mistake relative change for absolute. Hence they argue that the "history of energy is not one of transitions, but rather of successive *additions* of new sources of primary energy".[15] Given the widely accepted objective of reducing global energy use, as means to reduce human impacts on earth's systems, to study past transitions is to understand how we got into this situation rather than how we get out. As such, they advise that we abandon the very concept of transition. But in doing so, they rightly acknowledge the phrase has its own history. It was an anxiolytic managerial term used to allay fears during the energy crises of the nineteen-seventies.[16] But I would argue that this does not invalidate the term's historical significance, far from it. In a certain context, actor's use of the term transition, borrowed from natural science, is revealed as a synonym of that pre-eminent signifier of historical change, crisis.[17]

7 Moreover, the idea that we should dispense with transition as an analytic because such changes occur only in localised ways is at odds with their stated aim of specifying the Anthropos. In 1932 economic historian John Nef, considered the first serious energy historian, gave a detailed account of the substitution of coal for wood in sixteenth and seventeenth century British industry. Though his quantitative evidence has been criticised, his account of "something like a revolution in the use of fuel" remains an important account of how a certain structure of energy use arose at a specific time and place.[18] More recently, Andreas Malm's account of the role of capital in effecting a transition from waterpower to coal in the cotton mills of northern England, though situated in a specific geography, is presented as an event which assumed geohistorical importance in subsequent decades.[19] It would not be a shock to learn that wood, charcoal, and waterpower were still used in significant amounts long after these events, but to deny nothing of significance took place, because transitions did not involve wholesale movements between fuels or result in aggregate reductions in energy use, proposes a slightly absurd form of non-history, to borrow Quentin Skinner's phrase.[20]

8 Thankfully Bonneuil and Fressoz find aspects of current energy history to commend. They are thankful to past work for revealing how transitions have been determined by energy demand rather than supply. However, an unfortunate illustration is offered. They write 'the filament lamp created electric power stations, and not the other way around'.[21] In fact leading historian of electrification Thomas Hughes made almost the inverse argument. Alongside the provision of light, bulbs demonstrated the usefulness of his underutilised Pearl Street power plant and helped balance its electrical load. The bulb was less a discrete object, so much as a "parallel system of distribution" allowing the "indefinite subdivision of light" at low cost.[22] Hughes's account suggests demand for electric light was

14 *Ibid*., 70.
15 *Ibid*., 101.
16 *Ibid*., 102.
17 Reinhart Koselleck, Michaela Richter, 'Crisis', Journal of the History of Ideas, vol. 67, n° 2, 2005, 357-400.

18 John Nef, *The Rise of the British Coal Industry*, vol. 1 (London: George Routledge & Sons. 1932), 20.
19 Andreas Malm, "The origins of fossil capital: from water to steam in the British Cotton industry", *Historical Materialism*, vol. 21, no 1, 2013, 15-68.
20 Quentin Skinner, "Meaning and Understanding in the History of Ideas", *History and Theory*, vol. 8, no 1, 1969, 3-53.
21 Christophe Bonneuil, Jean-Baptiste Fressoz, *The Shock of the Anthropocene*, op. cit., 100 (cf. note 2).
22 Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983), 31.

something that was constructed, rather than some persistent entity called demand being met by the bulb's invention.[23] Though a minor difference in interpretation, this indicates a more general tendency. In a rush to differentiate their Thermocene history, on occasion the authors mischaracterise and oversimplify the work of past energy historians.

9 This mischaracterisation extends to their critique of contemporary "managerial" energy history. Whilst there is a seductive heterodoxy to the idea that transition is a foil for ever more energy use, a quick survey reveals that scholars rarely fall for this trick. Historian Bruce Podobnik acknowledges that relative decline in coal use in certain places does not counter how "in absolute terms, world coal production has increased in the post-World War II period and is projected to do so well into the next century".[24] Energy analyst Benjamin Sovacool states that transitions are mostly "cumulative rather than fully substitutive".[25] Whilst economic historian Roger Fouquet observes "past energy transitions have been characterised by major increases in energy consumption".[26] Podobnik and Fouquet are cited in the book, but their inconvenient disagreement with its narrative is not.[27] I agree with the authors that the term transition has been used as a misleadingly in certain public discourses and that these should be brought to account but beyond our authors' argument it is hard to find historians who are transition dopes.[28]

How can such mischaracterisation of energy historians be avoided? Geographers have recently debated the desirability of establishing a canon, a set of authoritative disciplinary texts. Whilst acknowledging risks of bias and exclusion, a conclusion was that canons offer a shared set of arguments from which new scholarship can emerge.[29] For historians of energy a canon should no doubt include Nef and Wrigley. Such a canon could also include historians of science, whose have historicised the concept of energy since their discipline's inception.[30] More generally, French scholars have their own environmentalist tradition stretching as far back as far as geographer Vidal de la Blache. His notion of possiblism, reciprocity rather than crude determinism between nature and society, presaged our authors' "double notion of internality", the recognition of the social in the natural and the natural in the social.[31] Another antecedent might be French Communist geographer Pierre George, author of the first monograph on the geography of energy which presaged later radical geographers in arguing that energy availability was a factor of social relations.[32] Not forgetting the Annales school, whose descriptive historical quantification led Fernand Braudel to write "geohistory", change over geographical time.[33] More recently, historians Jean-Paul Deléage, Jean-Claude Debeir and physicist Daniel Hémery combined ecological Marxism with global history to offer a critical history of energy use, sharpened by their opposition to the French 10

23 Bonneuil and Fressoz in Chapter 7, titled the "Phagocene" (phago: to consume), decry such essentialisation, arguing that advertising constructs many of the desires which combustion fulfils, Christophe Bonneuil, Jean-Baptiste Fressoz, *The Shock of the Anthropocene*, op. cit., 156. (cf. note 2).

24 Bruce Podobnik, "Toward a Sustainable Energy Regime: A Long-Wave Interpretation of Global Energy Shifts", *Technological Forecasting and Social Change*, vol. 62, n° 3, 1999, 155-172.

25 Benjamin Sovacool, "How long will it take? Conceptualizing the temporal dynamics of energy transitions", *Energy Research & Social Science*, vol. 13, 2016, 202-215.

26 Roger Fouquet, "Historical energy transitions: Speed, prices, and system transformation", *Energy Research & Social Science*, vol. 22, 2016, 7-12.

27 Christophe Bonneuil, Jean-Baptiste Fressoz, *The Shock of the Anthropocene*, op. cit., 119, 101 (cf. note 2).

28 *Ibid.*, 101.

29 Richard Powell, "Notes on a geographic canon? Measures, models, and scholarly enterprise", *Journal of Historical Geography*, vol. 49, 2015, 2-8.

30 George Sarton, "The discovery of the law of conservation of energy", *Isis*, vol. 13, no 1, 1929, 18-44.

31 Paul Vidal de la Blache, *Principles of Human Geography*, éd. Emmanuel de Martonne, trans. Millicent Bingham (London: Constable Publishers, 1965 [1926]); Christophe Bonneuil, Jean-Baptiste Fressoz, *The Shock of the Anthropocene*, op. cit, 36 (cf. note 2).

32 Pierre George, *Géographie de l'Énergie* (Paris : Librairie de Médicis, 1950).

33 Melvin Knight "The Geohistory of Fernand Braudel", *The Journal of Economic History*, vol. 10, no 2, 1950, 212-216.

nuclear industry.[34] Such canonical works require respectful reconsideration to avoid reinventing past findings and do justice to past historians.

11 Criticisms aside, there is plenty to commend in their call for a "disorientated" history of energy, a term they derive from Fressoz's earlier involvement with *Entropia,* a journal of the French de-growth movement.[35] In that journal disorientation is presented as both a historical juncture and mode of inquiry.[36] Bonneuil and Fressoz argue that energy history can disorientate by relativising and denaturalising our energy system by revealing how this destination was not reached by some inexorable teleology of progress and efficiency, but at times by poor business practices, collusion, and the suppression of certain technologies. Disorientation rightly emphasises the rich histories of opposition to the hegemony of fossil fuels, from Manhattan Project physicists turned solar energy pioneers to the subsidisation of public transport in Weimar Germany.[37] They hope to unsettle the idea that historical expertise can be an informational input to a pre-determined low carbon transition. In doing so, rather than distinguishing themselves, they join conventional energy historians who are already disavowing the idea that they can offer "pre-packaged policy proposals".[38]

12 As part of the process of disorientation I do not agree that we must free ourselves from "the very concept of energy".[39] In a confusing and far too concise argument the authors claim historians' use of energy statistics can mislead. Units, such as "energy use per capita" they argue, record "the energy theoretically available" from a given quantity of fuel rather than the actual energy derived in combustion. This abstraction, they suggest, "likely overestimates the upheaval introduced by fossil fuels".[40] To me, this suggests the need for *greater* consideration of the energy concept. As geographer Andrew Barry has suggested, in discussing energy, social scientists tend to focus on specific resources and technologies of extraction and use, failing to consider energy as it is understood in physics or engineering, as a measurement of a system's ability to do work.[41] Put another way, why not try to write histories of actually derived energy which focus on energy conversion? Bonneuil and Fressoz's argument does not address the concept of energy so much criticise the way in which fuel-use enters national accounting. This raises a larger disciplinary question, what distinguishes energy history from resource histories or the history of technology? Clearly a focus on energy as it is understood in physics and engineering offers one distinction.

13 A point of agreement comes when the authors rightly suggest that triumphant accounts of progressive efficiency increases can be revealed as histories of inefficiency if suitably disorientated by extending the scale of analysis, whether it be the introduction of gas-lighting in Paris or the mechanisation of agriculture during the Green Revolution.[42] Moreover, their proposal for a "general history of thermodynamic (in)efficiency", mentioned only briefly, opens the prospect of a new form of energy history.[43] Why not write energy history in response to the idea of the technosphere rather than the Anthropocene? The idea of the technosphere, proposed by Anthropocene-advocate and geologist Peter Haff, unmentioned in the book under review, is that the vast networked infrastructure of earth's terrestrial technologies rather than humans themselves are the preeminent terrestrial agent. Moreover, Haff

34 Jean-Paul Deléage, Jean-Claude Debeir, Deniel Hémery, *Les servitudes de la puissance: Une histoire de l'énergie* (Paris : Éditions Flammarion, 1986).

35 Jean-Baptiste Fressoz, "Pour une histoire désorientée de l'énergie", *Entropia: Revue d'étude théorique et politique de la décroissance*, n°15, automne 2013.

36 "a benevolent and oriented time must be abandoned, and in this respect we must reconsider the narratives we make of the past", my translation. Philippe Gruca, "Sept thèses sur l'histoire désorientée", *Entropia: Revue d'étude théorique et politique de la décroissance*, n°15, automne 2013.

37 *Ibid*., 112-6.

38 Richard Hirsh, Christopher Jones, "History's contributions to energy research and policy", *Energy Research & Social Science*, vol. 1, 2014, 106-111.

39 *Ibid*., 105.

40 *Id*.

41 Andrew Barry, "Thermodynamics, matter, politics", *Distinktion: Journal of Social Theory*, vol. 16, n°1, 2015, 110-125.

42 Christophe Bonneuil, Jean-Baptiste Fressoz, *The Shock of the Anthropocene*, op. cit., 105-7 (cf. note 2).

43 *Id*.

argues the technosphere's only discernible telos seems to be the maximisation of entropy.[44] Taken seriously, and heeding Adam's possibly parodic warning, the history of energy told as the result of the unceasing increase of entropy suggests a new mode of explanation that can account for the unfortunate ironies and limits of the human pursuit of energy efficiency.

14 Another of their proposed means of disorientation is to study "histories of energy degrowth", the circumstances and effects of dramatic decreases in energy use at various points in history, such as the Great Depression, in post-war Germany, and during the fall of the Soviet Union. Whilst this shift in perspective is welcome, these were exceptional events. Why not consider more commonplace histories of attempts, failures, and successes in reducing energy consumption via rationing, increased efficiency, or conservation efforts?[45] The authors are uninterested in such prosaic histories because, as they suggest, the global history of energy seems to affirm Jevons' paradox: despite significant increases in energy efficiency, the rate and scale of energy use still climbs.[46] But, as with transitions, increases in efficiency are clearly of regional consequence. Historical geographer Anthony Wrigley, for example, described how differences in the efficiency of energy production along a rich coal seam stretching from Pas-de Calais to Westphalia correlated with patterns of societal development.[47] Whilst detailed studies at the scale of cities or specific industries can go beyond platitudes in detailing the range of motivations underlying the pursuit of efficiency.[48] Moreover, the authors would surely categorise claims that increased efficiency has allowed certain nations to "decouple" economic growth from energy consumption as "agnotological", to use their borrowed term for the constructed ignorance of geophysical fact, given ample evidence of the outsourcing of energy-intensive manufacturing that has occurred in such countries.[49] These points are less criticisms, than acknowledgements that the authors' provocations succeed in encouraging new approaches to doing energy history, and for this they should be commended.

15 However, whilst there are undoubtedly historians who unquestioningly surrender themselves to an elitist Anthropocene "solutionism" who should heed Bonneuil and Fressoz's ire. But in turn, they must not dismiss scholars who are well aware of the limits of terms like transition and the contradictions of efficient energy use, but still consider these things of great historical importance. More generally, energy historians should applaud the authors' idea that the Anthropocene requires historians to take natural science more seriously and natural scientists to take social history more seriously. Historians must engage with principles such as thermodynamics but equally atmospheric chemists must consider sociological modes of explanation in their explanatory schemes. And if energy historians are to take this epoch seriously, we must demonstrate the effectiveness of energy history to explain change in a world in which simple accounts of environmental or human determinism are no longer credible. Whether or not the Anthropocene becomes an official period in Earth history, the ongoing debate affirms a more complicated conception of human and environmental agency, which is something the most perceptive historians, as our authors recognise, have always understood.[50]

44 Peter Haff, "Technology as a geological phenomenon: implications for human well-being", *Geological Society London, Special Publications*, vol. 395, n°24, 2013, 301-309.

45 The history of energy conservation is a somewhat ignored and undertheorized aspect of energy history. I will return to this subject in the second issue of the Journal of Energy History.

46 Christophe Bonneuil, Jean-Baptiste Fressoz, *The Shock of the Anthropocene*, op. cit., 101 (cf. note 2).

47 Edward A. Wrigley, *Industrial Growth and Population Change: A Regional Study of the Coalfield Areas of North-west Europe in the Later Nineteenth Century* (Cambridge: Cambridge University Press, 1961), 31.

48 Timothy Moss, "Socio-technical change and the politics of urban infrastructure: Managing energy in Berlin between dictatorship and democracy", *Urban Studies*, vol. 51, n°7, 2014, 1432 - 1448, 1432.

49 For a critique of assertions of decoupling see Andreas Malm, "China as Chimney of the World: The Fossil Capital Hypothesis", *Organization & Environment*, vol. 25, n°2, 2012, 146-177.

50 Christophe Bonneuil, Jean-Baptiste Fressoz, *The Shock of the Anthropocene*, op. cit., xii (cf. note 2).

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