JEH RHE
Journal of Energy History
Revue d'Histoire de l'Énergie

#4

Transitions in Energy History. History in Energy Transitions

Special issue

Dossier

Les transitions dans l'histoire de l'énergie. L'histoire dans les transitions

NUMBER 4 - JUNE 2020

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Journal of Energy History
Revue d'histoire de l'énergie

Summary

SPECIAL ISSUE

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ISSN 2649-3055

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Journal of Energy History
Revue d'histoire de l'énergie

SPECIAL ISSUE

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ISSN 2649-3055

JEH
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Journal of Energy History
Revue d'histoire de l'énergie

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POST DATE
27/01/2020
ISSUE NUMBER
JEHRHE #4
SECTION
Special issue
THEME OF THE SPECIAL ISSUE
Transitions in Energy History. History in Energy Transitions
KEYWORDS
Coal, Transition, Consumption, Dissent, Sustainability
DOI
in progress

TO CITE THIS ARTICLE
Charles-François Mathis, "The impossible transition? The fatality of coal in the United Kingdom", *Journal of Energy History/Revue d'Histoire de l'Énergie* [Online], n°4, published 27 January 2020 URL: energyhistory.eu/en/node/177.

The impossible transition? The fatality of coal in the United Kingdom

Abstract
This article seeks to understand the reasons for Victorian fatalism towards coal dependency – which led to in an inability to abandon this energy – in an effort to better understand what an energy transition would actually entail. The article depicts a providential form of thought in relation to energy at the time, when coal was seen as being a God-given gift that led to world domination: Victorian society was subsequently guilt-ridden due to its waste of coal. How could one imagine a post-coal country without imagining the worst? This tragic vision of the future – there will be no second chance – was based on an understanding of the transition as being connected to the source itself rather than the energy system as a whole.

Plan of the article

INTRODUCTION

1 In 1905, a group of scientists and engineers led by the winner of the Nobel Prize for Chemistry, Sir William Ramsay, founded the British Science Guild in an effort to use science to solve the problems faced by humanity.[1] The many debates regarding the coal shortage threatening the country, which had intensified in nature over the course of forty years, naturally prompted this learned society to address the question.[2] This led to the publication in 1912 of a collective work taking stock of natural sources of energy, especially to determine whether alternatives to coal existed. The response of the experts involved was clearly negative. According to the author of the chapter on coal, the only possible path for the country was frugal use of this resource:

> The most hopeful sign of a coming reform in this direction [domestic consumption] is found in the general awakening of the civic conscience on the subject of smoke prevention. It is earnestly to be desired that this awakening may be really permanent, and that the partially successful, or even the entirely unsuccessful, efforts in the direction of reform may not be interpreted by the public in any hopeless spirit.[3]

2 The fear expressed here of discouragement should not be surprising, for despite many reflections during the last third of the nineteenth century regarding energy alternatives,[4] the British seemed incapable at the turn of the twentieth century of initiating a shift away from coal, even as they continued to denounce its harmful environmental and health effects,[5] as well as the exclusive dependence in which it placed the country. From 1845 to 1945, coal supplied 90-95% of the energy needs of England and Wales, and the drop came only gradually (still 50% in 1970).[6] Understanding the reasons for this resistance to change can undoubtedly help to implicitly identify what the notion of transition entails. Many explanations have already been proposed, essentially with respect to economic and technological considerations connected to initial constraints: widespread use of the steam engine, electricity production by coal-burning plants, installations already existing among private individuals, and industrial actors reliant on this energy source all made the changes required to use another energy too costly, which at any rate could not be as accessible and abundant as British coal.[7] This interpretation is perfectly correct and convincing, but is not sufficient on its own. Postulating the rationality of actors in this way forgets the cultural and ideological motives of their actions. Andreas Malm has astutely suggested that the transition of British industry to coal was not based fully and solely on economic reasoning, but was also founded on political choices and energy-related fashions.[8] Stephen Mosley has also emphasized the fundamentally cultural refusal of Manchester inhabitants from depriving themselves of an open hearth, which they nevertheless knew was absurd from an energy standpoint.[9]

It is therefore important to take into account the fatalism that was expressed in English society 3

1 Roy MacLeod, "Science for Imperial Efficiency and Social Change: Reflections on the British Science Guild, 1905-1936", *Public Understanding of Science*, vol. 3, no. 2, 1994, 155-193.

2 Antoine Missemer, *Les Économistes et la fin des énergies fossiles* (Paris: Garnier, 2017), chapters 1 and 2.

3 G.T. Beilby, "The coal resources of Great Britain", *in* British Science Guild, *Natural sources of energy* (London: Burt & Sons, 1912), 18.

4 Charles-François Mathis, "'Renverser le roi Charbon.' Imaginer la transition énergétique en Grande-Bretagne, 1865-1914", *in* Yves Bouvier, Léonard Laborie (dir.), *L'Europe en transitions: Énergie, mobilité, communication, XVIIIe-XXIe siècles* (Paris: Nouveau Monde, 2016), 85-118.

5 See for example Peter Thorsheim, *Inventing Pollution: Coal, Smoke, and Culture in Britain since 1800* (Athens: Ohio University Press, 2006).

6 Astrid Kander, Paolo Malanima, and Paul Warde, *Power to the People* (Princeton: Princeton University Press, 2013), 274; also the data gathered by Paul Warde at energyhistory.org.

7 *Id.*; David Edgerton in *Science, Technology and the British Industrial 'Decline' 1870–1970* (Cambridge: CUP, 1996) has shown that the origin of these problems of adaptation was not a lack of technological innovation.

8 Andreas Malm, *Fossil Capital. The Rise of Steam Power and the Roots of Global Warming* (London/New York: Verso, 2016), 119 and 211.

9 Stephen Mosley, *The Chimney of the World* (Cambridge: White Horse Press, 2001), 75-78.

during the last third of the nineteenth century and the turn of the twentieth century, which had roots in the abiding concern over coal shortage expressed from 1789 onward.[10] This period was one of profound crisis for Victorian values and perceptions of the country's future, especially with regard to energy, for the United Kingdom felt a gradual loss of status in the face of new powers (Prussia, the United States), in addition to increased military, colonial, and economic competition. Doubts were calmed at the end of the Edwardian period, and from a strictly energy standpoint this moment ended shortly before the First World War, when the discovery of new coal deposits in the world and the early uses of oil dispelled the specter of shortage.[11] However, from the 1870s to approximately 1910, despite the proliferation of science fiction narratives and more scientific reflections on the subject, what dominated in the press, political analysis, and even among scientists from the period was indeed the notion that the United Kingdom could not escape coal, that its fate was tied to this fossil fuel, and that there was no possible way to escape this particular energy.[12] Parliament reports devoted to this question, newspaper articles, and works by members of learned societies, geologists, and certain economists regularly presented the apparent impasse in which the country found itself. Their writing often functioned as a system, as they inspired one another and repeated the same figures, or on the contrary questioned the evaluation of a particular individual (the economist Jevons relying on the work of the geologist Hull, both of whom were references during the second half of the century). Revisiting this fatalist thinking and its ramifications based on these documents[13] helps to clearly identify the country's dominant form of thought toward energy, as well as to use this "non-transition" from the early twentieth century to help understand what a transition could potentially entail.

A PROVIDENTIAL CONCEPTION OF ENERGY

The straight path to power

The first reason for this fatalism was a linear and 4
teleological understanding of history, especially the transition to coal. Both treatises on British industry or coal resources and newspaper editorials highlighted the almost inevitable logic of British domination over the world since at least the eighteenth century: the nation's character, great men, geographic location, and underground resources combined to bring it to power. Traces of such a conception can be found, for instance, in the writings of the economist Stanley Jevons, in his influential 1865 work entitled *The Coal Question*. In its conclusion he refutes the idea that the United Kingdom could be content with a mediocre fate.

> To secure a safe smallness we should have to go 5
> back, and strangle in their birth those thoughts and inventions which redeemed us from dullness and degradation a century ago. [...] Such experiments could not have succeeded, and

10 I have discussed this fatalism in a recent article: Charles-François Mathis, "King Coal Rules: Accepting or Refusing Coal Dependency in Victorian Britain", *Revue Française de Civilisation Britannique*, special issue on *Environmental questions in Great Britain: Between Visibility and Marginalisation*, vol. XXIII, no. 3, 2018. I notably showed in this article how faith in progress, attachment to free trade, and the paradox of coal's inevitability justified inaction in the shift away from coal use.

11 Antoine Missemer, *Les Économistes et la fin des énergies fossiles*, 87-89 (cf. note 2).

12 The creation of geology as a science at the turn of the nineteenth century, along with the establishment of the *Geological Survey* in 1835, helped refine prospecting methods: evaluation of actual coal reserves thus became more accurate at the end of the century, encouraged by the Royal Commission appointed in 1866, which issued its report in 1871. However, assessments of the time remaining before the exhaustion of coal resources varied considerably during the century, and was still debated in the early twentieth century, with the geologist Taylor estimating in 1814 that the country still had 1,727 years ahead of it, while in 1865 the economist Jevons reduced this reprieve to 110 years, which was extended to 324 or 1,695 years (!) by Price Williams in 1871. As rightly shown by Jevons, this evaluation had to take economic data into account, notably changes in the consumption of coal, which were much more difficult to determine. For an excellent clarification, see the essential work by Rolf Peter Sieferle, *The Subterranean Forest* (Cambridge: The White Horse Press, 2001).

13 As I have already studied, in the aforementioned article, late nineteenth century accounts of the future from an energy history perspective, I am voluntarily excluding them from the body of sources used here.

such writing been published among a free and active people *in our circumstances* [emphasis mine] without leading to the changes that have been. [...] One invention, one art, one development of commerce, one amelioration of society follows another almost as effect follows cause.[14]

6 In doing so, Jevons took his place in a shared tradition of teleological Whig history, whose model was *The History of England* by Thomas Babington Macaulay, which enjoyed phenomenal success with the publication of two of its first five volumes in 1848[15]: from the introduction onward the author depicts a nation amid constant material, intellectual, and moral progress since the Glorious Revolution of 1688, up to the height of grandeur attained in the nineteenth century.[16] An example of this thinking can be found—applied to the transition itself—in the writings of the jurist and economist Leone Levi, who in 1855 presented an almost natural and necessary succession of energy systems:

> In the early stages of civilisation man knew of no forces but his own. When human strength was found insufficient, the quadrupeds were put under yoke. [...]. From the use of animal force we progressed to the use of inorganic motors, such as water and wind. But these again did not meet *al*l exigencies. [...] How shall we value the wonderful influence, physical and moral, of steam – the foremost of all civilizers? It has aroused mankind to a degree of consciousness of their powers over matter, which no other discovery ever accomplished.[17]

There was consequently a constant progression, an almost necessary transition from one energy resource to another, leading to the height of power attained by the United Kingdom thanks to coal. None doubted at the time that the country was at the peak of its glory: its global domination was too obvious, and an immense block of coal, given pride of place alongside the Crystal Palace during the Great Exhibition of 1851, served to remind of its fossil-based origin lest anyone forget. For at least a half century, everyone boasted about this incomparable degree of civilization attained by the country thanks to God. 7

God, coal, and Victorian conscience

The possession of coal was in a way the most obvious sign of being chosen by providence: the United Kingdom had the great fortune of possessing immense, accessible, and high-quality reserves, whose use was made possible by the ingenuity of its great men and the dynamism of its people.[18] In 1873, an engineering magazine little given to mysticism evoked with regard to this energy source "the advantages which the very Creator has bestowed upon ?Britain?,"[19] while a letter sent to the *Colliery Guardian*, the mining and metallurgy industry newspaper, exclaimed: "The use, influence and value of coal as a national agent, are such as cannot fail to impress all with a feeling of gratitude for that munificence manifested and accorded to us by Divine wisdom."[20] 8

Such thinking was in keeping with a natural theology framework, which pervaded the first two thirds of the century:[21] plants, animals, and mineral resources were placed in the world for the instruction and well-being of humanity, 9

14 Stanley Jevons, *The Coal Question. An Inquiry Concerning the Progress of the Nation and the Probable Exhaustion of our Coal-mines* (London: Macmillan, 1865), 346-348.

15 Thomas William, "Thomas Babington, Baron Macaulay (1800–1859), historian, essayist, and poet", *Oxford Dictionary of National Biography.* **http://www.oxforddnb.com/view/10.1093/ref:odnb/9780198614128.001.0001/odnb-9780198614128-e-17349**

16 Nor did he hide the important role played by coal from the seventeenth century onward. See Thomas Babington Macaulay, *The History of England from the Accession of James II* (New York: Harper, 1849 ?1848?), vol. I, 296.

17 Leone Levi, *The Law of Nature and Nations as Affected by Divine Law* (London: Cash, 1855), 101-102.

18 Robert Fox, "Théologie naturelle et géologie à l'époque de William Buckland", *Travaux du Comité français d'Histoire de la Géologie*, Comité français d'Histoire de la Géologie, 2001, 3rd series, vol. 15, 89-105. <hal-00920000>

19 "The Committee on Coal", *The Engineer*, 11 July 1873, 28.

20 C. Hodgson, Letter to the Editor, "Importance of Coal", *Colliery Guardian*, 12 May 1866, 350.

21 David N. Livingstone, "Natural Theology and Neo-Lamarckism: the Changing Context of Nineteenth-century Geography in the United States and Great Britain", *Annals of the Association of American Geographers*, vol. 74, no. 1, 1984, 9-28.

who is responsible for discovering their possible uses and applying them. Developing the natural sciences in order to learn the uses of these resources, and even discovering where they can be found, consequently became a kind of Christian duty. Coal was no exception, for God had placed it for the happiness and prosperity of British citizens. Geoffrey Cantor has shown how scientific and technological progress was inscribed within a Christian perspective of human progress according to a divine plan, in which the Great Exhibition of 1851 was one stage.[22] While natural theology—fairly determinist and also marked by teleology—was in a difficult situation after Darwin, the notion of the duty of civilized peoples to exploit dormant natural resources endured,[23] as did the exceptional God-given energy that characterized the English people.[24] For example, in 1862 the eminent geologist Edward Hull proposed at the beginning of his influential *The Coal-Fields of Great Britain*: "May we not [...] as believers in an eternal Providence, acknowledge that the mineral ?coal? is a heaven-born gift to man?"[25]

10 This association of coal with divine benevolence was all the more pronounced as the power provided by coal was the subject of fascination across the century. Only electricity in its time enjoyed such a magical aura: the humanity that possesses coal and uses it in steam engines is almost completely different than the one that preceded it, so immense and almost limitless its powers appeared to be. The famous poem "Old King Coal" by Charles Mackay in *The Illustrated London News*, which made the expression "King Coal" popular, depicts a power that changes the world for the benefit of England:

> While his miners mine, and his engines work,
> Through all our happy land,
> We shall flourish fair in the morning light,
> And our name and our fame, and our might and our right,
> In the front of the world shall stand.[26]

With this in mind, Andreas Malm is entirely correct in evoking a kind of steam fetishism,[27] which he illustrates with a poem that appeared in the *Times* in December 1829: the poem's hero is awakened by the spirit of steam, who takes him traveling through a new world, which in 1930 was presided over by this new and somewhat frightening power, but one that was so much more effective than earlier eras...[28] 11

Historians themselves have also emphasized the United Kingdom's amazing luck, from a purely economic standpoint, in possessing such vast and accessible coal resources. Kenneth Pomeranz in particular has made this happenstance one of the reasons for British supremacy during the Victorian period.[29] For most contemporaries, such fortune could of course not be simply the result of complete chance, for a divine hand was necessarily involved in bestowing such a godsend on the country. 12

As the recipients of this divine gift and unprecedented power, nineteenth-century Britons bore an immense responsibility on their shoulders. Victorians continued to praise their civilization, but they also had doubts, which were driven by a recurring fear of shortage, and were based on two pillars: moral concern and a troubled 13

22 Geoffrey Cantor, "Science, Providence and Progress at the Great Exhibition", *Isis*, vol. 103, no. 3, 2012, 439-459.
23 "In speaking of the natural resources of any country, we refer to the ore in the mine, the stone unquarried, the timber unfelled, the native plants and animals – to all those latent elements of wealth only awaiting the labour of man to become of use, and therefore of value", John Yeats, *The Natural History of Commerce* (London: Cassell, 1870), 2.
24 Bernard Lightman has shown the continuities among popularizers of science, between what he calls "narratives of natural theology" and "narratives of natural history": Bernard Lightman, "The Story of Nature: Victorian Popularizers and Scientific Narrative", *Victorian Review*, vol. 25, no. 2, 2000, 1-29. See also his *Victorian Popularizers of Science* (Chicago: University of Chicago Press, 2007), 494.
25 Edward Hull, *The Coal-Fields of Great Britain* (London: Stanford, 1861), 17.
26 Charles Mackay, "Old King Coal", *The Illustrated London News*, 1 January 1859, 12.
27 Andreas Malm, *Fossil Capital. The Rise of Steam Power and the Roots of Global Warming* (London/New York: Verso, 2016), 195 sqq.
28 "A vision of steam", *The Times*, 26 December 1829, 3.
29 Kenneth Pomeranz, *The Great Divergence* (Princeton: Princeton University Press, 2000).

conscience. The latter was tormented by how coal had been used: were the British not guilty of wasting such a gift from God? This prompted moral and existential anxiety: Providence had provided for the elevation of the Victorians to the forefront of the world thanks to coal, so what would happen to them without this energy? *Could they* have a second change? The affirmations of the Royal Commission of 1905, tasked with evaluating coal reserves, left no doubt on this question: "We are convinced that coal is our only reliable source of power, and that there is no real substitute."[30] These two concerns merit being presented in greater detail.

BAD CONSCIENCE: "THOU SHALT NOT WASTE"

The precocity of a neglected ethical imperative

14 In the United Kingdom during the Victorian era, there was an imperative—as much moral and religious as economic—to preserve coal reserves. This worry, and especially its precocity, can be best understood by situating it within the ideological framework presented above. It was actually quite early on, in 1789, that worry over a possible coal shortage was expressed in the *Natural History of the Mineral Kingdom* by John Williams. It was not shared by all, as the historian Fredrik Albritton Jonsson has shown that two schools of thought opposed one another during the century, which he has called Malthusians and "Cornucopians"; the latter were convinced of the abundance of coal, and the possibility of replacing it at a chosen time by other resources, thanks to God and human ingeniousness. But Albritton Jonsson has also shown how theological arguments were intertwined with economic or environmental ones among Malthusians[31]: for instance, William Buckland, the greatest geologist of the nineteenth century, emphasized the pressing need for reasoned coal management *because* it was a divine gift.[32] This theological dimension endured, despite the fact that fear of shortage was expressed in various forms over the years. It could take on an essentially moral character, as when the famous man of science John Herschel, who contributed greatly to the success of Jevons's book, lost his temper in a letter from 1866 against "the enormous and outrageously wasteful consumption" of "populations calling themselves civilised – but in reality luxurious and selfish," who would "make the Earth a desert"; "a very ugly day of reckoning is impending sooner or later."[33]

These imprecations against waste were expressed at the end of the century in connection with future generations, whose fate should not be forgotten by the present one as it wallowed in temporary energy abundance.[34] Alfred Russel Wallace, the co-discoverer of the theory of evolution, affirmed the following in 1873: 15

> [The non-renewable resources of the earth] must be considered to be held in trust for the community, and for succeeding generations. They should be jealously guarded from all waste or unnecessary expenditure, and it should be considered (as it will certainly come to be regarded) as a positive crime against posterity to expend them lavishly for the sole purpose of increasing our own wealth, luxury, or commercial importance.[35]

What increased bad conscience and questions surrounding waste at that moment were observations of the general disfigurement of the country, the failure to provide material abundance 16

30 Royal Commission on Coal Supplies, *Final Report*, 1905, 17.

31 Fredrik Albritton Jonsson, "The Origins of Cornucopianism: A Preliminary Genealogy", *Critical Historical Studies*, vol. 1, no. 1, 2014, 151-168; and "Forecasting Collapse: the Problem of Coal Exhaustion from the Enlightenment to Victorian Britain," *Anticiper la pénurie énergétique* study day, 25 September 2015, Université Bordeaux Montaigne; "Abundance and Scarcity in Geological Time, 1784-1844," *in* Katrina Forrester, Sophie Smith (eds.), *Nature, Action and the Future* (Cambridge: CUP, 2018), 70-93.

32 William Buckland, *Geology and Mineralogy Considered with Reference to Natural Theology* (Pickering: n.p., 1836-1837).

33 John Herschel, cited in Asa Briggs, *Victorian Things* (Stroud: Sutton, 2003 ?1988), 267.

34 Fredrik Albritton Jonsson has traced this understanding of intergenerational solidarity back to Edmund Burke.

35 Alfred Russel Wallace, *Daily News*, 16 September 1873. He also uses this argument in the conclusion of *The Wonderful Century* (New York: Dodd, Mead & Co, 1899), entitled "The Plunder of the Earth."

for all, worries about the degeneration of the race, and the extraordinary pollution sparked precisely by wasteful consumption of coal. The crisis experienced by Victorian society beginning in the 1870s was fundamentally a crisis of civilization, which called earlier choices into question, and as such inevitably revived energy-related anxiety. Is this what we did with the power? The engineer Richard Price-Williams said it somewhat bluntly: "The long black flags of smoke which still fly from many a tall factory chimney in our manufacturing towns, and the many thousand smaller flags which stream from our house tops, bear constant and most mournful testimony to this enormous waste of coal."[36]

17 Since no other energy source seemed capable of replacing it, and it was an incomparable providential gift in comparison to other sources, it had to be saved.

Saving to endure

18 People were not content with expressing regret and complaints regarding waste, for there were attempts to quantify it and provide solutions. In 1873, the eminent industrial actor Sir William Armstrong believed that half of the coal used in steam engines and for domestic heating was wasted,[37] an assessment that was subsequently echoed at every opportunity and with little discrimination.[38] Similarly, the aforementioned collective work by the British Science Guild led, at the instigation of William Ramsay, to the creation within this guild of a Conservation of Natural Sources of Energy Committee, in which he noted a "frightful waste" of coal and tried to provide solutions.[39] Two changes were subsequently implemented to save this precious resource and remedy this state of affairs: changing converters and uses.

There was firstly an effort to promote savings in production and consumption, notably by proposing to either improve (the steam engine for industrial actors) or modify existing converters (abandoning the open hearth and transitioning to stoves for private individuals). This is what Armstrong insisted on in his article, whose impact was such that a few months later, a Society for the Promotion of Scientific Industry was created, and held its inaugural meeting in Manchester on 16 January 1874.[40] That same year, it organized a fairly successful "Exhibition of appliances for the economical consumption of fuel" in Peel Park, Salford.[41] The proposed solution was therefore essentially technical and economic, and was based first and foremost on innovation, along with its adoption by industrial actors and citizens. It is of course difficult to determine the extent to which these calls for moderation and coal savings were heeded, although Paul Warde has shown that British energy intensity decreased beginning with the late 1870s.[42] Contemporaries do not appear to have been aware of it. Thirty years later, in 1905, the Royal Commission used the same arguments and figures as Armstrong: half of domestic coal consumption could be saved with the installation of central heating, while steam engines of higher quality could reduce their consumption along the same proportions. The verdict was thus the same: "Of the wastefulness of existing methods and of the necessity for economy there is no doubt."[43] These measures were taken regardless of the warnings of Stanley Jevons, who in *The Coal Question* formulated his famous paradox, with technical improvements permitting 19

36 Richard Price-Williams, "The Coal Question", *Journal of the Royal Statistical Society*, vol. 52, no. 1, 1889, 19.

37 Sir William Armstrong, "The Coal Supply", *Presidential Address to the North of England Institute of Mining and Mechanical Engineers* (Newcastle-upon-Tyne: A. Reid, 1873).

38 "The coal famine. Economies and remedies", *The Engineer*, 21 February 1873, 115.

39 British Science Guild, *Fourth Annual Report of the Executive Committee*, 18 March 1910, 11.

40 Robert Hugh Kargon, *Science in Victorian Manchester: Enterprise and Expertise* (Manchester: MUP, 1977), 200.

41 The exhibition apparently drew 50,000 visitors according to the *The Manchester Courier and Lancashire General Advertiser*, 20 April 1874, 6.

42 Paul Warde, "Low carbon futures and high carbon pasts: policy challenges in historical perspective", *History & Policy*, 1 December 2010. Online: **http://www.historyandpolicy.org/policy-papers/papers/low-carbon-futures-and-high-carbon-pasts-policy-challenges-in-historical-pe**. See also Astrid Kander, Paolo Malanima, and Paul Warde, *Power to the People*, 232-247 (cf. note 6).

43 Royal Commission on Coal Supplies, *Final Report*, 1905, 20.

energy savings that ultimately lead to a rise in overall energy consumption.[44]

20 Since the improvement of energy converters was not enough to prevent waste, new uses and a new organization of the energy sector were also envisioned. The debate surrounding the nationalization of coal production, which was so pervasive during the interwar period, began at the turn of the twentieth century. The central issue was increased state intervention in such an essential sector for the country, for instance with respect to salary negotiations. Yet there was also sometimes mention of public control over production, in an effort to rationalize and ensure greater efficiency and savings, for instance with the launching of a debate on this topic in the House of Commons in 1912 by the Liberal MP Chiozza Money.[45] In addition to public control, he suggested more centralized use of coal through an increase in electrical plants. The project was in the spirit of the times, as William Ramsay proposed that same year to burn coal directly underground instead of extracting it, in order to produce gas that could be used at the site, once again in electric plants.[46] There was little doubt that this centralization of energy production would be more economic than the scattered use of coal in individual households for domestic heating. Such reflections were undoubtedly so many steps toward the implementation of the National Grid in 1926. In the meantime, however, they did not solve the problem. Electricity may very well have been the only energy able to compete with the dream-like power of coal, and to spark the imagination as steam did in its time; its magic dissipated as it became clear to many that it had to be produced as well, with coal remaining the chief primary energy source for this purpose. Such efforts could do no more than adapt an ineffective energy system by postponing its decline, without addressing the existential anxiety felt by *fin de siècle* Victorian society.

THE STORM-CLOUD OF THE NINETEENTH CENTURY

This was the title that John Ruskin gave to two 21
conferences in 1884, which were later published. The storm cloud heralded by the Victorian thinker was the one he had seen accumulating for a half century thanks to his meteorological observations; one that could only be the expression of his industrial era's supreme blasphemy against natural and divine beauty, and its transformation of the climate of Europe.[47] It can serve as a revealing symbol of the cloud hovering over the country's energy future.

The tragic destiny of the United Kingdom

Early worry over reserves and the ensuing strug- 22
gle to combat waste were joined by another consequence of providential thought regarding energy: a tragic and sometimes apocalyptic vision of the future. Since coal was the United Kingdom's opportunity—a single opportunity that enabled its extraordinary rise above all other nations—it would surely not be renewed. If reserves were exhausted and prices increased, it would be the undoing of both the country and its power. The descriptions of this collapse were legion each time there was talk of increasing the cost of coal, establishing a tax on exports, or evaluating existing reserves. To take just one example, here is a prediction made by the *Times* in 1913, which relied on Stanley Jevons, that great prophet of decline for the British:

> "Coal in truth stands not beside, but entirely above all other commodities. It is the material source of the energies of the country – the universal aid – the factor in everything we do. With coal almost any feat is possible or easy; without it we are thrown back into the laborious poverty of early times". These words, which Stanley Jevons wrote in 1865, are equally true

44 On this rebound effect and Jevons, see Antoine Missemer, *Les Économistes et la fin des énergies fossiles*, 42-43 (cf. note 2).

45 L.G. Chiozza Money, *Hansard*, House of Commons, vol. XXXVI, col. 1372, 10 April 1912. See also Charles-François Mathis "'Renverser le roi Charbon'" (cf. note 4).

46 William Ramsay, cited in "Can Science Abolish the Coal-Miner?", *The Illustrated London News*, 30 March 1912.

47 John Ruskin, *The Storm Cloud of the Nineteenth Century* (Orpington: Allen, 1884).

> today, for coal has not been, nor does it appear likely to be, supplanted as the main source of industrial energy.[48]

23 There is nothing surprising either about the popularity of a New Zealander contemplating the ruins of London ever since the figure was created by Thomas Babington Macaulay in 1840[49]; when Gustave Doré drew it in 1871, it had already become a cliché of the genre, as the prolific author on British mines and miners, John R. Leifchild, bore witness in 1853:

> A modern historian has drawn a [...] striking picture of a New Zealander, sitting and musing on the ruins of London, at the débris of the fallen St. Paul's. It has been reserved for the author of this book to conceive the picture of some one of his lineal posterity sitting on the top of the ruins of a great, but exhausted Newcastle colliery and mourning and moralizing over the fate of fallen Britain! Should such a picture ever be drawn, its subject will be more pathetic and powerful than that of [...] the feathered New Zealander![50]

24 Through their very exaggeration, found in some of the futuristic stories that proliferated at the turn of the twentieth century,[51] these descriptions reveal the absolute conviction of an unfailing link between prosperity and coal, one that could also be painful: King Coal is a tyrant that one must submit to in order to remain the world's leading people.[52]

Prince or pauper

25 What is ultimately interesting about these accounts is that the United Kingdom had to choose between being a superpower thanks to coal on the one hand, and misery on the other. Any form of more refined or nuanced thinking came up against what I will call an imperative of power: dominate or cease to be. This is the meaning of Jevons's provocative turn of phrase, who concluded his work: "We have to make the momentous choice between brief greatness and longer continued mediocrity."[53] In an 1822 book on geology, Reverend Conybeare and his colleague Phillips saw a gentle transition to backwardness rather than a collapse: shrinking population, forests replacing fields, declining industry, evaporating national wealth...[54]

This worry seemed no less exaggerated even though almost all of the country's energy needs were met by coal starting in the mid-nineteenth century, as we saw earlier. The United Kingdom would never entirely lack coal, for it could import it if its reserves were exhausted or became too costly to exploit. A situation such as the following, described in the *Times* during the spring of 1900, would never occur: 26

> A famine in fuel [...] is one of the most serious troubles that can affect civilized humanity. In some respects, indeed, a coal famine is much worse than a food famine, for without coal it would be practically impossible to keep our mills, forges, mines, and factories in operation; to maintain our systems of transportation by sea and land; to provide heat and light for a hundred different requirements; or to discharge many other functions that are now rendered so easy as to seem commonplace and matters of course.[55]

What the country could lack was low-cost coal that placed it in a favorable competitive position compared to its European or American rivals. It wasn't British civilization that was under threat, but its absolute superiority over its competitors. The best informed were aware of this, voicing 27

48 "Coal resources of the world", *The Times*, 1 December 1913, 21.

49 David Skilton, "Contemplating the Ruins of London: Macaulay's New Zealander and Others", *The Literary London Journal*, vol. 2, no. 1, 2004: **http://www.literarylondon.org/london-journal/march2004/skilton.html.**

50 John Leifchild, *Our Coal and Our Coal-Pits* (London: Longman, 1853), 12-13.

51 For example: Henry O'Neil, *Two Thousand Years Hence* (London: Chapman & Hall, 1868).

52 See, among many other examples, the following description of King Coal: Reverend Harry Jones, "Coal and its Substitutes", *Illustrated London News*, 18 November 1893, 646.

53 Stanley Jevons, *The Coal Question*, 349 (cf. note 14).

54 William Daniel Conybeare and William Phillips, *Outlines of the geology of England and Wales* (London: William Phillips, 1822), part I, 324-325.

55 *The Times*, 19 April 1900.

concerns that were much more level-headed than the panicked expressions of people of modest means unable to purchase coal when it was too expensive. For instance in 1874, the industrialist William Rathbone Greg evaluated available global coal resources, and subsequently affirmed that they were sufficient:

> to set at rest all anxiety as to the future fuel of the human race. But to us, and for our immediate purpose, these figures and speculations are utterly irrelevant. Coal is too bulky an article to pay the cost of distant carriage by land or sea; and if ever England is reduced to import her fuel from America or China, the day of her manufacturing prosperity – to say nothing of her supremacy, the matter now in question – will have set for ever.[56]

28 Greg surely took inspiration from the conclusions of the Royal Commission of 1866, which conveyed the same message in quieter language:

> Before complete exhaustion is reached the importation of coal will become the rule, and not the exception, of our practice [...]. But it may well be doubted whether the manufacturing supremacy of this kingdom can be maintained after the importation of coal has become a necessity.[57]

29 The issue of maintaining this relative superiority, breached during the last third of the nineteenth century by the rise of the United States, Germany, and new countries, explains the intensity of debates, especially at the turn of the twentieth century, of whether to tax coal exports, which continued to increase.[58] Those who were the most concerned called for an exception to the ideology of free trade with respect to a good so valuable and vital to the United Kingdom, whose hemorrhaging had to be stopped. Let us keep what remains of coal in order to extend our prosperity and that of future generations, affirmed both Londoners affected by peaks in energy prices, as well as an intellectual such as Alfred Russel Wallace.[59] Politicians and industrialists were indignant over a measure that could cut the country off from international commerce by provoking retaliatory measures; they believed that mine prospecting should be promoted in the empire (which would help lower coal exports to these areas, who themselves could become exporters), and progress made with regard to energy saving.[60]

CONCLUSION

I believe there was a fatalist attachment to coal in British society of the long nineteenth century, which was rooted in a providential conception of the God-given energy it enjoyed. This attachment contained a dual anxiety: a conscience tormented by the waste of this highly precious resource, and anxiety over an opportunity that would not occur again. This is why most of the British political, economic, and intellectual elite was incapable of conceiving the end of coal without simultaneously envisioning the collapse of English civilization. They proposed certain *adaptations* – essentially by optimizing production and consumption – all while knowing full well that this would only postpone its decline, but not prevent it. They were running toward a wall, as it were. 30

This incapacity most likely resulted from a conception that focused on the energy source rather than the system: the British expended tremendous effort thinking about replacing coal with another energy source that would provide the same advantages within the same social, 31

56 William Rathbone Greg, "Rocks ahead", *Contemporary Review*, vol. 24, 1874, 42. For an analysis of these questions, see Antoine Missemer, *Les Économistes et la fin des énergies fossiles*, 77-78 (cf. note 2).

57 Royal Commission on Coal, *Report*, 1871, vol. I, XVIII.

58 Two percent of the coal produced was exported in 1800, as opposed to 34% in 1913, at a time when coal represented 1/10th of British exports.

59 See for example the account of a protest in *The Nottinghamshire Guardian*, 7 March 1873; Alfred Wallace, "Free Trade Principles and the Coal Question," *Daily News*, 16 September 1873.

60 For example: "'Don't Care' and the Coal Tax", *Colliery Guardian*, 17 May 1901, 1088; Carlyon W. Bellairs, "The Coal Problem: its relations to the Empire," *Colliery Guardian*, 17 May 1901, 1082-1083.

economic, and even potentially political organization, which was in fact impossible. No other energy source could do so. As clearly shown by the aforementioned book published by the British Science Guild in 1912, neither water power nor oil, nor the exceedingly rare wood in the United Kingdom—not to speak of course of solar energy—were as abundant, evenly distributed across the territory, cheap, or well-adapted to British society as it had built itself for a century as coal. As observers from the time had understood, there was a British energy singularity[61] that made coal an exceptional godsend that ensured the country's supremacy in a given international, technological, and commercial context, and that forged a particular culture.[62] The secondary source of electricity could not maintain an illusion in this respect for long.

32 This is most certainly the major lesson to be learned from this non-transition: envisioning a transition precisely entails changing a system *as a whole*. Yet the British of the turn of the twentieth century were unable to do so, for they remained prisoner to a conception of their country that was unfailingly connected to free trade, manufacturing production, and material abundance – at least for some – which is to say so many elements that closely depended at the time on low-cost and abundant coal. For that matter, this is potentially a trap specific to systems based on fossil resources: energy affluence is such that it is difficult to imagine anything other than a decline if it were to stop; yet we know by definition that these resources are finite, hence the anxiety that bursts forth when they become more expensive or scarce.[63] To escape such declinist thought and to change more fundamentally as a whole, the system must at a minimum be adapted to allow an energy mix. However, an energy system does not just consist of technical networks, economic infrastructure, etc. It is a global socio-political configuration, underpinned by specific representations and imaginaries. Reflecting on transition consequently involves inventing possibilities and credible alternative futures, which require taking a step back in order to better grasp the system in its entirety.[64]

In a sense this is what major intellectuals such as John Ruskin, William Morris, and those who imagined utopias at the turn of the twentieth century succeeded in doing, most of whom preached a more respectful frugality toward resources, in addition to a return to nature. In doing so they criticized the materialism of their time, how it had made the world ugly, thereby breaking the seemingly unshakeable link between coal, energy abundance, and happiness. This is a reminder of the fundamentally political dimension of the transition as it is envisioned here,[65] or at least with respect to its subversive dimension. The poet and literary critic Matthew Arnold was not mistaken in his major work *Culture and* Anarchy from 1869, when he made culture the force that enabled this step back, and a clearer vision of his country's situation: 33

61 Astrid Kander, Paolo Malanima, and Paul Warde have highlighted this British singularity in *Power to the People* (cf. note 6): in the United Kingdom around 1870, static steam engines had twice the power of those in the United States and Belgium, and five times the power of those in France (184); in 1913 coal represented 80% of energy consumed in France (compared to 95% for the United Kingdom) (210), but for a per capita consumption that was three times lower in France (243).

62 Industrial novels, for instance *Mary Barton* (1848) or *North and South* (1855) by Elizabeth Gaskell, bear witness to this imagination and way of life through a multitude of concrete details and anecdotes. However, they do not reveal the concerns surrounding coal shortages, instead taking an interest in the condition of laborers.

63 Ducio Basosi has shown, in a conference paper entitled *Les transitions dans l'histoire de l'énergie* (Milan, 28 November – 1 December 2017), that reflections on energy transition during the 1970s were based on fears surrounding the exhaustion of oil, dispelled (for a time) by the sustained production of the 1980s. Antoine Missemer has revealed that after the First World War, fears of coal shortage also eased in the United Kingdom for the same reason (Antoine Missemer, *Les Économistes et la fin des énergies fossiles*, 88-89 – cf. note 2).

64 On this subject see the work by Yannick Rumpala, *Hors des décombres du monde. Écologie, science-fiction et éthique du futur* (Ceyzérieu: Champ Vallon, 2018), which analyzes how science fiction narratives precisely allow for reflecting on the environmental issues of our time, and for envisioning possibilities.

65 Charles-François Mathis "'Renverser le roi Charbon'" (cf. note 4).

> Our coal, thousands of people were saying, is the real basis of our national greatness; if our coal runs short, there is an end of the greatness of England. But what is greatness? culture makes us ask. [...] If England were swallowed up by the sea to-morrow, which of the two, a hundred years hence, would most excite the love, interest, and admiration of mankind, would most, therefore, show the evidences of having possessed greatness, the England of the last twenty years, or the England of Elizabeth, of a time of splendid spiritual effort, but when our coal, and our industrial operations depending on coal, were very little developed?[66]

66 Matthew Arnold, *Culture and Anarchy* (Cambridge: CUP, 1932 ?1869), 51.

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JEH
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Journal of Energy History
Revue d'histoire de l'énergie

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POST DATE
18/03/2020

ISSUE NUMBER
JEHRHE #4

SECTION
Special issue

THEME OF THE SPECIAL ISSUE
Transitions in Energy History. History in Energy Transitions

KEYWORDS
Gas, Gas pipeline, Territory, Business, Transition

DOI
in progress

TO CITE THIS ARTICLE
Jean-Pierre Williot, "Black Gas, Blue Gas, Green Gas: In Search of Gas-Related Transitions", *Journal of Energy History/Revue d'Histoire de l'Énergie* [Online], n°4, published 18 March 2020 URL: energyhistory.eu/en/node/180.

Black Gas, Blue Gas, Green Gas: In Search of Gas-Related Transitions

Abstract

Exploring the notion of an energy transition by way of specific energy calls for reconsidering the history of each energy individually, with gas being no exception over the long term. Three sequences have been observed since the early 19th C., which can be represented by three colors: black gas (or manufactured gas), blue gas (or natural gas), and green gas (or biogas). Each one demonstrates the instability of techniques, internal evolutions, and their integration within economic and social contexts, which were themselves in transition. Is it most appropriate to speak of a transition, a turning point, or a change?

Plan of the article

INTRODUCTION

1 "Energy transition" has been the subject of an expanding scientific literature as well as increasing public media attention. In connection with this dynamic, the replacement of fossil fuel production methods by renewable energy production methods has been established as a major concern in many countries, each according to a different timescale. Since the emergence of a global reflection on sustainable development starting in the 1970s, the subject has included multiple definitions, issues, and perspectives.[1] In the short term, "the" energy transition is shaped by a combination of reducing carbon-based energy and promoting energies that are supposed to be more environmentally friendly. The energy transition law no. 2015-992 from August 17, 2015 clearly laid out this principle in France.

2 With this in mind, the gas that is distributed within the network is of particular interest. The gas industry has genuine cause for concern, for it is one of the fossil fuels slated for degrowth. For all that, will gas energy face a definitive break, and will the outlook for natural gas consumption be linked exclusively to the implementation of the current energy transition?

3 The subject invites closer study in both France and other European countries. The use of natural gas differs depending on the country. For example in 2016, the industrial sector accounted for 53% of gas consumption in Germany, with this figure being only 17% in the United Kingdom and 19% in Italy. Gas used for heating varied between 39% in Germany and 49% in the United Kingdom. Electricity generation, which is limited to 8% in Germany, counts for one third of consumption in both Italy and the United Kingdom.[2] Supply was not identical either, although the gradual construction of a gas transportation network in Europe since the 1970s has greatly contributed to tilt the geographical origin of gas suppliers toward Western Europe. It nevertheless remains diversified, with varying rates of exposure to dependence on Russian gas. For that matter, in each country the power relations between political parties and the environmental aspirations of the population have created dissimilar conditions for limiting gas consumption or, on the contrary, developing it. As a result, there is nothing uniform about the move toward new forms of gas consumption in France, Europe, and even more so the world.

Our objective was much more limited when we submitted an exploration of gas energy over the *longue durée* in France, as part of a conference held in Milan[3] in 2017 on transitions in the history of energy. Two proposals made by the conference organizers defined the framework: Were there energy transitions in the past? Does the malleability of the notion of an energy transition allow for a common definition? We therefore neither explored the future of gas energy nor rewrote its overall history! Our approach was to instead understand the depth of the contemporary transition from a longer-term perspective. The proposal began with a simple question: were there other kinds of gas transitions during the preceding decades? 4

The history of gas energy includes a number of stages, with each one bringing changes to this energy as well as the traditional duo of manufactured gas/natural gas. Two sequences of unequal length—150 years for the first, and 70 years for the second up through the present—correspond to different uses of gas energy. The first involved manufactured gas, which was initially produced from a wide range of combustibles 5

1 See for example Christian Bouchard, "Transition énergétique : contexte, enjeux et possibilités", *VertigO - la revue électronique en sciences de l'environnement* [online], vol. 14/3, published online on December 28, 2014. URL: http://vertigo.revues.org/15975. Within a particularly rich bibliography that intersects with that of all other energies, see two recent works: Pierre Lamard, Nicolas Stoskopf, *La transition énergétique. Un concept historique ?* (Lille: Septentrion, 2018), and Nathalie Ortar, Hélène Subrémon, *L'énergie et ses usages domestiques. Anthropologie d'une transition en cours* (Paris: Editions Pétra, 2018).

2 Source: Eurostat, https://ec.europa.eu/eurostat/fr (accessed on April 5, 2019).

3 Milan, November 30-December 1, 2017. Les transitions dans l'histoire de l'énergie : état des lieux et nouvelles perspectives (Transitions in Energy History: Overview and Outlook).

materials, and from coal beginning in the early 1840s. Gasworks also used liquefied petroleum gas, and oils from petroleum and light distillates beginning in the interwar period. Consumption was limited to public or private urban lighting until the 1880s. Gas markets broadened starting in the late 19th C. with the use of gas as a motive force, especially in craft industries, as well as a calorific source in cooking or for home heating. A new period began in France during the Second World War, one that fully emerged during the 1950s and 1960s. The installation of transportation networks for natural gas began a new history. Natural gas was consumed for calorific uses (heating, cooking, hot water) in domestic and tertiary markets, but also had its uses in industry, for instance to heat ovens in glass-making, as well as in cement factories and the food-processing industry. Techniques for manufactured and natural gas were not particularly comparable. However, the introduction of manufactured gas, and the subsequent shift from manufactured gas to natural gas—with the introduction today of new forms of gas production such as biomethane and the use of biomass—justify talk of multiple kinds of energy transitions with respect to gas energy. The nature of these changes has not always been of the same order. The switch from manufactured gas to natural gas resulted from the emergence of a new resource, and the use of an energy that was more efficient than the preceding one. This shift was initially imposed by economic considerations rather than a political or societal context, before ultimately being justified by technical criteria. The current transition toward a gas future that does not include natural gas is simultaneously prompted by the renewal of resources, technical innovations, powerful social demands, and key political decisions. The gas produced from biomass promotes a circular economy that is rather encouraged in France, whereas the production of shale gas is socially refused.

6 A number of transitions can therefore be proposed if we compare these phases of change: the succession of types of gas, as well as the stages of technical stabilization for each one. The "time" of the transition is essential to identifying differences and similarities; it can be included among the criteria for defining an energy transition. A sudden break, staggered evolution, and transformation via the parallel coexistence of different energy systems are so many approaches that can be applied to the history of gas energy over the long term. The duration of the sequence, through its briefness or extension, indicates the scope of the transition.

The introduction of manufactured gas, the use of natural gas, and the evolution toward biomethane cannot all be placed on the same level. Should we compare consumers of manufactured gas—who engaged in new forms of consumption by becoming "converts" of natural gas, abandoning "town gas" by force or out of benefit—with those who did not even know that the gas being delivered changed from Siberian natural gas to that produced on a farm in Ile-de-France methanizing biomass? Speaking of transitions calls for considering the time needed to implement town gas (40 years in the case of early processes), to transition from manufactured gas to natural gas (20 years before stabilizing conversion), in addition to the promised time period for the shift to new biogas (an approach that was already developed in 1988 during the World Gas Conference in Washington, and slated for 2030). 7

In our approach transition is not transformation, but is instead synonymous with imbrication. Our objective is to show how this would apply to gas energy. Three symbolic colors can represent these phases of gas: black gas, blue gas, and green gas. They are three steps in the history of gas, as it is limited to gas distributed via a network. They suggest the notion of earlier transitions, which are repeated based on long temporalities. These three groups are also in keeping with the notion of technical instability as a source of innovation. They temper the illusion of a radical shift into novelty, even one inspired by a political and social voluntarism under the cover of "energy transition." 8

This "chromatic chronology" can obviously not provide an account of the entire history of gas in a few pages, nor that of the relation of gas 9 with other sources of energy. Focusing on the complete history of coal is another subject, as is the history of pit-coal, peat, and anthracite—the raw materials for producing manufactured gas—in addition to that of coke and later petroleum and its by-products, which changed gas production. Why not also take an interest in the history of oil lighting, which gas thrust aside without eliminating, or the history of the dirty and suffocating coal stove that gas competed with, or the history of electricity in competition with gas for certain uses? It would be foolish to propose doing so in just a few pages! We would instead cite other syntheses.[4]

BLACK GAS

10 Manufactured gas made from the carbonization of pit-coal was not the choice of the first gas entrepreneurs. Coal took hold when its distillation enabled the development of a complex industrial process. When used in proportional combinations, coal allowed the directors of gas-works to obtain more lighting power or more by-products (domestic coke, tar, ammonia water, phenol, benzol, etc.). Gas company engineers chose raw materials not only based on market criteria, accessibly supply, and price per ton, but also based on criteria of quality. This prevailing need was present in the largest companies, and justified the creation of a dedicated position at the Compagnie Parisienne du Gaz, as well as specific monitoring of the choice of raw material. Between 1872 and 1884, its experimental factory conducted over a thousand tests on 59 kinds of coal. In 1866, the Compagnie replaced the agent who acted as a broker at the Grand-Hornu site in Belgium with a factory director from Polytechnique.[5]

Numerous cases show that before arriving at this point, initiatives to produce gas from other raw materials were both less organized and on the increase in France. In Paris, the Hôpital Saint-Louis tested production using old leather, bones, and canola, poppyseed, and linseed oils until the late 1810s. In 1821, the chemist Darcet showed in a report on the factory's accounts that the gas industry's advantage resided instead in the economic benefit of by-products if one were to use coal. He observed that "coke is a fuel that was recently introduced in the workshops of Paris. It is already so sought after that a number of producers are profitably manufacturing it by distilling coal in ovens, or even in furnaces or cast iron retorts, without even collecting the gas and other products of distillation."[6] Hemp seeds were the first choice for one of the pioneering companies located in Paris, the Compagnie Anglaise founded in the 1820s. During the same period, comparative analysis of different types of raw materials interested circles of chemists and Parisian councilmembers. The production of gas using hemp, canola, poppyseed, linseed, and rapeseed, in addition to willowwood, ash-wood, and birchwood, were equally mentioned in both patents and reports of the Académie des Sciences and the Société de l'Encouragement pour l'industrie nationale (Society for the 11

4 Vaclav Smil, *Energy and Civilization: A History* (Cambridge: MIT Press, 2017); Smil, *Natural Gas: Fuel for the 21th century* (Chichester: Wiley, 2015). For a general view of the history of the gas industry oriented toward the history of companies, networks, and consumption in France, see: Alain Beltran, Jean-Pierre Williot, *Gaz. Deux siècles de culture gazière* (Paris: Le Cherche Midi, 2009); Beltran, Williot, *Le noir et le bleu. Histoire de Gaz de France* (Paris: Belfond, 1992); Beltran, Williot, *Les routes du gaz. Histoire du transport de gaz naturel en* France (Paris: Cherche Midi, 2012). For a geographic extension of gas history, see: Isabel Bartolomé, Mercedes Fernández-Paradas, José Mirás Araujo, (eds.), *Globalización, nacionalización y liberalización de la industria del gas en la Europa latina (siglos XIX-XXI)* (Madrid: Marcial Pons, 2017); Alexandre Fernandez, *Un progressisme urbain en Espagne. Eau, gaz, électricité à Bilbao et dans les villes cantabriques, 1840*-1930 (Pessac: Presses Universitaires de Bordeaux, 2009); Serge Paquier, Williot, *L'industrie du gaz en Europe aux XIXe et XXe siècles* (Brussels: Peter Lang, 2005); Andrea Giuntini, "Il gas in Italia fra industria e servizio urbano dall'avento dell'elettricità alla scoperta del metano", *in* Giorgio Bigatti, Andrea Giuntini, Claudia Rotondi, Amilcare Mantegazza, *L'acqua e il gas in Italia* (Milan: Franco Angeli, 1997), 165-255.

5 See our argument in, *Naissance d'un service public : le gaz à Paris* (Paris: Editions Rive Droite, 1999), 384.

6 *Inauguration d'une plaque commémorative de l'installation de la première usine à gaz française dans les bâtiments de l'Hôpital Saint-Louis*, speech by Francis Rouland, president of the Société technique de l'industrie du gaz en France (Technical Society of the French Gas Industry), May 24, 1924.

Promotion of National Industry). The tests that Philippe Lebon conducted to develop his patent for the production of gas for lighting in 1798 used wood rather than coal. Gaz Seguin, which was founded in 1839, distilled animal materials, while in Strasbourg shale oil gas lasted until 1843. In 1835, the inventor of a process for extracting gas from fatty substances and resinous products submitted a request to build a factory in the Batignolles neighborhood of Paris. He planned to use portable gas distribution, as practiced in Reims since 1829 and Amiens since1833.[7] Some patents proposed manufacturing gas for lighting from grape marc (Tours), rich soapy water from textile factories (Reims), or the remnants of crushed olives (Aix-en-Provence). For example in Tours, entrepreneurs estimated that lighting 1,200 burners in the city for 4 hours would require 72 tons of raw material in the form of dregs from pressed wines and distilled grape marc. Production was considered profitable because it increased revenues from sales of wine by 33%, of residual materials for the production of fertilizer by 42%, and of gas by 24%.[8] A company founded in 1847 by two industrial actors, Livenais and Kersabiec, who also planned to produce gas for lighting from winegrowing products, shows that this was not an illusory avenue of exploration. Its backers considered the potential market of the Loiret, Haute-Saône, Gers, and Gironde departments.[9] The *gaz à l'eau* (water gas) technique—referred to during the mid-19th C. as *gaz d'eau* rather than *gaz à l'eau,* an expression adopted at the end of the century—represented another interesting avenue. It imagined decomposing water vapor into hydrogen and carbon oxide that would then be enriched with fuel materials to provide the lighting power of gas. A factory located in the Batignolles neighborhood began producing it in 1837 thanks to the association of the engineer Jobard, who had held the patent since 1834, and the entrepreneur Selligue, who was one of the first to imagine using the gas drawn from bituminous shale. Water gas would reappear much later, in the early 20th C., as part of the gas activity of major coking plants.

These various attempts continued until the mid- 12
19th C. This experimentation was not a passing fancy, as gas companies were seeking the right combination within new environmental contexts. Among the many possibilities explored, the competition between resin gas and coal gas was the most important. Resin gas was already competing with coal in Edinburgh in 1824. It did not have the exact same components as coal gas, as it did not contain sulfuric or ammonia acid. The Compagnie de Belleville tried to produce its gas from different resins and oils, as balsamic odors were pleasant; it used resins from the Landes as well as Corsican forests. Lighting based on *gaz de Nantes* (Nantes gas) was proposed in 1828 using a similar production process based on resin. A study of public hygiene in Marseille in 1853 referred to it as "*gaz provençal*" (Provençal gas), which was obtained from the distillation of pinewood. The author of a brochure on the subject emphasized, based on the conclusions of the Conseil d'hygiène publique de la ville de Marseille (Marseille Public Hygiene Council), that it provided "guaranties for urban health conditions that certainly do not exist for lighting from coal gas."[10] Its abandonment is highly instructive with regard to transitions in forms of energy. When the Compagnie de Belleville's new partner chose to switch to coal gas in 1838, it met with fifteen opponents, whereas it only faced two when it announced resin gas in 1834.[11]

What arguments made gas production switch 13
to the carbonization of coal, which can be seen

7 *Recueil administratif du département de la Seine,* Paris, Lottin de Saint-Germain, tome 1, 1836, 95.

8 Brevet pour l'éclairage de la ville de Tours (Patent for lighting for the city of Tours), 1837.

9 Statuts de la société formée pour l'éclairage en France par le gaz, provenant des produits vinicoles, suivant le système de MM. Livenais et de Kersabiec (Articles of Incorporation of the company created for gas lighting in France, originating from vinicultural products, based on the systems of Mr. Livenais and Mr. Kersabiec), Paris, February 22, 1847.

10 Evariste Bertulus, *Mémoire d'hygiène publique sur cette question : Rechercher l'influence que peut exercer l'éclairage au gaz sur la santé des masses dans l'intérieur des villes* (Marseille: Vve M. Olive, 1853), 26.

11 Archives de la Préfecture de police, D A/50, usine de Belleville (Archives of the Paris Police Prefecture, Belleville factory).

as an adaptational transition? The use of coal became permanent only in the 1840s, due to a combination of factors: its increased role in industrialization, the diffusion of English methods for gas production, the economic advantage of converting bulky waste into by-products with value in markets with demand.

14 A number of gasworks nevertheless used coal from the beginning of their activity, such as the Compagnie Pauwels, which distilled pit-coal using gas purification in limewater in 1822. The royal factory did so even earlier, as the cost estimate for building the factory explicitly provided for a 264 m2 workshop for distilling coal.[12] When the Hôpital Saint-Louis factory used coal, it had its coal for distillation brought from Saint-Étienne and its coal for heating furnaces from Le Creusot. Coal from Saint-Étienne and Montrambert had the industrial advantage of a high content in volatile matter, thereby enabling the production of both gas and its by-products. Yet it took until the 1830s and even more so the 1840s to see convergence toward the production of gas for lighting from coal. Coal was part of a shift in energy that promoted the diffusion of the English and Belgian industrialist model. Its progression explains why English capital so often contributed to the emergence of the first gas companies in France. The industrial actors Manby and Wilson were in Paris in 1821. The Compagnie Européenne committed British capital to the construction of gasworks in Normandy (Le Havre, Caen, Rouen), other port cities (Nantes, Boulogne), and Amiens during the 1830s, in keeping with a capitalist logic similar to that of the creation of railroad companies. English influence was not limited to France, as Imperial Continental Gas brought gas to a number of German cities, as well as Vienna, Amsterdam, Brussels, Antwerp, and Rotterdam. Other evidence of this shift toward the English production model is the Anglicization of the technical vocabulary—"retorts" to refer to *cornues*—or the use of specialized workers from Great Britain such as James Ikin, a London-trained technician and supervisor for the gasworks in Rochester and Chatam, who was hired away as project manager of the royal factory in Paris.[13]

Nuisances were denounced from the beginning of 15
coal-based gas production, a reality that is best reflected in the archives. Contemporaries noted the vapors that escaped during the unloading and extinguishing of incandescent coke in courtyards, the emission of hydrogen sulfide, as well as runoff tar and ammonia. Residents near the Belleville gasworks brought it to the police prefect's attention in the mid-1840s as a development that would prove difficult to curb: "This establishment, which has grown by the day and appears intent on doing so indefinitely, has become increasingly harmful, not only due to the continual smoke and odor that is inevitable in this kind of industry, but also through inflammable materials such as resin, sulfur, and fats, the purification of oils, and finally that of coke, which fills the neighborhood with a putrid vapor."[14] The problem was not limited to gas made from coal. During the first inspections of the gasworks in the 1830s—it was located in southern Paris in the not-yet-annexed village of Vaugirard—the production of resin gas was disapproved of because the ground was infused with distillation oils that emitted a very powerful empyreumatic odor. The transition to another form of street lighting and the manufacturing of by-products did not occur without adaptations.

In 1820, the Conseil de salubrité du départe- 16
ment de la Seine (Health Council for the Seine Department) laid out the issues: "we must note that the distillation of wood and coal has increased, and that it is urgent to resolve how we will use or destroy the resulting waste, so that health is not compromised."[15] Arguments for tempering criticism weighed pollution against

12 Archives Nationales, O3 1587, Devis du 18 mai 1819 (Cost estimate from May 18, 1819).

13 Archives Nationales, O 3 1589. Rapport de Girard, 1820 (Report from Girard).

14 Archives de la Préfecture de police, D A 50, usine de Belleville, June 11, 1845 (Archives of the Paris Police Prefecture, Belleville factory).

15 Archives de la Préfecture de police, Rapports du Conseil de salubrité, July 24, 1820, no. 120 (Archives of the Paris Police Prefecture, Reports from the Health Council).

the social acceptance that they presumed existed. The representative from the Health Council moderated the disadvantages: three minutes of smoke released per hour when the furnaces are loaded. This shift will ultimately be brought about by the economic profitability of the gas sector, via production growth and the obtaining of by-products, coke, ammonia, and tar. The improvement of purification processes after 1845 was an important factor in this evolution. The Mallet process in particular, which introduced the cleaning of gas in neutral dissolutions before its passage through lime-water, enabled the retention and processing of ammonia. It offered a domino effect of economic advantages, as it made use of the chlorine waste produced by laundries and paper mills, which had previously been dumped into rivers. A circuit for the recycling and economic rationalization of production bolstered the transition toward an industrial mode of production for gas for lighting.

17 Faced with detractors, gas for lighting was in its own way also seeking an energy transition.

18 The wood crisis of the 18th C. had left a lasting mark with its rising prices and lack of supply, whose many consequences included unmet needs, for instance that of tar for the navy. The crisis was such that during the 1780s, aid and incentives were used to prompt bakers to convert their ovens from wood to coal. Saving forest resources by producing gas without the carbonization of wood thus modified energy choices. The same was true of returning land to food production. Extracting oil from oleaginous plants required the needless use of land that could otherwise be devoted to growing crops: no longer using plant oils for urban lighting would redirect the use of this land. In addition, gas had superior energy capacity. Finally, supporters of gas also took note of the new and undeniable advantages for nocturnal lighting, including safety and intensity. The gas industry and city councilmembers emphasized various arguments, such as the ability to light fire stations barracks throughout the night. Comparisons with the slowness of oil lighting and its malfunctioning (poorly purified oil, mixed with whale oil that produced sooty flames, unhealthy vapors, and a persistent bad smell) became a systematic argument.[16] Gas for lighting was not only an innovative way of better lighting cities, it also contributed to an intensive use of coal within a comprehensive industrial plan.

BLUE GAS

Black gas, which was associated with the soot-brown smoke of gasworks, was succeeded by blue gas, the color of natural gas flames. Whether it was in the Gaz de France logo—used in 1960s advertising designed to sell "more gas comfort"—or the emphasis on burners for cooking, the visual mutation associated gas with the color blue as soon as calorific value became the energy's primary selling point. It set aside the lighting power that had been the advantage of manufactured gas, as well as the yellow flame that was synonymous with it. While this shift began in the late 19th C., it was only with the arrival of natural gas that the chromatic reference became increasingly explicit from the 1950s onward. 19

The sequence of conversion to natural gas included a three-part transition.[17] For the gas industry, it completely transformed processes, which went from a factory production process (from coal, petroleum distillates, and through coking) to a process of delivering a gas drawn from beneath the ground. The transportation of gas—associated with the remarkable internationalization of the supply market in the space of thirty years—became the core sector for gas companies. Regardless of the European country being considered, the creation of gas pipelines over long distances served as the visible sign of a transition toward new energy possibilities. Technologies were disrupted as a result. 20

16 *Rapports du Conseil de salubrité*, tome 1840-1845, 311 (Reports of the Health Council).

17 On this sequence of the history of gas in France, see the rare studies (other than the works cited in note 4) that were part of the analysis of consumption in this technical change in gas energy, focusing on the example of France: Joan Carles Alayo, Francesc Barca Salom, *La tecnologia del gas a travès de su historia* (Barcelona: Foundation Fenosa , 2011); Anne-Sophie Corbeau and David Ledesma, *LNG Markets in Transition: The Great Reconfiguration* (Oxford: Oxford University Press, 2017).

The disappearance of gas production sites came to a close in 1971 with the disappearance of the Belfort factory, and then in 1983 when the cracked gas plant in Cherbourg was shuttered. Both the increased capacity of gas transportation infrastructure via pipelines, as well as the improved reliability of urban distribution networks, resulted from a change of scale. Innovations succeeded one another over a period of thirty years. Compression systems were placed along the major axes of natural gas. Antiquated distribution conduits made way for polyethylene pipes, but alas not everywhere. An even more remarkable expression of the internationalization of gas supply was the development of a transportation network for methane in the form of a liquefied natural gas, along with its associated infrastructure (liquefaction terminals, different generations of methane tankers, regasification terminals). The tipping point came in 1965 with the opening of the methane terminal at Le Havre, the port of destination for the first shipments of Algerian gas. The gas landscape itself was also transformed, as there were no longer factories on the outskirts of cities offering visibility to the gas industry, which henceforth consisted of invisible networks.

21 For the gas user, the change was also connected to a transition. While fairly short for an individual consumer, the replacement of one type of gas by another took multiple years on the scale of the territory. The energy performance of gas changed. The superior calorific power of natural gas was leveraged in industries that used this source of energy (cement and porcelain manufacturers, glass factories, food industries). Distributed gas offered new production capacities and more refined operation techniques in some areas of manufacturing. This conversion was naturally favorable for companies, but it tied their fate to the growth of these industries. The benefits were less obvious for domestic uses (cooking, heating, hot water) within a market characterized by a high level of equipment—for instance with cooking—as well as due to other competitors supported by the modernization of housing, and especially thanks to the growth of electricity consumption.[18] It was nevertheless in this market sector that the "conversion to natural gas" takes on its full meaning in demonstrating the reality of a transition.

Finally, on the scale of the territory, the arrival of natural gas enabled an additional actor to be included in energy policy, one that was increasingly connected to considerations of independence on the European level. The discovery of the Lacq deposit in 1951 provided new possibilities for developing the territory. This was something of a national epic at the outset, with the construction associated with transporting this gas from Aquitaine beginning in 1957.[19] The emergence of other sources of supply shifted policy choices from the national to the international level, a rule that already applied to petroleum supply. Successively, from the first connection to Holland's immense gas fields in 1959 to the signing of the first delivery contract for Russian gas in 1971—called Soviet gas at the time—relations with supplier countries were never disconnected from political considerations. Natural gas prompted another transition, no longer one of energy independence but of ensuring stable supplies from fairly different partners: Algeria, Holland, the USSR, and Norway at first, and beginning in the 1980s Iran, Nigeria, and Qatar. The period between 1970s and the late the late 20th C. saw a shift from a national gas network to multiple international interconnections, by land across borders and by sea from long distances.[20] 22

18 On the growth of electricity consumption in France see: Martin Chick, *Electricity and Energy Policy in Britain, France and the United States since 1845* (Cheltenham Northampton: Edward Elgar, 2007); Alain Beltran and Patrice Carré, *La vie électrique. Histoire et imaginaire (XVIIIe-XXIe siècle)* (Paris: Belin, 2016); Henri Morsel, *Histoire de l'électricité en France*, vol. 3, 1946-1987 (Paris: Fayard, 1996).

19 See our article "Lacq vu d'ailleurs : convertir la France au gaz naturel de 1957 à 1967", *in* Laetitia Maison-Soulard, Beltran, Christophe Bouneau (dir.), *Le Bassin de Lacq : métamorphoses d'un territoire*, Cahiers du Patrimoine 105 (Pessac: MSHA, 2014), 108-120.

20 For the transition toward a gas transportation network in Europe and the associated political and economic consequences see: Jeronim Perovic, *Cold War Energy: A Transnational History of Soviet Oil and Gas* (New York: Palgrave Macmillan, 2016); Williot, "Le gaz naturel : une énergie nouvelle au centre de l'Europe entre les années

23 The transition that occurred between the manufactured gas stage and the natural gas stage thus engendered this intense period of "conversion" to new gas. This represented a refounding of the gas economy, one that calls for identifying each piece of the puzzle, and considering all of the consequences of the technical change. The appropriate chronological sequence entails defining the transition across a fairly long time period. Gasworks were still in full activity when the Saint-Marcet gas wells were identified in 1939. The transoceanic relations that define commercial gas relations today were barely sketched out in the early 1970s, when coal was no longer being carbonized to extract gas. Yet there was spot market, gas hub, or exchange on the level of Pegas.[21] Narrowing the observation to the conversion of subscribers cuts to the heart of this transition from black gas to blue gas, one that is distinct from another sequence, that of the development of natural gas, which is not our subject here. The emergence of natural gas raised two questions. The perception of a transition was incorporated in their resolution. How to deliver the new gas to the final consumer? How could they be made to embrace the change provided by a national company that remained their partner, and delivered both the gas of the past and the future?

24 The change of gas was also not very visible, with the transportation network's limited presence in the landscape, the substitution of distribution networks in cities, and gas storage sites unknown to the public, such as subterranean reservoirs or the only three methane terminals built in France. None of these locations sparked polemics or debates as the building of large dams or nuclear power plants did. On the contrary, urban operations for the conversion of natural gas were more apparent. They remain a good vantage point for observing the transition, for they involved plants for different categories of consumers (industry, service industries, private individuals), and hence the very functioning of the new energy, and were conceived as a way of giving gas a new image.

The preliminary phase focused on the implementation of the transportation network, the first one built in France with the exception of the gas pipelines connecting the coking plants of the Lorraine region with Paris in 1949. The Lacq network replaced a suburban ring and inter-city connections stretching a few dozen kilometers with a large-scale plan whose outlines contained the transition toward a new gas economy. Should it be reserved for Southwest France, or should it be made into a national network? Should industrial connections be promoted, or additional energy for all households? As we know, the debate was decided in favor of a national system, whose implementation was a major affair. The conversion itself subsequently affected distribution networks, and presupposed the teaching of acceptance. Paul Delbourg, who was the Chef du Centre d'essais et de recherches de Gaz de France (Director of the Gaz de France Testing and Research Center) in 1958, bore witness to the difficulty. He was tasked with conceiving the conversion: "You had to have a dynamic mentality, and that was a generational problem. This required skipping a generation in order to easily change gas."[22] 25

The central point nevertheless remained the capacity to convert subscribers and make them into consumers. Enthusiasm was dampened by a preparatory mission to the United States, in addition to an earlier experience in Toulouse that had lasted seven years during the Second World War. There were differences of opinion 26

1960 et 1980 ?", *in* Beltran, Eric Bussiere, Giuliano Garavini, *L'Europe et la question énergétique. Les années 1960/1980* (Brussels: Peter Lang, 2016), 297-314; Per Högselius, *Red Gas: Russia ant the Origins of Europe's Energy Dependence* (New York: Palgrave Macmillan, 2013); Susan Nies, *Gaz et pétrole vers l'Europe* (Paris: IFRI, 2008); Bijan Mossavar-Rahmani, Oystein Noreng, Gregory T. Treverton, *Natural Gas in Western Europe: Structure, Strategies and Politics* (Cambridge: Harvard University Press, 1987).

21 Pegas resulted from the commercial cooperation initiated in 2013 by the company Powernext (founded in 2001) and the European Energy Exchange in Leipzig, in order to create a European exchange for spot and derivative gas markets.

22 Personal interview with Paul Delbourg in connection with the history of Gaz de France, November 23, 1988.

within Gaz de France itself, which were still present in 1966: "The case of Paris shows that it is well advised to stay with manufactured gas and to use the technique of increased pressure… this solution is only theoretical, for production capacity is limited, and the need to distribute non-toxic gas is increasingly present. The conversion to natural gas is therefore inevitable." [23] The very admission of the need to distribute non-toxic gas can on its own explain the transition toward other forms of energy.

27 A Centre de changement de gaz (Gas Changing Center) was created in April 1957. It coordinated different operations and had over one thousand agents in the late 1960s, who carried out the gasification preliminary to natural gas (propane, propane air) as a replacement for coal gas. They inspected and adapted plants, which served as a first method of conversion that can be seen as an education in transition: awareness campaigns for the population, preconversion, gasification, and definitive conversion. Trips were made to the United States to learn how to proceed with the change of gas. The American-style conversion created a rational process: transportation of natural gas, changing of appliances, and connection by neighborhood. Approximately twenty subscribers were converted each day. The nocturnal spectacle of flaring draining points surprised more than one city-dweller. Industrial plants presented the additional complexity of connecting new furnaces, because the calorific value had to be adjusted to the production process. Such operations required the intervention of the Direction des études et techniques nouvelles (Department for New Studies and Techniques) to control the highly precise length of flames.

28 The importance of conversion can be seen in the statistics. The year 1960 saw 150,000 conversions, compared to 460,000 domestic conversions and 6,900 industrial conversions in 1970! In 1963, the amount of natural gas distributed surpassed that of manufactured gas, with the subscribers on the Lacq network numbering one million. The Paris area was particularly complex to convert because it included 40% of Gaz de France's subscribers during the 1960s, or more than 2.5 million subscribers. Operations were completed only on March 21, 1979.

A number of secondary effects should be highlighted. Distribution pipes had to be adapted due to their antiquated state. This allowed for raising pressure, with 7% of the network still having low pressure in 1960. Network management called for new skills, a phenomenon that was reflected in the creation of the Professionnels du gaz naturel network (PGN, Natural Gas Professionals Network) in 1988, as well as the implementation of Qualigaz in 1990. One indication of a change in habits was that natural gas had to be odorized, as opposed to manufactured gas, whose odor revealed its presence. In 1978, 98% of subscribers had switched to natural gas in France. The goal established twenty years earlier in the Gaz de France management report was proven correct. In 1958, the context of growth in hydrocarbons and the internationalization of energy supply were spoken of in the following terms: "the 3rd gas equipment plan will be dominated by the operation of Lacq, which represents an important step in improving the national energy assessment, with gas and petroleum products being in the resource category that will experience the greatest development in relative value."[24] Twenty years later, a city such as Tulle increased its rank in the modernization being sold by gas companies: 38% of cookers and stoves had been changed, 32% of hot water appliances, and 10% of radiators and boilers. New social expectations had emerged, as though the transition toward a new comfort was proof of change in society. Advertising campaigns boasted about the slogan to clients, while corporate communication abandoned the representation of gas factories in exchange for gleaming terminals and impressive methane tankers.[25] The evolution 29

23 Gaz de France, Direction de la Distribution, Commission de l'équipement, December 19, 1966 (Gaz de France, Distribution Department, Equipment Commission).

24 Gaz de France, rapport de gestion (Gaz de France, management report), 1958.

25 This was especially true of the cover illustrations for reports to the Board of Directors, or institutional brochures diffused at the World Gas Conference in Washington in 1988.

that followed this shift changed scales, but not the general framework. The energy transition that is unfolding today could thus mark one end, although the emerging outlook actually suggests the opposite.

GREEN GAS

30 The GDF company, which became GDF Suez, went green with its image before the declared "energy transition." Taking the environment into consideration was in fact regularly associated with the implementation of transportation networks. This dynamic increased with the new regulations introduced by the Barnier law in 1995.[26] As a visible sign of communication beginning in the 2000s, the company's scroll-shaped logo combined the blue of a gas flame with the green of networks. The term "green gas" includes this environmental dimension, although its definition is significantly broader, characterized by the production of new types of gas. Its roots appeared during the 1980s when the development of biogas was just being planned. The affirmation of this possible shift to other sources of supply illustrates the capacity to adapt to new societal contexts.

31 The energy transition law—2015-992 from August 17, 2015 relating to the energy transition for green growth—established goals that at first glance are not very favorable for gas. The law stressed the need to reduce hydrocarbon imports, and emphasized the goal of reducing greenhouse gases. An essential aspect of it is a European Union of energy that guarantees supply security in order to build a decarbonized and competitive economy through the development of renewable energy. Article 2 summarizes its spirit: "Public policies support green growth by developing and deploying processes that are low in greenhouse gas emissions and atmospheric pollutants, controlling consumption of energy and materials, providing information on the environmental impact of goods and services, and promoting the circular economy, doing so across all sectors of the economy." The law provided incentives for the renovation of buildings, and made commitments to develop clean public transportation in order to improve air quality. It recommended developing the circular economy through recycling, with special emphasis on renewable energy. All told, green growth was defined as an environmentally-friendly form of economic development and was presented—no doubt somewhat abusively at the risk of denying earlier evolutions—as a voluntarist break, one that served as a basis for objectives that gas companies could not ignore. In 2030, renewable energy must represent 40% of electricity production, 38% of final heat consumption, 15% of final fuel consumption, and 10% of gas consumption. Gas companies thus have an interest in promoting green gas, from the standpoint of the environmental protection promoted by the law, but also as part of a gas production system that generates new savings. This transition is not as radical as it may seem.

The signs began to emerge during the 1980s. The natural gas networks that connected the country were not yet finished. The third gas terminal, in Montoir de Bretagne, had just been brought online as evidence of a supposed future devoted to liquefied natural gas. However, research on the methanization of biomass was already underway through a major research-development effort. These dawning possibilities were presented at the World Gas Conference in Washington in 1988: "the complex biochemical mechanisms involved in anaerobic fermentation are starting to be controlled."[27] A number of actors had initiated research to move toward biogas, including the CNRS, INRA, ANVAR, Compagnie générale des eaux, Air Liquide, Elf, and research units specializing in methanization (Biomagaz, Valorga, etc.). Three avenues were being studied. The methanization of waste from livestock farming had sparked interest starting in the 1940s at the École d'agriculture d'Alger (Agriculture School of 32

26 The Barnier law from February 2, 1995 established the principles of general environmental law. It was strengthened in 2000.

27 Georges Donat, "Le biogaz en France. Études et réalisations", *17th World Gas Conference, Washington*, June 5-9, 1988, report IGU / B5-88, 17.

Algiers), in an attempt to methanize manure.[28] The processing of sludge from treatment plants and industrial sewage, especially from the agrifood industry, were conceived of as a depollution process through the methanization of waste. The reclamation of biogas in controlled dumps for household waste also offered additional advantages.

33 At Gaz de France, the Department of Studies and New Techniques was working on the methanization process. It set up the first factory using the Valorga system for household waste methanization near Grenoble in 1984. Average production was as high as 125 m3 of biogas per ton of raw material. A second site in Amiens reached 13 million m3 of biogas for 111,000 tons of waste. With the identification of methanizable resources in the late 1980s, the idea of a combination of energy production, depollution, and the production of organic soil enrichers began to take form. The context was not yet entirely ready due to investment costs, as observed by the speaker at the World Gas Conference: "The primary advantage of biogas in France is that it is an energy of depollution, which can solve the environmental problems raised in rural (slurries), industrial (sewage), and urban (sewage sludge and household garbage) areas."[29] From his point of view biogas was not yet a national consideration on a strictly energy level, although all it took for new technologies to be introduced was a change in context. Should this exploratory phase be seen as a possible transition if economic performance changed? The consideration of larger environmental concerns, as raised by the current energy transformation, actually shows that a transition process can begin only if there are proven techniques and capacities of innovation. The intensifying interest of biogas is exactly in keeping with this configuration.

It can take its place within a circular local economy, for instance with the methanization process for winemaking waste. Order no. 2014-903 from August 18, 2014 (European regulation from December 17, 2013) on the recovery of winemaking waste stipulated that winemakers must eliminate all waste from winemaking or any other grape processing operation, for instance by delivering all or part of their grape marc and wine dregs to a distiller, methanization center, or composting center. They can also opt for on-site methanization or composting of all or part of the grape marc and the manuring of this waste, thereby avoiding open-air putrefaction. Biogas solved the problem of storing certain kinds of waste, and provides multipurpose energy through combustion in a furnace or the cogeneration of heat. It facilitates the recovery of heat for heating water or buildings, and can also be used as traditional gas, especially NGV (natural gas for vehicles). Finally, it provides a solution for the transformation of methanization digestates through their transformation via manuring. 34

In the late 1980s, this approach was the subject of research efforts, some of which had grown out of the energy context of the 1970s. Gaz de France's Department for New Studies and Techniques explored solutions for producing syngas from petroleum and coal products, although mediocre national resources prevented proceeding further. The period after the oil crisis prompted a collaboration between Gaz de France, Charbonnages de France (state-owned coal-mining company), BRGM, and the Institut français du pétrole (French Institute of Petroleum) in 1977 to explore subterranean gasification. Experiments were conducted in Artois two years later. However, the Méthamine economic interest group for the use of firedamp, 35

28 The research was initiated by professors Gilbert Ducelier and Marcel Isman from 1945 to 1953, in an effort to obtain a compressed and purified "farm" or manure gas. The advantage of using this gas as fuel was demonstrated in 1957. The process was abandoned with the energy abundance of ensuing decades, but then attracted attention during the 1973 oil crisis, with the creation of a center for experimentation at the Institut technique des céréales et des fourrages (Technical Institute for Grains and Fodder) in Boigneville (Essonne) in 1975. The production of biomethane is its legacy, especially through European Community financing in 1998 for research on the energy recovery of biomass and waste.

29 Donat, "Le biogaz en France. Etudes et réalisations", 19 (see note 27).

which was based in Avion in the Pas-de-Calais department, proved to be long-lived.[30]

36 In order for green gas to become the medium for a transition, economic factors of profitability had to go along with a political will that was favorable to this gas transformation. This had been at work since the late 2000s. The law of August 3, 2009 on the programming for the Grenelle de l'environnement initiative included biomethane among new and renewable energies as a source of heat distribution. Since February 16, 2011, the recognition of methanization as an agricultural activity has promoted tax breaks. The order from May 19, 2011 established the conditions for the purchase of electricity produced by biogas recovery plants, and enhanced the attractiveness of rates for small local units of production. The authorization to inject biogas into networks in November 2011, due to its total miscibility with natural gas once purified, initiated a decisive turning point in both transportation and distribution.[31] The 2014 extension of the authorization to inject biogas in water treatment plants reflects the will of the Ministry of Ecology, Sustainable Development and Energy to develop biogas projects.

37 This green gas was still marginal in 2013, accounting for 2% of renewable energy production (43% wood, 25% hydraulic, 6% wind, 2% photovoltaic), or 0.17% of total primary energy demand. This biogas production came from public landfills (60%), water treatment plants (18%), and the methanization of organic waste (22%). In 2014 there were 113 waste recovery plants, 10 for household waste, 87 for urban wastewater treatment, and 80 for industrial and agri-food wastewater treatment. The primary market opportunity was electricity production (78%) rather than direct recovery as a heat source. Given this low yield—the transformation of heat into electricity provides only a third of possible power—the true market opportunity, as incidentally indicated by ADEME, is the recovery of agricultural waste by methane stations (enabling the production of 90% of the methanizable supply in 2030). This is in keeping with the Énergie Méthanisation Autonomie Azote plan (EMAA, Energy Methanization Nitrogen Independence plan) launched in March 2013, which provided for the installation of 1,000 methanizers on agricultural sites by 2020.

The injection of biogas in the gas network was a game-changer in the gas lancscape. Lille was the first city to switch its networks, while public vehicles such as those in Moselle became another opportunity, as indicated on the vehicles that are part of this energy evolution. Projects increased. On May 19, 2017, GRDF announced the launch of a study to reach 100% green gas in the network by 2050. In the summer of 2017, experimentation with a smart gas grid brought a new configuration to local gas energy (West Grid Synergy, launched by GRT Gaz, GRDF, Soregies, Morbihan Énergies, Sieml, Sydev, and the Bretagne and Pays de la Loire regions). The blossoming of 115 biomethane projects in the Bretagne and Pays de la Loire regions, as well as plans to supply medium-sized cities with 80% locally produced gas, as in Quimper, reflect the initiation of this movement. Other regions are following suit. In January 2017, the Nouvelle Aquitaine region launched a request for an expression of interest for compressed biomethane (for NGV). It relaunched an industrial undertaking in the Southwest that had taken shape in Saint-Marcet in 1942. Until 1987, compression stations (approximately twenty) and distribution centers (over 180) allowed a fleet of NGV vehicles to operate. The validity of this choice was pointed out in 1993 in view of relaunching this use, as NGV produced 184 g of CO_2 per km as opposed to 224g for gasoline. 38

Two other prospects contributed to the rise of green gas. The "power to gas" technique of producing gas from surplus wind-generated and 39

30 The company Gazonor purchased Methamine in 2007, and sold the operation to the Australian group European gas Limited, which was seeking to position itself on non-conventional gas production sites in 2008. The company again changed hands in 2011, this time becoming part of the Belgian company Transcore Astra. Since 2013, gas quality has prevented its introduction in the network, although racking continues. In 2008, production equaled less than 0.1% of French gas consumption.

31 Raw biogas consists of 60% methane and carbon dioxide. Its purification brings it to 97% methane, which is defined as natural gas.

photovoltaic electricity upended traditional plans for electricity production from gas. The emergence of the concept of "reverse flow" modified the structure of networks. The decentralization of production combining rural methanization units with local consumption areas initiated a different spatialization of gas distribution, which would no longer be the final link in a transportation network but instead the extension of production units. While the falling cost of long networks is one possible economic advantage, there is an evident return to an earlier situation, in which production takes precedence over transportation. This local waste recovery is in keeping with sustainable regional development. However, the investment cost for installations remains a handicap, thereby weakening the economic model for these sites, which presuppose financing on the European or local level, or the mobilization of multiple actors. Another question relates to the relation engendered by this conversion to green gas using agricultural waste. Just as there was opposition to agrofuels, the expanded use of land in agricultural production as a by-product of energy supply became part of the debate surrounding this energy transition.[32]

40 In late 2017, green gas was nevertheless becoming a reality, with 38 plants injecting biomethane. In 2019 their number rose to 76 units. Production capacity reached 574 GWh/year, half of which was connected to small units. In all 531 electricity production plants from biogas were operating for an installed power of 412 MW, with installations over 1 MW representing 69%. The result was less the share of electricity produced than the transformation that was initiated, which was highlighted by ADEME, with emphasis on the fact that 64% of biogas installations are located on farms. The objectives established by the government became more ambitious, as the production of biomethane was supposed to surpass 1.7 TWh in 2018 and 8 TWh in 2023. Gas companies based their strategy on this evolution. While during the 1980s combining gas with a green energy meant that it was being used for greenhouse heating or for enriching crops through carbon fertilizer,[33] green gas today is part of a development strategy for decarbonization. The transition to green gas is no longer an adaptation, but has become an avenue to ensure the viability of gas energy. Environmental promotion during the 1980s, such as sponsorship to restore the pastures of the Pointe du Raz, or the efforts by GRT Gaz during the 2010s to promote the biodiversity of green strips along the routes of gas pipelines, were in keeping with its corporate communication. The impact of green gas was different, for faced with the marginalization of fossil energy, it founded a third gas "transition" through its technical choices and new spatialization of the network. Representing just 0.2% of primary energy resources as opposed to 12.4% for natural gas, it is safe to say that the transition has just begun! However, financial incentives such as payment for part of the costs to connect biomethane plants to the gas transportation network reflects the will of public authorities.

CONCLUSION

Black gas from coal, blue gas from methane reserves, green gas from biomass, each one illustrates sequences within a long history that began two centuries ago in France and Europe. Each has contributed to defining what the transitions of an energy would be. It could be summarized as a succession of stages determined by internal technical evolutions in sync with a context of application, resulting from economic rationality, a social benefit, and the commitment of multiple actors, thereby creating a supply and a demand. Black gas found its place because it provided new lighting possibilities in cities, as well as motive and calorific uses for both domestic and professional purposes. It was a genuine transition in competition with other raw materials for energy (oil, wood) that created new uses. Yet the industry that grew out of it flourished only in the broader context of industrialization based on coal. Blue gas represented 41

32 Essam Almansour, Jean-François Bonnet, Manuel Heredia, "Potentiel de production de biogaz à partir de résidus agricoles ou de cultures dédiées en France", *Sciences Eaux & Territoires,* 2011/1 n° 4, 64-72.

33 "Gaz naturel, l'énergie verte", *Gaz Découvertes*, n°19, February 1989, 13.

another transition by changing the nature of gas. It was nurtured by the experience amassed by a gas industry that had already existed for a century and a half. But it disrupted everything, as transportation became more important than production. Decisions between gas pipelines on land and maritime routes for LNG spared both of them. Distribution networks had to be renovated, measured, and monitored with new instruments. Gas consumers had to learn how to use this new gas, first by transforming their appliances, and then by using its possibilities for new kinds of comfort or energy efficiency. Finally, an industry essentially concerned with urban concessions shifted in less than thirty years toward international relations, which today are part of a complex and strategic gas geopolitics. Green gas resembles the two previous transitions. From the first one it borrowed the revival of gas production, which is based on a diversified and renewable base of raw materials. It has consequently created a new economic cycle. From the second transition it took the implementation of a new network blueprint, but did so the other way around. The gas is injected at points that already exist in the network, with respect to both transportation and distribution. It enables something that has never been the case for gas energy in a network, namely including rural areas through networks with small footprints, which are integrated locally within a circular economy system. Green gas also differs from the two preceding sequences because it does not require consumers to adapt to a new energy. However, it is a specific transition because it correlates a renewable energy with a societal choice, thereby moving from a doomed fossil energy situation to an energy that can be adapted to new concerns, both economic and societal. Gas companies have not hesitated to point this out in their communication.

42 While in 2006 Gaz de France announced “We are imagining renewable energies today to preserve the world of tomorrow” with the use of wind turbines and solar energy as a supplement in the energy mix, today GRT Gaz is emphasizing “windgas” produced through the conversion of surplus energy into gas by using the power to gas process. The distributor GRDF took the same line in a suggestive campaign: “A choice for gas is also a choice for the future” by evoking the different sources of green. Black gas, blue gas, green gas, each sequence was a transition. Each one has its own distinctive features, although they all proceeded from a staggered evolution balanced by the instability of techniques in the face of changing social demands.

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Revue d'histoire de l'énergie

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POST DATE
16/01/2021
ISSUE NUMBER
JEHRHE #4
SECTION
Special issue
THEME OF THE SPECIAL ISSUE
Transitions in Energy History. History in Energy Transitions
KEYWORDS
Coal, Transition, Carbon, Capitalism, Enterprise
DOI
in progress

TO CITE THIS ARTICLE
Cristián Ducoing, Fredrik Olsson-Spjut, "The energy transition in the Swedish iron and steel sector, 1800 – 1939", *Journal of Energy History/Revue d'Histoire de l'Énergie* [Online], n°4, published 16 January 2021, URL: energyhistory.eu/en/node/237.

The energy transition in the Swedish iron and steel sector, 1800 – 1939

Abstract

This article analyses the energy transition of the Swedish iron and steel industry (1800–1939), a leading actor in the European iron and steel market during the 19th and 20th centuries. This industry is an interesting case to analyse from the perspective of energy transition and the composition and change of capital stock (classified by energy technology). in-depth review of the this topic will enable the analysis of the dynamics of energy transition; moreover, this case study, with particular emphasis on technology adoption, lock-in carbon infrastructure, and energy transition, is a relevant tool for understanding the current difficulties in implementing cleaner energy sources and infrastructures.

Acknowledgements

This article is funded by the Jan Wallanders and Tom Hedelius Foundation, P2017-0196:1, as part of the "Engines for sustainability. Horsepower prices, capital substitution and energy transitions in the long run" project. The authors acknowledge the comments and suggestions received by the participants of the conference "Transitions in Energy History: State of the Art and New Perspectives", held in Milan from 29 November to 1st December 2017, and two anonymous referees.

Plan of the article

INTRODUCTION

1 Energy transitions are one of the most interesting phenomena of the present and past. The effects of C02 emissions on our climate are so massive that the age in which we are living is now known as the *Anthropocene*. One of the main challenges of this geological epoch lies in combining economic growth with reduced emissions. What could we learn from the past in order to face these challenges? Energy transitions in specific sectors are relevant starting points from which to gain useful insights.

2 Iron and steel have been major actors in the Swedish economy. Since the 18th century, Sweden consolidated itself as the major actor in the European iron market, and the reconstruction of trade under the British Industrial revolution demonstrated the importance of Swedish iron ore to the growth and diffusion of the industry.[1] But an overlooked aspect of the Swedish iron trade, despite its historical prominence in the country's economy, has been the internal energy transition and how coal and charcoal prices influenced the industry's progress (and decline) throughout the 19th and 20th centuries. Moreover, and from an international perspective, the iron and steel industry have several unique characteristics, such as the energy carriers used in production, (charcoal, coal, electricity), the enormous fixed investment costs involved in establishing a furnace, the backward and forward linkages, and their leading role in the first and second industrial revolutions. Previous research on changes in the Swedish energy system has focused primarily on the political and the national levels, and, alternately, on how different types of energy developed and evolved during the twentieth century. In the Swedish case, for obvious reasons, the expansion of hydropower has been an important research area, and so too has the growth of fossil fuels as a share of Sweden's total energy consumption from the end of the 19th century.[2] In this context, the present study makes a contribution as an in-depth analysis of energy transition at industry level.

A striking feature of the Swedish iron industry is that it did not switch to coal in the 1800s, unlike England/Wales, France, and Germany.[3] Instead, the business underwent a technical change within the confines of charcoal-based production.[4] From the 1850s onwards, capital investments in iron and steel were targeted at energy efficiency in furnaces and new steel-making methods.[5] Larger units and more efficient methods decreased the amount of charcoal required per ton of iron and steel produced, but the total energy consumed by the sector still increased during the late 19th and early 20th centuries.[6] These developments are intrinsically linked to the debate on the underlying causes of Industrial Revolution, framed by the theory of the *high wage economy* and the capital–labour ratio. In the case of England, high wages plus cheap energy made the incentives to invest in capital-saving labour. Using this framework to analyse the Swedish iron and steel industry with the aim of understanding the causes of the energy transitions therein, we first need to account 3

1 Bob Allen, "International competition in iron and steel, 1850–1913", *The Journal of Economic History*, vol. 39, n°4, 1979, 911-937; Bob Allen, "Technology and the great divergence: Global economic development since 1820", *Explorations in Economic History*, vol. 49, n°1, 2012, 1-16 ; Magnus Lindmark and Fredrik Olsson-Spjut, "From organic to fossil and in-between: new estimates of energy consumption in the Swedish manufacturing industry during 1800–1913", *Scandinavian Economic History Review*, vol. 66, n°1, 2018, 18-33.

2 See for instance Eva Jakobsson, *Industrialisering av älvar* (Göteborg: Department of History, n°13, 1996); Arne Kaiser, "From Tile Stoves to Nuclear Plants – the History of Swedish Energy Systems," in Semida Silveira (ed.). *Building Sustainable Energy Systems - Swedish Experiences* (Stockholm: Swedish National Energy Administration, 2001); Astrid Kander, Paolo Malanima and Paul Warde, *Power to the People: Energy in Europe over the Last Five Centuries* (Princeton: Princeton University Press, 2014) and Lars Lundgren, *Energipolitik i Sverige 1890-1975* (Stockholm: Liber Förlag, 1978).

3 Nuno Luis Madureira, "The iron industry energy transition", *Energy Policy*, vol. 50, November, 2012, 24-34.

4 Id.

5 Fredrik Olsson, *Järnhanteringens dynamik. produktion, lokalisering och agglomerationer i Bergslagen och Mellansverige 1368-1910* (Umeå: Umeå University, 2007).

6 Lindmark & Olsson-Spjut, *From organic to fossil and in-between* (cf. note 1) for the price structure of the energy carriers and the final price paid per horsepower unit. Accordingly, the aim of this article is to unpack the reasons behind these energy transitions and how path dependence, natural resources endowment, price structure, and policy are interlinked to generate this output. Why was the energy transition in the Swedish iron sector delayed? What were the main factors behind this delay? Why was charcoal so competitive for so many years? Was the previous investment related to natural resource endowments or policy?

4 To address these questions, the present study draws on new data on industrial energy consumption, qualitative sources on the problems faced by the industry in the interwar period, and previous literature. The article is organised as follows: section two presents the historical development of the Swedish iron and steel industry. Section three shows the main changes in the energy matrix in the iron and steel sector. Section four concludes.

HISTORICAL DEVELOPMENT OF THE SWEDISH IRON AND STEEL SECTOR 1800-1939

Swedish iron and steel 1800-1939: General development of production and competitiveness

5 The iron industry in Sweden dates back to the Middle Ages and has been a major part of the Swedish economy since the 15th century.[7] It is well known that the industry consumed large amounts of charcoal (wood).[8] Then as now, Sweden was sparsely populated, with relatively large woodlands and substantial deposits of high-quality iron ore. This drove the competitiveness of the Swedish iron producers, especially during the period leading up to the breakthrough of coal-based iron production in England and Wales. Sweden was Europe's leading iron exporter from the latter part of the 17th century to the middle of the 1800s , when it shared the top position with Russia.[9] Around the turn of the 18th century the international iron market underwent a rapid and radical change with the advent of the puddling process in England and Wales, when coal became the primary source of energy for local iron production.[10] From the Swedish perspective, the international changes of technology and the British energy transition during the Industrial Revolution lent new impetus to the production and exportation of iron and steel. Shifting European demand for Swedish iron prompted two fundamental change processes in the county's output during the 19th and the early 20th centuries.

First, the industry became more oriented towards higher quality products; that is, it was forced to abandon the strategy of 'bulk-oriented' production of bar iron and focus on meeting the new demand for high-quality iron, and later steel, that sprang from industrialisation and emerging manufacturing activity in other countries. With regard to the shifting demand for Swedish iron ore, the European, and especially the British, appetite for the metal decreased significantly during the 19th and early 20th centuries. However, Sweden's dwindling competitiveness on the European iron markets was largely offset by rising demand for its iron and steel from the USA. 6

Second, the changing international markets resulted in streamlining and specialisation within the Swedish iron and steel industry. As we have seen, these processes necessitated larger but fewer units of iron production and targeted energy efficiency via furnaces and new steelmaking methods. These bigger production units and new methods decreased the amount of charcoal called for per ton of iron and steel produced, yet the sector's total energy consumption increased all the same during the late 1900s and into 20th century. Known as the first 'death of the ironworks' in Sweden, the period 1850–1890 was marked by the closure of several 7

7 Karl-Gustav Hildebrand, *Swedish Iron in the Seventeenth and Eighteenth Centuries: Export Industry Before the Industrialization* (Stockholm: Jernkontorets Bergshistoriska Skriftserie 29, 1992).

8 Ibid.

9 Ibid., 11.

10 Peter King, "The Production and Consumption of Bar Iron in Early Modern England and Wales," *Economic History Review*, vol. 58, n°1, 2005, 1-33.

production units and their replacement by new charcoal-fuelled iron and steel plants that had energy, geographical, or logistical advantages.[11] These developments did not slow the general trend of stronger international competition and decreasing margins within the Swedish iron and steel industry, however. Then, during the 1920s and 1930s, falling international competitiveness led to Sweden's second 'death of the ironworks'. Previous research has shown that 72 ironworks closed down during this period. In the inter-war period, the Swedish iron and steel industry underwent an energy transition from charcoal to coal, to be followed later in the 20th century with the addition of electricity to them mix.[12]

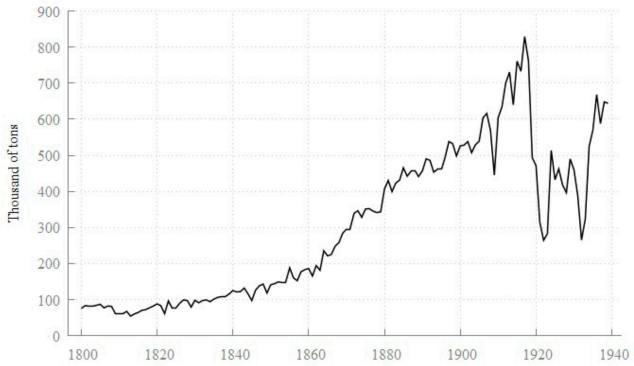

Figure 1: Swedish Iron output in thousands of tons, 1800–1939
Sources: Andersson & Lindmark, 2008; Olsson, 2007. Sources for production and exportation, 1800–1910: Olsson (2007); Exports 1908–1939: Historical statistics of Sweden (1972) , Part 3. Foreign trade, SCB, National Central Bureau of Statistics, Stockholm; Production after 1911: SOS Bergshandteringen (C, SCB, National Central Bureau of Statistics, Stockholm. The figures for bar iron and steel production are unclear from the early 1900s and onwards; alternative series for crude steel are Mitchell (1981), European Historical Statistics.

Sticking to charcoal during the 19th century

8 Sweden has a near-complete absence of domestic coal reserves. Hence, the country was unable to transform its energy system, from wood to coal, without foreign trade; this is part of the reason why, as we have noted, the Swedish iron industry did not change to coal in the 1800s. Instead, the industry introduced technical changes to its model of charcoal-based production.[13] The capital investments in the iron and steel industry targeted energy efficiency in furnaces and new steel making methods, especially from the 1850s and onwards.[14] Relatively larger units and more efficient methods did decrease the amount charcoal per produced ton of iron and steel, but the total energy consumed by the sector increased during the latter half of the 19th century and the first decades of the 20th century.[15] With the price of charcoal increasing vis-a-vis coal during this period,[16] Sweden's iron and steel industry bore the brunt of stronger international competition and diminishing margins. International developments in the iron and steel industry during the 19th century played a major role in the streamlining processes deployed in the traditional iron industry. Another major issue in the Swedish iron industry was the cost of energy before the coal-based technological breakthrough in England and Wales. The rising relative prices of charcoal during the 1800s compounded this situation, and the industry in Sweden responded with capital investments in new plants and the usage of new methods of production.

Previous research on charcoal consumption in the 9
iron industry has put charcoal consumption per ton of bar iron at 417 hectolitres (hl) in 1825. This figure also includes the charcoal consumed the manufacturing of pig iron.[17] But as the century wore on, charcoal consumption per ton bar iron was reduced by major new technological applications (see Figure 4), such as the Bessemer and

11 Olsson, *Järnhanteringens* (cf. note 5).
12 Jan-Erik Pettersson, *Från kris till kris. Den svenska stålindustrins omvandling under 1920- och 1970-talen* [From slump to slump. The transformation of the Swedish steel industry during the 1920s and 1970s] (Stockholm: Department for economic history research at the Business School (EHF), 1988).
13 Nuno Luis Madureia, "The iron industry energy…" (cf. note 3).
14 Olsson, *Järnhanteringens* (cf. note 5).
15 Lindmark and Olsson Spjut, "From organic to fossil and in-between…" (cf. note 1)
16 Olsson, *Järnhanteringens* (cf. note 5).
17 Gunnar Arpi, *Den svenska järnhanteringens träkolsförsörjning 1830–1950* [The charcoal consumption in the Swedish iron industry 1830–1950] (Stockholm: Jernkontorets Bergshistoriska Skriftserie 14, 1951).

Martin processes. By the start of the 20th century, new investments had reduced fuel requirements to 129 hl of charcoal per ton bar iron.[18] Looking as far back as 1700, calculations and fuel intensity point to an approximate energy consumption of 525 hl of charcoal per ton.[19] The technological development of and investments in new furnaces and methods is one important factor in how and why the Swedish iron and steel industry did not change its main energy carrier during the 19th century. Another significant factor in why the industry did not undergo an energy transition is the historical institutional context within Sweden and its iron industry; strict regulations were introduced from the 1630s, perhaps because of high energy consumption. Apart from being part of the mercantilist model of the era, these regulations also facilitated management of the country's strategically important forests.

10 Stringent regulations and controls on Swedish iron production were formally introduced in 1637, with the establishment of the *Bergskollegium* (Board of Mines). From the 1740s the regulations were tightened further, with restrictions placed on total output per ironworks. The regulations also governed site locations, as well as privileges such as local precedence to needed forest and taxation of those living within the geographical boundaries of the ironworks.[20] These Crown interventions have been debated within the Swedish literature on iron production, giving rise to two hypotheses about the restrictions on output per year/ironworks. First, Heckscher has suggested that the regulations were aimed at increasing the price of bar iron on the international market. This theory is based on the author's view that the Crown wished to exploit the monopolistic position of Swedish iron in the 18th century.[21] Hildebrand, on the other hand, puts forward a different argument: that new regulations from the 1740s onwards were the result of increasing local de-forestation around the ironworks. In this interpretation, the Crown's aim was to curtail the massive and growing output of the traditional iron region of central Sweden and thus decentralise production.[22]

The debate is still ongoing. However, estimations of total output show that central Sweden's production stagnated and nearly stalled in the mid-18th century. This finding, combined with other evidence of geographical decentralisation during the 1800s, appear to lend credence to the hypothesis ventured by Hildebrand and others.[23] The regulations began to be loosened in the first half of the 19th century, and in the second half the liberalisation process was completed; for example, the *Bergskollegium* was dismantled in 1857.[24] Thus, the institutional context hampered the overall exports and production of the Swedish iron industry until the 1850s. 11

As the traditional energy carrier, charcoal played a major part in the industry and the old institutions that governed it. Technological changes, capital investments, and product specialisation within the wood-based energy system, together with deep-rooted institutional developments, can be seen as explanations as to why Swedish iron and steel stuck to charcoal during the 1800s. More specifically, traditional location patterns, historical regulations on charcoal production, and the absence of major coal deposits within Sweden played a vital role in the industry's choice to focus on charcoal as the major energy source until the early 20th century. 12

The transition away from charcoal as the preferred choice of energy began during the 1920s and 1930s, when the Swedish iron and steel 13

18 Lindmark and Olsson-Spjut, "From organic to fossil and in-between…" (cf. note 1)

19 Johan Svidén, *Industrialisering och förändrad miljöpåverkan: Råvaruflöden samt svavel- och kvicksilverutsläpp vidbruk i norra Kalmar län 1655–1920* [Industrialization and changing environmental impact: Flows of raw materials and sulphur and mercury emissions at iron plants in Northern Kalmar county 1655–1920] (Linköping: Linköping Studies in Arts and Science, 1996).

20 Svante Lindqvist, *Technology on Trail. The Introduction of Steam Power Technology into Sweden, 1715-1736* (Uppsala: Uppsala Studies in History of Science, 1, 1984).

21 Eli Heckscher, *Svenskt arbete och liv: Från medeltiden till nutid [Swedish work and life. From the Middel Ages to present]* (Stockholm: Albert Bonniers förlag, 1941)

22 Hildebrand, *Swedish iron in the seventeenth* (cf. note 7)

23 Olsson, *Järnhanteringens* (cf. note 5).

24 Ibid.

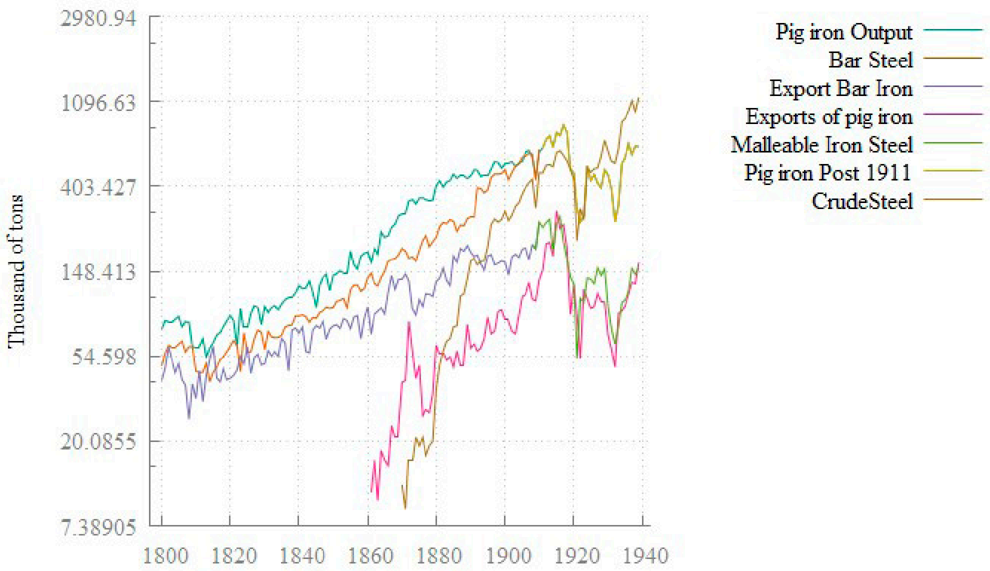

Figure 2: Main indicators of the Swedish iron and steel industry. Thousands of tons, 1800–1939
Sources: *Statistiska centralbyrån Historik statistik för Sverige* Del 3, Utrikeshandel 1732-1970. (Stockholm: Statistiska centralbyrån, 1972). Olsson *Järnhanteringens dynamic* (cf. note 5).

industry switched to a mix of electricity and coal-based production (but with the latter initially used in greater proportions). The pace of this shift to a new form of energy has been attributed by previous research to the crises that the industry experienced in the 1920s. After WWI, the prices of imported iron and steel fell sharply, and the prices of regionally produced charcoal increased. This situation led a structural change within industry. Seventy-two ironworks closed during the interwar period, an absolute majority of which were charcoaled based.[25] But although the general developments and structural changes within Swedish iron and steel during the 1920s and 1930s have been quite well documented, the relatively rapid energy transition – and the dynamics related to this process – have not been analysed in the same extent.

CHANGES IN THE MIX OF ENERGY CARRIERS IN THE SWEDISH IRON AND STEEL INDUSTRY

14 Sweden lagged behind other western European nations in the transition from wood to coal during the 19th century – a key marker of national industrialisation. One can argue that Sweden's industrial breakthrough came relatively late in relation to those countries that witnessed the First Industrial Revolution in the late 18th and early 19th centuries, and that this affected the timing of the energy transition. On the other hand, the literature has shown that coal played an important role in Swedish industrialisation from the 1870s onwards, but that the bulk of the industry's energy consumption consisted of bio-energy up to the end of the 19th century. The explanation for this is found largely in the non-existent energy transition undergone by the steel and iron industry – the largest energy consumer within the Swedish manufacturing sector – over the period. Lindmark and Olsson-Spjut argue that coal, from the 1870s, was vital to the development of transportation (railroads) and to the mechanisation (steam-engines) of manufacturing. A consequence of this development was that coal became a prerequisite for the utilisation of bioenergy in remote parts of the country that were hard to access with traditional transportation and mechanisation. But analysis of the energy used for producing iron and steel in Sweden, and of the aggregate numbers for different energy carriers, shows that the

25 Pettersson, *Från kris till kris* (cf note 12). See also Martin Fritz, *Svenskt stål – Nittonhundratal – Från järnhantering till stålindustri* (Södertälje: Jernkontorets Bergshistoriska Skriftserie, Nr. 33, 1997).

industry did not switch from charcoal-based to coal-based production during the 19th century.[26] This is a major part of the explanation for why Sweden's industrial breakthrough can be seen as industrialisation within a bio-energy framework. The findings of Lindmark and Olsson-Spjut show that this can be debated in consideration of the dynamics of energy consumption.

15 During the 1910s, Swedish pig-iron production started to make use of coke to fuel its furnaces. Up until the end of WWI, coal-based production constituted a small fraction of total pig-iron production in the country. But during the interwar period, the iron and steel industry came to regard this substance as its preferred energy carrier. Coke-based pig iron production started to increase during the 1920s, and the following decade this carrier accounted for half of Sweden's total pig iron output (charcoal accounted for the other half). This dynamic changed during WWII, which hit coal and coke imports. After the war the clear trend of energy transition to coal continued, which rapidly decreased charcoal-based production. The energy transition within the industry also included, to a lesser but steadily increasing extent, electrical-based production.[27]

Energy transition during the interwar period

16 The energy transition in the Swedish iron and steel trade during the interwar period came as part of, but also as a result of, major changes in national and international production and demand for iron and steel. In 1921–1922 the Swedish economy experienced a deflation crisis, and labour-market conflict brought the iron and steel industry to a complete halt for six months in 1923. This can be seen in Figure 1, which shows total iron output over the period 1800–1939. In other words, the 1920s marked a period of stagnation in the iron and steel industry. This phenomenon was also a result of changes to national and international demand for both metals. This is especially salient in the case of pig-iron production; international demand for Sweden's high-quality pig iron (that is, containing low levels of sulphur and phosphorus) decreased during the 1920s with the emergence of new steelmaking processes capable of using lower-quality forms. To an even greater extent, Swedish pig-iron production was affected by changing local demand. New production technologies implemented in Sweden's iron and steel industry – such as production of ingot iron, which used scrap metal as its main input – became an alternative to pig iron and caused a fall in demand for the latter.[28]

	Charcoal	Firewood	Coal
1800	99%	0.50%	
1850	98%	0.12%	
1890	96%	3%	
1914	88%	ND	11%
1920	55%	13%	31%
1939	25%	7%	67%

Table 1: Energy matrix in the iron and steel sector. Percentage by energy carrier, in petajoules. Selected years. Sources:1800- 1913: Lindmark & Olsson (2018), 1914–1939 *SOS* (Swedish Official Statistics), *Bergshandteringen* (Mining industry).

Table 1 shows the development of energy carriers utilised in the Swedish iron and steel sector during the period 1800–1939. The analyse is based on petajoules (PJ), which enables a comparison of energy consumption between wood and coal/coke. Until the end of WWI, charcoal dominated the energy consumption. The Swedish iron and steel industry had started to make limited use of coal around 1910, but the energy transition really gathered momentum in the 1920s. By 1939, 67 percent of energy consumption was derived from fossil fuels (coal and coke). 17

26 Lindmark and Olsson-Spjut, "From Organic to Fossil and in-between…". Regarding imports coal and the Second World War, see also Sven-Olof Olsson, *German Coal and Swedish Fuel, 1939-1945* (Göteborg: The Institute of Economic History, 36, 1975).

27 Ernst Söderlund ans Per-Erik Wretblad, *Fagerstabrukens historia. Nittonhundratalet* [The history of Fagersta iron works. The twentieth century], vol. 5 (Uppsala: Almqvist & Wiksell, 1957), 17-22.

28 Söderlund & Wretblad, *Fagerstabrukens historia* (cf. note 27), 50-52 and Fritz, *Svenskt stål* (cf. note 25).

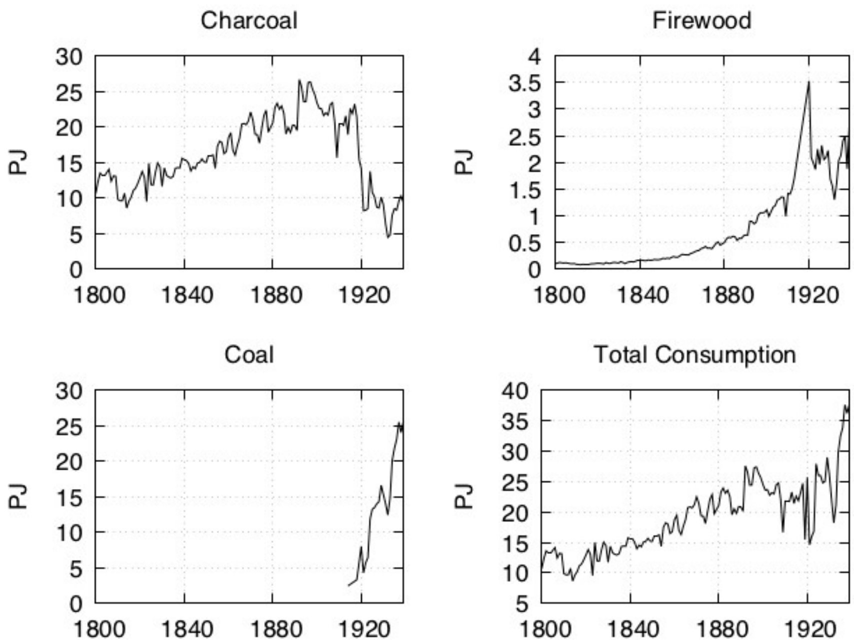

Figure 3: Energy consumption in the iron and steel industry. In petajoules, 1800–1939.
Sources: Lindmark and Olsson-Spjut, 2018.

18 The changing demand structure led to a decrease in numbers of iron furnaces – that is, the above-mentioned 'second death of the iron-works'. Increasing volumes of imported pig iron during the interwar period is also an important factor in the structural changes to the Swedish iron and steel sector. Stronger international competition put pressure on the Swedish industry to lower production costs in the industry. In the case of iron production, the first step was to invest in new coke-based production processes. When it came to high-end steel production, the interwar period encompassed the development of electro-steel production, which began to take off during the 1920s. At the start of that decade, this form of production represented three percent of the total ingot-iron production, rising to sixteen percent by 1929. The electro-steel process was one way of substituting imported coal and coke with hydro-electricity.[29] As a result, a coal/coke and hydro-electricity mix became the new, established energy system in the Swedish iron and steel industry after WWII, following a transition period between the wars. This development also explains the increase in iron and steel production during the 1930s (see figures 1 and 2).

National demand for forestry and the Swedish iron and steel industry as a strategic industry

The structural change to the iron and steel 19
industry in Sweden during the 1920s and 1930s is quite well documented in previous research,[30] which shows the decline of traditional charcoal-based production and the growth of investment in larger coal/coke-based production units. In this context, it is worth considering the dynamics of the industry when it came to the change of energy system in the 1920s and 1930s; that is, why did the industry only undergo an energy transition during this period, when coal had been an option on the international stage for more than one hundred years? One way to deepen our understanding of the energy transition is to make use of qualitive data from the historical period. During the problematic

29 Söderlund & Wretblad, *Fagerstabrukens historia* (cf. note 27), 52-65 and Fritz, *Svenskt stål* (cf. note 25).

30 Fritz, *Svensk stål* (cf. note 25), and Lars Magusson, *Sveriges ekonomiska historia* (Lund: Studentlitteratur, 2016), Pettersson, *Från kris till kris* (cf. note 25), Lennart Schön, *En modern svensk ekonomisk historia: tillväxt och omvandling under två sekler* (Lund: Studentlitteratur, 2014).

interwar period, the Swedish government and the industry itself conducted investigations into the situation facing the latter. For instance, one study, which concluded in 1927, was led by a committee of experts from government bodies, the *Jernkontoret* (the iron and steel producers' association), and economists. The *Jernkontoret* had initiated the specific investigation with calls for increased import tariffs on iron and an export ban on scrap iron. This association argued that the industry could not cope with 'unfair' competition from European iron producers, which were 'dumping' iron onto the Swedish market.[31] In the event the investigation led to the desired export ban on scrap iron, starting in September 1927.[32] On the question of increasing tariffs, the committee was not able to reach a consensus. The government and the influential economists who were consulted – Gustaf Cassel, Eli Heckscher, and Bertil Ohlin – argued that increased tariffs would harm the industry in the long run; they thought that higher tariffs would inhibit the structural changes and the streamlining that the industry needed. As an example of streamlining, they cited the need to increase the production of higher-quality iron at the expense of commercial iron. However, the work of the committee did not result in increased tariffs on iron.[33] On the question of tariffs, the economists shared the view that tariffs would jeopardise the industry in the long-run; as an alternative, they all argued for investments in new technologies and larger production units.[34] The historical documents on the committee's work give us insights into the key considerations presented and targeted with regard to the problems in the Swedish iron and steel industry from 1900 until 1927. This period marks the start of the energy transition in the Swedish iron and steel industry, and the archival materials show that the committee was quite unambiguous about what it saw as the major problem facing the industry. Together, the investigations compared the cost of production of Swedish charcoal-based iron with that of European coke-based iron, and the results were clear. Although fuel efficiency had increased tremendously from the second half of the 19th century, in the 1920s the Swedish industry could not match the cost of production of European coke-based iron and steel. This can be explained by two general factors: external and internal competition, and the development of relative prices. With regard to external competition, the committee's investigation concludes that the international market had lower iron prices than the Swedish market; that is, Swedish iron producers had problems competing on the market for commercial iron. The internal explanations also revolve around the relative price of charcoal in Sweden, which had risen during the second part of the 19th century for two main reasons. First, new and increasing competition from the paper and pulp industry, which preferred the same types of wood as did charcoal production. This pushed charcoal production further north, which resulted in higher transport coast for the charcoal. Second, charcoal production experienced increased labour costs as part of general industrialisation in Sweden and higher demand for labour in the charcoal-producing regions. The investigations also pointed to the newly regulated eight-hour workday as an explanation for increasing labour costs in charcoal production.[35]

20 The relative price of charcoal would appear to be the most important explanation for why the Swedish iron and steel industry underwent an energy transition starting in in the 1920s (see figures 4 and 5). The decreasing trend between coal and charcoal prices was around 1.78% per year, with the result that at the beginning of the 19th century, a megajoule of coal was between

31 RA, Sakkunnige för viss utredning å järnhanteringens område, Kommittéer tillsatta av Kungl. Maj:t/regeringen, 1927, vol. 1.

32 Söderlund & Wretblad, *Fagerstabrukens historia* (cf. note 27), 52.

33 RA, Sakkunnige för viss utredning å järnhanteringens område, Kommittéer tillsatta av Kungl. Maj:t/regeringen, 1927, vol. 1.

34 RA, Sakkunnige för viss utredning å järnhanteringens område, Kommittéer tillsatta av Kungl. Maj:t/regeringen, 1927, vol. 5.

35 RA, Sakkunnige för viss utredning å järnhanteringens område, Kommittéer tillsatta av Kungl. Maj:t/regeringen, 1927, vol. 1.

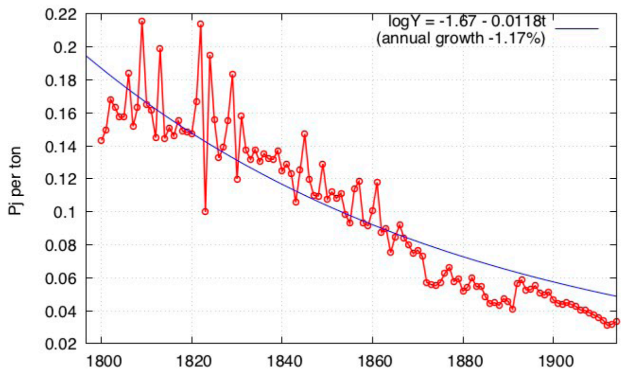

Figure 4: Petajoules per tons of iron. Estimation of consumption in the industry per output unit, 1800-1914. Sources: Lindmark and Olsson Spjut, 2018; Olsson, 2007.

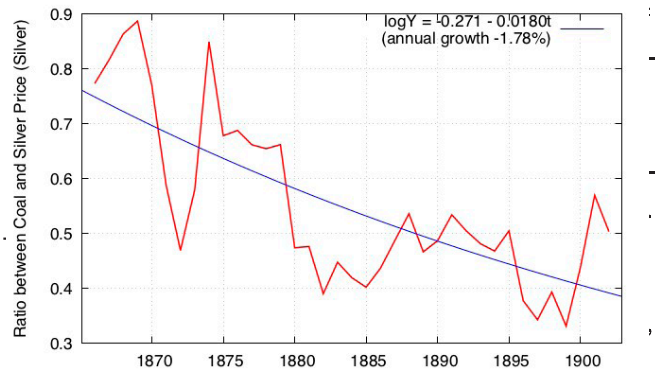

Figure 5: Relative price of coal in comparison with charcoal. Grams of silver per megajoule,1860–1910. Sources: Allen, 1979; Kander, 2002..

forty and fifty percent the value of the same unit of charcoal. However, this comparison does not take into account the value of capital stock, a major financial issue for business. But the decreasing trend in coal prices was not enough to promote energy transition in the sector, delaying the change of energy carriers until the 1920s (See Figure 3 and Table 1).

CONCLUSION AND DISCUSSION

21 What can we learn from the energy transition in the Swedish iron and steel industry? First of all, that prices matters. The relationship between charcoal and coal prices was a strong incentive to keep the energy sources in the sector. Moreover, the past investments in charcoal technologies were so important that the comparatively cheaper coal did not match the total cost of charcoal as an energy carrier. We have to wait until the 1920s to see a major shift from charcoal to coal and hydroelectricity, due the technological change in the industry and its difficulties in keeping pace with the world market. Second, the charcoal endowments could be a relevant indicator of path dependence in the was a key factor in understanding the prevalence of charcoal.

There are several lessons from the past that 22
can be useful for our current challenges. New technologies in a given sector are not enough to promote changes, because past investments and price factor structures are the main elements in structural changes to energy systems. At this point, policy enters. Without exogenous incentives, economies could be tempted to keep their current energy system, developing lock-in technologies; but this is a luxury that we cannot afford. The institutional framework becomes crucial in the challenge to achieve lower-emission economic growth through clean energy systems. As an example, falling prices in fossil fuels could provide an incentive for maintaining the combustion engine as-well as coal- and oil-powered heating systems. If there are no policies oriented towards reducing fossil fuel consumption, even with lower energy prices in renewables, the change to clean energy sources could take longer than we expect—causing histories such as that of the Swedish iron and steel industry to repeat themselves.

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JEH
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Journal of Energy History
Revue d'histoire de l'énergie

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POST DATE
25/05/2020
ISSUE NUMBER
JEHRHE #4
SECTION
Special issue
THEME OF THE SPECIAL ISSUE
Transitions in Energy History. History in Energy Transitions
KEYWORDS
Efficiency, Oil, Politics, Waste, Transition
DOI
in progress

TO CITE THIS ARTICLE
Thomas Turnbull, "Toward histories of saving energy: Erich Walter Zimmermann and the struggle against 'one-sided materialistic determinism'", *Journal of Energy History/Revue d'Histoire de l'Énergie* [Online], n°4, published 25 January 2021 URL: energyhistory.eu/en/node/191.

Toward histories of saving energy: Erich Walter Zimmermann and the struggle against "one-sided materialistic determinism"

Abstract

While energy use has appeared historically consequent for most of human history, it now seems energy non-use may determine our future. It is clear that the worst effects of climate change can only be averted if vast quantities of fossil fuels go unburnt. Accordingly, this paper argues historians of energy should pay attention to the rich histories of past attempts to conserve, save, constrain, and use energy with greater efficiency. To make this argument, the paper revisits the life and work of resource economist Erich Zimmermann, and extends his thinking beyond his lifetime to address more recent concerns. In historicising past energy saving initiatives, the hope is we may find new means to achieve reductions in harmful energy use.

Plan of the article

ISSN 2649-3055

INTRODUCTION

1 When we flick off a switch, we may believe this action will save energy. But with a moment's reflection, we might struggle to explain precisely how our actions reduce overall energy consumption. We might imagine a series of events prompted by our action. Depending on how we derive our power, perhaps our action acts as an informational signal, entering the grid, marginally slowing the rotation of vast electromagnetic coils in a distant power plant, and reducing both the load and the corresponding combustion of fuel used to generate steam to drive the turbine. We might imagine, then, our actions save an infinitesimal amount of coal or natural gas. In which case, what stops this forestalled quantity being consumed elsewhere? How might we disentangle the concept of efficiency from that of conservation? Moreover, what was our intention? Did we intend to reduce the overall rate of fossil fuel use or to prolong the availability of such fuels? In doing so, were we motivated by household economy, altruism, a sense of equity, or growing evidence that the accumulated effects of burning fossil fuels are dramatically altering Earth's climate?

2 That last motivation raises the idea of a global carbon budget, an estimate of the quantity of hydrocarbons that can be burnt without creating catastrophic changes to the climate. This idea of a climatologically determined limit to energy use was first raised by analyst Florentin Krause, climatologist Wilfrid Bach, and energy economist Jonathan Koomey in 1989. As climate change became a concern, they argued that rather than just using fossil fuels efficiently "major restrictions on the use of global fossil resources" were necessary to avoid dangerous warming.[1] Initially the idea had little impact. But by 2010, the joint hottest year on climatological record at the time, the notion of "unburnable carbon" became a potent warning for the fossil fuel industry and those campaigning for divestment.[2] A recent estimate is that the latent emissions in known fossil fuel reserves are three-times higher than that which would exceed a widely agreed safe warming limit of two degrees centigrade. To avoid this limit, these authors warn, a third of oil reserves, half of natural gas, and over eighty percent of coal must go unburnt until 2050.[3]

3 Unburnable hydrocarbon reserves lie predominantly in Saudi Arabia, the United States, and Russia.[4] Given the objectives of the ruling classes of all three nations, the non-combustion of these resources seems unlikely. Whatever its feasibility, what the notion of unburnable carbon makes clear that fossil-fuelled climate change has superseded both economy and scarcity as the prime reason to reduce energy use. It also makes clear that, as in earlier decades of the 20th C., our problem is not energy scarcity but fossil energy abundance; a situation requiring fossil fuels to go unburnt, or for unproven geo-engineering technologies for atmospheric carbon dioxide removal to be deployed at an unprecedented scale.[5] Amid this stark situation, and despite the weight of expectation many place on energy saving as a planetary cure-all, the underlying mechanisms by which such savings are believed to occur remains curiously free from historical inquiry. To help address this deficit, this paper revisits the somewhat forgotten work of resource economist Erich Walter Zimmerman (1888-1961) as an entry point into a wider discussion about the need for histories of energy saving, whether ultimately successful or not.

1 Florentin Krause, Wilfrid Bach, Jon Koomey, Energy *Policy in the Greenhouse: From Warming Fate to Warming Limit* (London: Earthscan, 1990) cited in Ben Caldecott (ed.), *Stranded Assets, Developments in Finance and Investment* (London: Taylor and Francis, 2019), 4.

2 Jan Bebbington, Thomas Schneider, Lorna Stevenson, Alison Fox, "Fossil Fuel reserves and resources reporting and unburnable carbon: Investigating conflicting accounts", *Critical Perspectives on Accounting*, vol. 66, 2020, 1-22.

3 Christophe McGlade, Paul Ekins, "The Geographical Distribution of Fossil Fuels unused when limiting global warming to 2oC.", *Nature*, vol. 517, 2015, 187-190.

4 *Ibid.*, table 1, 189.

5 Filip Johnsson, Jan Kjärstad, Johan Rootzén, "The threat to climate change mitigation pose by the abundance of fossil fuels", *Climate Policy*, vol. 19, n° 2, 2019, 258-274.

A NASCENT SUBFIELD

4 Humanities scholars concerned with energy have so far addressed a fairly circumscribed set of industries, resources, and the human and environmental consequences of their use.[6] The field of energy history has even been accused of "petromyopia", a focus on petroleum at the expense of other fuels. But even this call for an expanded research agenda fails to mention energy saving.[7] This absence is all the more perplexing given that one of the field's leading texts has described how intermittently throughout the 20th C., coal miners had withheld their extractive labour, restricting energy flow to demand political representation.[8] This paper therefore asks, what if, rather than "following the oil", as Mitchell advised, we follow the more prosaic practices of saving energy? By closely attending to the notion of energy as it is understood in physics and engineering, as geographer Andrew Barry has argued, we might gain a more comprehensive and holistic view of how energy, measured in increments of conservation and waste, contributes to historical change.[9]

5 In this vein, this paper joins those of a number of historians who have begun to address energy non-use. Environmental historians Christophe Bonneuil and Jean-Baptiste Fressoz have argued that energy historians must move from studying energy transitions toward the study of "situations in which societies were forced to reduce their energy consumption" such as the Great Depression or the fall of the Soviet Union.[10]Diplomatic historian Giuliano Garavini has recast the Organization of Petroleum Exporting Countries (OPEC) as anti-extractivists, whose embargo could be understood as an "ecological force" able to constrain overall oil consumption.[11] Economic historians Louis-Gaëtan Giraude and Antoine Missemer have contrasted notions of energy efficiency in engineering and economics to help better understand developments in energy policymaking.[12] While environmental historian Caleb Wellum has unearthed the nationalistic and ecological principles underlying North American energy conservation policy of the 1970s.[13]

Added to these works, this author's doctoral thesis documents the history of science upon which energy saving policy was based in Britain and the United States over the long 20th C. In this period, it was argued that a belief in the energy-saving capacities of increased energy efficiency shifted from a paradox to a widely accepted notion. Additionally, it was proposed that conserved energy should be understood as a "metrological resource" given the degree to which measurement and forecasting are central to the realisation of its resource-like capacities.[14] A wider observation was that the science of energy saving was both a reflection of and influential upon contemporaneous theories of political economy. Attending to this reciprocal influence bore witness to a significant transition in energy saving rationales. Early in the 20th C., intervention by the state was seen as a means of saving energy and a corrective to the wastefulness of a competitive market. But over time, such interventions came to be seen as impediments to the energy saving capacities of a freely operating market. Accordingly, by the 1980s, both British and North American political leaders, and those of other nations, scaled back direct energy saving interventions, attempting to instead ensure the dynamics of energy use approximated to that of an idealised efficient market.[15] 6

6 Andrew Barry, "Thermodynamics, Matter, Politics", *Distinktion: Journal of Social Theory*, vol. 16, no 1, 2015, 111.
7 Christopher Jones, "Petromyopia: Oil and the Energy Humanities", *Humanities*, vol. 5, no 36, 2016, 1-10.
8 Timothy Mitchell, *Carbon Democracy: Political Power in the Age of Oil* (London: Verso, 2011), 5.
9 Andrew Barry, "Thermodynamics", 113 (cf. note 6)
10 Christophe Bonneuil, Jean-Baptiste Fressoz, *The Shock of the Anthropocene* (London/New York: Verso, 2017), 181.
11 Giuliano Garavini, *The Rise and Fall of OPEC in the Twentieth Century* (Oxford: Oxford University Press, 2019), 9.
12 Louis-Gaëtan Giraudet, Antoine Missemer, "The Economics of Energy Efficiency: a Historical Perspective", *Centre International de Recherche sur l'Environnement et le Développement (CIRED) Working Paper*, no 74, 2019, 1-26.
13 Caleb Wellum, "'A Vibrant National Pre-occupation: Embracing an Energy Conservation Ethic in the 1970s'", *Environmental History*, vol. 25, no 1, 2020, 85-109.
14 Thomas Turnbull, "From Paradox to Policy: The Problem of Energy Resource Conservation in Britain and America, 1865-1981" (PhD dissertation, University of Oxford, 2017), 433.
15 *Ibid.*, 327-332.

7 Drawing on this work, and seeking to contribute to a nascent subfield of energy historical inquiry, this paper will outline this transition in the overarching principles of energy saving. To do so, it revisits and extends the work of resource economist Erich Walter Zimmermann. The intention is to outline the possible scope of a subfield of energy history focused upon demand reduction rather than increased supply. Examples of attempts at energy non-use, from substitution, to electrification, the rationing of production, and the reallocation energy consumption over space and time, will be touched upon throughout. In concluding, some of the problems faced by historians of saving energy are addressed and a number of resolutions offered.

THE RATIONALISED ECONOMY OF ENERGY

8 Increasing energy efficiency has long been seen as historically consequential. Around 1890 physical chemist Wilhelm Ostwald began to argue that civilisation advanced in step with the "transformation coefficient", the ratio with which society transformed available energy into productive outcomes. Ostwald therefore considered the avoidance of wasted energy a civilizational imperative.[16] Around the same time, the North-American historian Henry Adams described the growing intensity of coal-use more pessimistically. Regularly crossing the Atlantic on coal-fired steamships, for Adams, their ever more efficient operation seemingly demonstrated the acceleration of historical time.[17] Far from implying progress, Adams took such acceleration as a sign of advancing civilizational disorder: a disorientating dynamic he blamed for societal ills ranging from drug abuse to insanity.[18] In effect, Adams argued that increased energy efficiency caused only societal entropy and led the "ash-heap" of history to grow ever larger.[19]

Between these two extremes, the view of German-American resource economist Erich Zimmermann can be situated. In 1933, Zimmermann grandly declared the "rationalised economy of energy" as "mans' greatest triumph and his biggest task".[20] Drawing upon the work of Ostwald, Serbian physicist Mihajlo Pupin, and British geographer James Fairgrieve, Zimmermann had authored an extensive survey of global resource use with energy at the fore. Written during the Great Depression, the book sought to caution against ignoring the specific "physical basis" upon which the at-the-time ailing "price economy rests".[21] But the book was far from a materialist rebuke to orthodox economics; in fact it articulated an aversion to any simple form of determinism.[22] Of central importance to historians of energy saving, he accused those who saw history advancing via the discovery of "new forms or additional amounts of energy" of a "one-sided materialistic determinism". Having surveyed the prosaic realities of resource use, he called attention to the "equal, if not greater, importance of making fuller utilization of old forms and of limited amounts of energy."[23] Zimmermann's emphasis on efficiency set his work apart from more recent scholarship which tends to focus on the materiality of energy use.[24] 9

16 Janet Stewart, "Sociology, Culture, and Energy: the case of Wilhelm Ostwald's 'Sociological Energetics' – A translation and exposition of a classic text", *Cultural Sociology*, vol. 8, no 3, 2014, 11-12.

17 Crosbie Smith, Ian Higginson, "Consuming Energies: Henry Adams and the Tyranny of Thermodynamics", *Interdisciplinary Science Reviews*, vol. 26, no 2, 2001, 103-111.

18 Henry Adams, *The Education of Henry Adams* (New York: Modern Library, 1931), 402; Keith Burich, "Henry Adams, the Second Law of Thermodynamics, and the course of History", *Journal of the History of Ideas*, vol. 48, no 3, 1987, 467-482.

19 Henry Adams, *The Tendency of History* (New York: Macmillan, 1919), 5.

20 Erich Zimmermann, *World Resources and Industries: A Functional Appraisal of the Availability of Agricultural and Industrial Resources* (New York and London: Harper & Brothers Publishing, 1933), 75.

21 *Ibid.*, foreword, vii.

22 William Meyer, Dylan Guss, *Neo-Environmental Determinism: Geographical Critiques* (Basingstoke: Palgrave Macmillan, 2018), 34.

23 Erich Zimmermann, *World Resources and Industries*, 53 (cf. note 20).

24 Matthew Huber, "Energizing Historical Materialism", *Geoforum*, vol. 40, no 1, 2009, 105-115.

ERICH ZIMMERMANN

10 Born in Mainz in 1888, Zimmermann remains amongst the foremost theorists of energy and resource conservation. After studying in Berlin, Birmingham, and Munich, in 1911 he received a doctorate from the University of Bonn for a thesis on the history of the British coal trade. Soon after, he travelled to the United States to study the economic geography of the Great Lakes. Following the outbreak of war in Europe, Zimmermann settled in North America, first in Illinois and then at the University of North Carolina. Drawing on his thesis, his first book concerns the economics of ocean shipping and documented "the transition from coal to oil" as means of propulsion in the British and American Naval fleets.[25] But it was *World Resources and Industries*, published in 1933, which brought widespread praise. In 1942, as war raged against Germany and with his loyalty to the United States sufficiently recognised, Zimmermann was nominated to a professorship at the University of Texas. Soon after, a revised version of *World Resources* was published to further acclaim. Zimmermann then devoted the rest of his career to studying the petroleum industry, which Texas dominated at the time. His final book, published in 1957, concerns a nationwide attempt to conserve petroleum by controlling its production rate. Four years after its publication Zimmermann died.[26]

11 Zimmermann's work offers much of importance for contemporary energy historians. His most influential maxim was that "resources are not, they become".[27] Within the confines of the laws of physics, this mean resource availability was as much a function of human want and ability as geophysical availability. In effect, Zimmermann sought to ground the economist's notion of a resource in physical reality while also articulating the degree to which resources were, to some degree, a relative concept. Resources, he evoked "evolve out of the triune interaction of nature, man, and culture, in which nature sets outer limits, but man and culture are largely responsible for the portion of physical totality that is made available for human use".[28] In outlining this "functional theory" of resource availability, he emphasised how "every advance in sciences and art compensates to some extent for the loss of physical reserves."[29] This assertion of reciprocity emphasises the central importance of the history of science and technology to the history of energy and resources, and in particular, the history of attempts to save energy.

Zimmermann was an avowed institutionalist, a form of economic thought that stressed the specific role that institutions play in shaping economies in place of mathematical abstraction. This perspective encouraged his belief that "institutions have as much to do with the ultimate efficacy of energy use as have engines, machines, and logarithm tables."[30] He saw resources as inescapably anthropic, entities that could not exist outside the specific means of their exploitation and the society they served. But this did not lead to a naïve cornucopianism. The 1951 edition of *World Resources* clarifies that "not even omniscience can create matter or energy out of nothing. Nor can any science, no matter how skilful and advanced, ever restore to human use the energy once locked up in coal, oil, or gas, but spent."[31] 12

This has not prevented some from misinterpreting Zimmermann's work as a form of idealism which justifies untrammelled resource exploitation.[32] In fact, having experienced the 13

25 Erich Zimmermann, *Zimmermann on Ocean Shipping* (New York: Prentice Hall, 1921), 178.
26 Stephen McDonald, "Erich W. Zimmermann, the Dynamics of Resourceship", in Ronnie Phillips (ed.), *Economic Mavericks: The Texas Institutionalists* (Bingley: Emerald Publishing, 1995), 182.
27 Erich Zimmermann, *World Resources and Industries*, 782 (cf. note 20).
28 Erich Zimmermann, *World Resources and Industries: A Functional Appraisal of the Availability of Agricultural and Industrial Materials* (New York: Harper, 1951), 15.
29 Erich Zimmermann, *World Resources and Industries*, 799 (cf. note 20).
30 *Ibid*., 44.
31 Erich Zimmermann, *World Resources and Industries*, 10 (cf. note 28).
32 Robert Bradley, "Resourceship: an Austrian theory of mineral resources", *Review of Austrian Economics*, vol. 20, no 1, 2007, 63-90.

economic disequilibria of the Great Depression, Zimmermann believed that government had an obligation to stabilise resource availability as it fluctuated in line with technological changes.[33] And far from an unconditional faith in scientific progress, Zimmermann believed the "technological unemployment" of the 1930s had been caused by the growing efficiencies and quantity of productive machinery.[34] Science alone was not enough to ensure the stable provision of energy and resources.

14 But Zimmermann was also not an energy determinist. In fact, he was critical of the Technocrats, that short-lived political movement in the 1930s whose adherents saw the Great Depression as a result of collective failure to recognise the energetic basis of national wealth.[35] He accused them of failing to account for the "relative efficiency" with which energy was used. Alerting his readers to the comparatively greater efficiency of French automobiles versus those of North America, Zimmermann pointed out that the same quantity of energy consumed in one place could achieve a markedly different outcome elsewhere.[36]

15 Context was central to the effectiveness of energy consumption. In fact, he believed variation in the efficiency of energy and resource use would become ever more important, as a form of energetic "productivism" was becoming the new means by which nations engaged in geopolitical rivalry.[37] Zimmermann's sense that progress lay in increased efficiency rather than territorial expansion led him to argue that "the greatest progress may be expected not from the country which possesses the largest coal deposits, but from the country which uses its coal most efficiently and wisely". However, a fundamental problem remained, the very definition of efficiency, not to mention wisdom, remained "a difficult question", one that required the consideration of "a large number of intangible and seemingly unrelated elements."[38]

STELLAR ENERGY

16 One important element in understanding efficiency as it relates to energy is the underlying physics. In its functionalism, Zimmermann's thinking attempted to accommodate the physical principle of relativity within resource economics;[39] he speculated on the implications of Albert Einstein's work for economics.[40] At the same time, his view of nature was underwritten by a classical approach to thermodynamics. Deferring to Pupin and Ostwald, Zimmermann described the availability of terrestrial energy as a result of incoming "stellar energy". Energy radiating from the sun fuelled photosynthesis, powered carbon and nitrogen cycles, dictated Earth's climate, and ultimately provided the gravitational force which drove the hydrological cycle. As a subset of the universally constant quantity of energy, it was the sun that granted the terrestrial system its specific "capability to do work".[41] However, this was "no guarantee of undiminishing supply", as the quality of energy

33 Stephen McDonald, "Erich W. Zimmermann", 32 (cf. note 26).
34 Erich Zimmermann, "The Resource Hierarchy of the Modern World Economy", *Weltwirtschaftliches Archive*, vol. 33, 1931, 431-463.
35 Ernst Bernd, "From Technocracy to Net Energy Analysis: Engineers, Economists, and Recurring Energy Theories of Value", in Anthony Scott, John Heliewel, Tracy Lewis, Philip Neher (eds.), *Progress in Natural Resource Economics* (Oxford: Clarendon Press, 1985), 337-366.
36 Erich Zimmermann, "The Relationship between output of work and economic well-being", *The American Economic Review*, vol. 24, no 2, 1934, 245.
37 Anson Rabinbach, *The Human Motor: Energy, Fatigue, and the Origins of Modernity* (Los Angeles CA: University of California Press, 1992), 70; see also Neil Smith, *American Empire: Roosevelt's Geographer and the Prelude to Globalisation* (London: University of California Press, 2004), 11.
38 Erich Zimmermann, *World Resources and Industries*, 53 (cf. note 20).
39 The influence of relativity beyond physics is evident in Forman's account of Oswald Spengler's work. Though a vulgarisation of the physics, writing in 1918, in Der Untergang des Abendlandes (The Decline of the West, trans. 1926) Spengler argued that "There simply are no conceptions other than anthropomorphic conceptions", on this see Paul Forman, "Weimar Culture, Causality, and Quantum Theory, 1918-1927", *Historical Studies in the Physical Sciences*, vol. 3, 1971, 30-31.
40 Erich Zimmermann, "Crossing the Frontiers of Science", *Social Forces*, vol. 14, no 1, 1935, 139.
41 Erich Zimmermann, *World Resources and Industries*, 39 (cf. note 20).

tended to deteriorate in accordance with the second law of thermodynamics. Over time, all energy became "diffuse" and no longer a feasible resource.[42] Somewhere between these two conditions, energy's universal constancy and its diffusion into less useful forms, the anthropically significant work of minimising the waste of "free" energy occurred.

17 Though not an energy determinist, Zimmermann believed the efficient use of energy was of singular importance. Its continued availability was "the key to resource availability" as it could expand the functional availability of other industrial inputs: "Coal hoists and moves; steel helps to make more steel".[43] Akin to the contemporary notions of Gaia or the Technosphere, like many geographers of the late 19th and early 20th C., Zimmermann saw the world as an aggregate organism, "a living growing complex of matter and energy" which assumed a significant degree of independent agency.[44]

18 Thus, the supplies of mineral fuels and machine materials must be viewed not as a dead mass of inert materials, but as parts belonging to a living organism which is possessed with dynamics powers of its own even though they are subject to human will and human control.[45]

19 This idea, that Earth and its industrial system were an organism in process has led at least two authors to relate Zimmermann's views to those of his contemporary, the philosopher Alfred North Whitehead, in semblance if not explicitly.[46] Developed over a lifetime, Whitehead's philosophy argued that no entity could exist in isolation and that reality was an outcome of processes of interrelation.[47] At his most philosophical, Zimmermann similarly theorised that his inquiries into the use and conservation of resources had revealed the "altogetherness of things", an 'inextricable mesh of forces and conditions' against which human intentionality struggled for realisation.[48]

These constraints could be discerned in the work of steam engineers and their efforts to make "conversion more efficient, to lessen the losses engendered".[49] Since the 1800s, engineers had demonstrated that the combustion of a certain quantity of coal produced a measurable amount of work. The power transferred was described as having been conserved, and came to be known as energy.[50] Somewhat confusingly, all kinds of engine could therefore be thought of as means of conservation, in so far as they realised a proportion of a fuel's potential to do work and—as they improved in efficiency—lessened energy waste.[51] This efficiency-driven conservation could, of course, only be achieved in relation to an act of consumption. This was only a problem in so far as the cosmic "storehouse" of energy, as Pupin had called it, was finite.[52] For humans, in the case of "animate" or renewable energies, such as falling water or human labour, efficiency of use was less a concern than the maintenance of conditions of continued renewal. But "inanimate" energies, those "spill-overs" of carbon formed hundreds of millions of years earlier, whose use involved irreversible destruction, this problematic distinction between efficiency and conservation was more complicated.[53] 20

42 *Ibid.*, 46.

43 *Ibid.*, 430.

44 David Livingstone, "Evolution, Science and Society: Historical Reflections on the Geographical Experiment", *Geoforum*, vol. 16, no 2, 1985, 119-130.

45 Erich Zimmermann, *World Resources and Industries*, 530 (cf. note 20).

46 Alfred Chalk, "Schumpeter's Views" (cf. note 30); Jamie Linton, *What is Water? The History of a Modern Abstraction* (Vancouver: University of British Columbia Press, 2010), 27-29.

47 As Phillip Rose notes Whitehead's philosophy lends itself to ecological thought. Philip Rose, *On Whitehead* (Belmont: Wadsworth, 2002), 92.

48 Erich Zimmermann, *World Resources and Industries*, 818 (cf. note 20).

49 *Ibid.*, 48.

50 Thomas Kuhn, "Energy Conservation as an example of simultaneous discovery", *The Essential Tension: Selected Studies in Scientific Tradition and Change* (Chicago, University of Chicago Press: 1977), 68.

51 Norton Wise, Crosbie Smith "Work and Waste 1: Political Economy and Natural Philosophy in Nineteenth Century Britain", *History of Science*, vol. 27, no 3, 1989, 263-301.

52 Erich Zimmermann, *World Resources and Industries*, 9 (cf. note 20).

53 *Ibid.*, 51.

EFFICIENCIES

21 Having ranged far from the conventional abstractions of economics, Zimmermann had still to define efficiency. He believed one's disciplinary perspective could obscure the altogetherness of the problem. The natural scientist, be they steam engineer or geologist, emphasised the biophysical, and chemical limits of Earth's resources and their interaction with technologies. For example, improvements in smelting processes might allow lower concentrations of copper ore to become a workable commodity, vastly expanding the availability of global copper. However, perhaps wrongly, Zimmermann believed natural scientists largely failed to consider "the implications of pecuniary economics".[54] Social scientists, Zimmermann argued, upheld a similarly plastic view of resource availability, but one based on increments of socio-economic change. Economists in particular associated increased productive efficiency with lower costs, a dynamic that would result in lower prices and stimulate demand, causing an acceleration in overall rates of resource use. In certain configurations therefore, far from conserving resources, increased efficiency could have the opposite effect.[55]

22 Here Zimmermann deferred to British economist William Stanley Jevons. Prompted by fears about Britain's continued industrial supremacy, in 1865 Jevons had addressed the longstanding question of the duration of Britain's coal.[56] Though abundant at the time, he forecast that by the year 2000, if use rates continued to increase at the rate at which they had in the 1800s, Britain's mines would be effectively exhausted. As quantitative indicators of utility, if prices fell as a result of an increase in efficiency, this would likely cause an increase, up to a certain point, in the rate and scale of resource consumption in a given market. This dynamic later became known as "Jevons' paradox" or the "rebound effect".[57] In his doctoral thesis, Zimmermann had used Jevons' work to argue that as steam engines had become more efficient over the 19th C., far from saving coal, coal use had expanded in rate and scale.[58] Clearly, the unanticipated outcomes of increased energy efficiency of energy use have long been known.

Zimmermann lamented that, in his own time, the term conservation was used with imprecision. If "to conserve means nothing more than to economize, why burden our vocabulary with this synonym?"[59] The question was rhetorical. He set out the distinction. In general usage conservation meant reducing the rate of a given resource's consumption. By contrast, "economisation", or efficiency, could be defined as an increase in the ratio of the input and output of a given productive activity. As Jevons argued, economisation did not necessarily result in conservation. If coal hydrogenation became more efficient, for example, this would lower its price, which would likely raise demand and hasten depletion.[60] Just as efficiency did not always conserve, conservation did not mean imposing an immediate restriction on resource use, so much as forestalling its use to a certain point in the future. The goal of conservation could therefore come into conflict with that of efficiency. At the same time, if conservation was understood as waste minimisation, complete denudation could still count as a success. 23

Zimmermann also added a significant addendum to Jevons's argument. Unlike Jevons, he had witnessed the Russian Revolution, the establishment of the Soviet Union, and the "wonders" of its five-year plans: a demonstration that other forms of economic life were possible.[61] Theoretically, in a centrally controlled market, if overall production rates were reduced, economisation could result in conservation. Whereas in a capitalist system, in which price movements 24

54 *Ibid.*, 789.
55 *Ibid.*, 791.
56 Fredrik Albritton Jonsson, "The Coal Question Before Jevons", *Historical Journal*, vol. 62, no1, 2020, 108-109.
57 See "Conservation encounters climate" section below.
58 Erich Zimmerman, *Die britische Kohlenausfuhr, ihre Geschichte, Organisation unde Bedeutung* (Essen: Girardt, 1911), 4.
59 Erich Zimmermann, *World Resources and Industries*, 790 (cf. note 20).
60 *Ibid.*, 438.
61 *Ibid.*, 648.

largely dictated demand, unchecked economisation would likely increase overall resource consumption. As he put it, in market system in which "conservation is inseparably linked up with a reduced rate of output or of consumption, economies which stimulate output or consumption cannot be called conservation."[62] But far from advocating centralised control, Zimmermann merely conceded that, for the conservation of resources to be achieved in a holistic way, a degree of market intervention was necessary, be it via the police power of the state or via taxation.

25 To better clarify the many aspects of conservation, Zimmermann proposed a suite of definitions: *economisation* meant to improve the ratio between input to output, for reasons of increased productivity, competitiveness, and profit-making in the present; whereas *conservation* was distinguished by its orientation toward the future, immediate economic benefit would be sacrificed for prosperity's gain; *conservancy* meant a reduction in use rate as a by-product of economisation, an example might by a naval fleet's shift from coal to oil for reasons of economy which incidentally conserves a quantity of coal; *economancy*, by contrast, meant economisation as a by-product of conservation, as occurred with Jevons' paradox.[63] Though subject to later criticism, and somewhat confusing, Zimmermann's neologisms point to the ambiguities that hide behind the term conservation.[64]

THE FUTURE

26 If conservation meant "restraint in current use for possible future benefit" the future would unsurprisingly assume a central role in saving energy.[65] Throughout the 20th C., in various guises, the future would provide a horizon toward which the work of conservation could be deferred, and offer hypothetical forecasts against which the cumulative effects of present-day energy saving initiatives could be measured. Unsurprisingly, of all disciplines, economics was often the most confident in staking claims in the future. One example, described by Zimmermann, was the work of Harold Hotelling, a pioneering Minnesotan mathematical economist. In a period when such methods lacked credibility, Hotelling had used mathematics to argue that oil should be consumed freely within a market. As it became scarce, its price would rise alongside that of other goods and such rises would discourage consumption and mean that, in the case of oil, extraction would be deferred to some point in the future.[66]

27 By 1957, the economics of temporal deferment would be further enshrined by German-American Siegfried Ciriacy-Wantrup. Another Bonn graduate, Ciriacy-Wantrup combined principles of scientific agronomy with cutting-edge mathematical economics to develop an analytical approach to resource conservation.[67] Superseding Hotelling's formalisms, advances in econometrics and calculative technologies now allowed large sets of linear equations to be computed, from which the optimal means of allocating resources over time could be derived.[68] Each resource, energetic or

62 *Ibid*., 806.

63 The term economancy was added to the 1951 edition, Erich Zimmermann, *World Resources and Industries*, 27 (cf. note 28).

64 Stephen McDonald, "Erich W. Zimmermann" (cf. note 26).

65 Erich Zimmermann, *Conservation in the Production of Petroleum* (Connecticut: Yale University Press, 1957), 26.

66 Harold Hotelling, "The Economics of Exhaustible Resources", *Journal of Political Economy*, vol. 39, no 2, 1931. 137-175; see also, Timothy Mitchell, *Carbon Democracy*, 196 (cf. note 8); recent archival analysis demonstrates Hotelling had a greater appreciation of geological constraints than subsequent interpretations of this paper would suggest, see Roberto Ferreira da Cunha, Antoine Missemer, "The Hotelling rule in non-renewable resource economics: a reassessment", *Canadian Journal of Economics/Revue Canadienne d'Economique*, vol. 53, no 2, 2020, 1-21.

67 Influential German agronomists included Johann Heinrich von Thünen (1783-1850) Friedrich Aereboe (1865-1942) and Theodor Brinkmann (1877-1951). Ciriacy-Wantrup described his approach as 'analytically oriented institutional economics'. See Gerald Vaughn, "Siegfried von Ciriacy Wantrup and his Safe Minimum Standards of Conservation", *Choices: The Magazine of Food, Farm, and Resources Issues*, vol. 12, no 4, 1997, 1-4.

68 On relevant developments in mathematical economics see Thomas Turnbull, "A Transition in the Economics of North American Energy Resource Conservation", Stephen Gross and Andrew Needham (eds.), *Toward a New Energy*

otherwise, had a dynamically optimal use rate, depending on past, present, and future. Ciriacy-Wantrup therefore described conservation as the pursuit of the "time distribution of use rates (of resources) that maximizes the present value of the flow of (expected) net revenues".[69] As a resource became scarce, its untapped reserves would become more valuable, and as overall interest rates rose, increases to the exploitation cost would defer a degree of resource consumption to the future. In effect, this meant the work of conservation could be left to the market, an aggregate of constantly economising consumers.

28 An institutionalist, Zimmermann resisted the encroachment of econometrics. He saw the economist's faith in the free-market as "a far cry from the pleas for preservation" associated with the ideals of the first Roosevelt Presidency.[70] To his mind, Ciriacy-Wantrup had achieved "little more than a substitution of mathematical symbols for the solution of the real problems of policy making".[71] More generally, Zimmermann believed the onus to conserve exceeded the bounds of such narrow economic reasoning. To sacrifice the productivity of the present for the needs of prosperity was to invoke "a moral issue, giving rise to claims and counterclaims not subject to verification or proof."[72] Econometric abstractions ignored the complex constraints individual resources imposed. It was the properties of each resource that dictated the terms of their conservation. For example, petroleum was "fugacious"; it tended to dissipate once a reservoir was tapped, as a result of its chemical composition and the specific geology in which it was encased. Given such idiosyncrasies, as we shall see, petroleum conservation would initially go beyond the economising capacities of the market.[73]

Given his lack of faith in economic reasoning and his acknowledgement of the moral aspect of conservation, Zimmermann considered it an appropriate problem not just for the engineer and geologist but also for the social scientist. In an almost classical sociological formulation, he stated that "In the problem of conservation, the question of conflict between group and individual, between social and private interests, finds its most concrete expression."[74] So, far from endorsing a single position, Zimmermann would call for the study of the "*conservational* implication of efficiency". To do so, he admitted, would require not only an understanding of the future consequences of efficiency increases but also "the evaluation of all the effects" that followed from such an increase. Such evaluation could not be "limited to a mere segment". Amid the complex mesh of forces humanity found itself in, evidence that a conservation saving had been achieved would have to be "extremely complex and comprehensive".[75] 29

ELECTRIFICATION AS CONSERVATION

Over his lifetime Zimmermann had witnessed many metamorphoses in the semantics of conservation, fueling his observation that the term's "meaning changes with time and place".[76] Beyond physics, the term had first become prominent in North America as the mantra of a government-led wilderness and resource preservation movement. Following an agricultural depression, in 1908 Republican President Theodore Roosevelt spoke of foresight and restraint in land and resource use. His government requisitioned vast tracts of land to ensure "wise use", which invariably meant drawing on the principles of scientific management to rationally plan efficient resource use.[77] Alongside his dim view of the term conservation, Zimmermann considered the term wisdom vacuous in this context 30

History: Energy Transitions in Europe and America during the Twentieth Century (Pennsylvania: University of Pittsburgh Press, forthcoming).

69 Siegfried Ciriacy-Wantrup, *Resource Conservation: Economics and Policies* (University of California: Berkeley, 1952), 44.

70 Erich Zimmermann, *Conservation*, 30 (cf. note 65).

71 *Ibid.*, 31.

72 Erich Zimmermann, *World Resources and Industries*, 781 (cf. note 20).

73 *Ibid.*, 67.

74 *Ibid.*, 805.

75 Erich Zimmermann, *Conservation*, 29 (cf. note 65).

76 Erich Zimmermann, *World Resources and Industries*, 788 (cf. note 20).

77 Samuel Hays, *Conservation and the Gospel of Efficiency. The Progressive Conservation Movement, 1890-1920* (Pittsburgh: Pittsburgh University Press, 1959), 3.

and its ambiguities partly responsible for the eventual failure of the movement.[78] Roosevelt's government had been unwilling to restrict competition or intervene in economic activity, hence, as Jevons had warned, increased efficiencies had stimulated demand and accelerated consumption. As Zimmermann saw it, it was as if the first conservation movement recognized the relation between competition, overproduction, and waste, but "there the line of thought seemed to stop".[79]

31 Electrification illustrated this conflict between conservation and competition. Industry boosters had long made great claims of the coal-saving capacities of electrical power. In 1909, at the height of the Progressive Era conservation movement, Lewis Stillwell, chief engineer at the electricity company Westinghouse, had argued that electrical power be generated in larger and more efficient plant than those powered by steam, thereby consuming less coal per unit of power.[80] Zimmermann also pointed to the impressive sixty-six percent decrease in the amount of coal needed to generate a kilowatt hour of electricity which had been achieved between 1900 and 1929. But he cautioned that coal savings were only credible if overall use rates remained static.[81] As historian of electricity Julie Cohn later noted, in fact such efficiency increases had allowed electrical utilities to attract "more customers who used electricity at every hour of the day [...] to operate the plants at maximum efficiency and thus realize the per-unit savings of coal".[82] Jevons' familiar dynamic was in effect. In the long-run and at scale, electrification could seemingly contribute to an overall *increase* in coal consumption.[83] Not even hydro-electrical power could claim exemption from this dynamic. Zimmermann noted how the interconnection of remote sites where water fell with sufficient velocity acted to extend the transmission grid. In effect, water-derived electricity effectively subsidized and helped spread the means for fossil-derived electricity supply.[84]

PRODUCTION RATIONING

What of the specific conditions that petroleum imposed on its conservation? Zimmermann had asserted that the fugacity of petroleum meant its conservation required an approach that exceeded "economic imperatives".[85] A volatile mixture of oil, gas, and occasionally water, petroleum's molecular composition contributes to a buildup of pressure over geological timescales. When a drill strikes a reservoir, this ancient pressure acts as a propellant, forcing the petroleum to the surface.[86] Controlled expulsion of a well's "charge" remains critical to efficient petroleum extraction. If multiple operators raced to sink wells, reservoir pressure would be lost, and the average recovery rate could fall to just ten percent. The remaining petroleum would have to either be abandoned or pumped out at considerable cost.[87] By the time Zimmermann was living in Texas, the state's oil regulator had begun to impose policies that limited the rate of petroleum production, with the support of the Federal government. Zimmermann noted that these interventions were believed to raise the average reservoir recovery rate by as much as seventy percent.[88] 32

What were the origins of this compact? Contrary to its buccaneering image, the oil industry had in fact entered into a regulatory agreement with the U.S. government, sanctioning a degree of centralized control. At the Federal level, the need for such intervention had first emerged under President Warren Harding, who had formed a 33

78 Erich Zimmermann, *World Resources and Industries*, 790 (cf. note 20).
79 *Ibid.*, 785.
80 Lewis B. Stillwell, "Electricity and the Conservation of Energy", *Transactions of the American Institute of Electrical Engineers*, vol. 18, no 1, 1909, 165.
81 Erich Zimmermann, *World Resources and Industries*, 569 (cf. note 20).
82 Julie Cohn, *The Grid: Biography of an American Technology* (Massachusetts: MIT Press, 2017), 352.
83 Erich Zimmermann, *World Resources and Industries*, 569, 788 (cf. note 20).
84 *Ibid.*, 569-570.
85 *Ibid.*, 808.
86 Erich Zimmermann, *Conservation*, 58, 63-64 (cf. note 65).
87 *Ibid.*, 432.
88 *Id.*

Federal Fuel Administration in 1917 to oversee the maintenance of petroleum and coal during the war.[89] Afterward, still facing shortages, the organisation's moderate successes encouraged President Calvin Coolidge to create a peace-time commission in 1924. The resulting Federal Oil Conservation Board (FOCB) was tasked with trying to ensure petroleum's long-term availability by formulating means "to conserve oil in the ground".[90] But wartime shortages were soon superseded by the discovery of large new oil fields. So, by the late 1920s, concerns had switched from scarcity to overproduction. The FOCB were now worried about petroleum's "cheapness, which in turn leads to wastefulness and disregard".[91]

34 Faced with a glut of low-cost oil, the FOCB began to promote the idea of nationwide rationing of the overall rate of petroleum production, to ensure supply increased in line with future demand rather than exceeding it. Despite initial opposition from industry, in the early 1930s, facing ruinous prices after the discovery of a vast oilfield in East Texas, the recently formed American Petroleum Institute (API) gradually warmed to the idea, recognising that Federal interest in conserving their product might help resuscitate its price.[92] In East Texas, where the discovery had reduced the cost of a barrel of oil to just eight cents, prices had been increased by the industry's regulator at the state level, the Texas Railroad Commission, which imposed limits on the production rate of individual wells, by force when needed.[93]

35 In 1933, under the sweeping reforms of President Franklin Roosevelt's New Deal, specifically the National Industrial Recovery Act (NIRA), the FOCB was first given power to oversee petroleum production rationing (termed "pro-rationing") in all oil producing states. However, in 1935 the Supreme Court ruled that such Federal control conflicted with anti-trust legislation. New legislation was drafted calling on individual states to oversee their own rate of petroleum production rates to avoid wasteful gluts and price gouges. All oil producing states bar California joined the resulting Interstate Oil Compact Commission.[94] The Federal government's role was significantly limited. It now simply issued monthly forecasts of expected demand, which state regulators were to consider as guidelines for their respective rates of petroleum production.[95]

It fell to the Federal Bureau of Mines to delimit monthly levels of petroleum demand. To make this forecast, they began with the number of registered automobiles and their average gasoline consumption. Added to this, the amount of heating oil needed was estimated according to the season. These two variables could then be calculated in crude oil equivalencies by multiplying them by a number reflecting the average efficiency of American refineries.[96] Companies could then appeal to State conservation agencies for the right to produce a proportion of this forecast demand.[97] For industry majors, well placed to lobby state regulators, this arrangement meant their petroleum could be sold at a price approximating a hypothetical equilibrium between supply and demand, even when this deviated from the reality of the situation, thereby ensuring healthy profits for the industry under the aegis of conservation.[98] 36

89 John Clark, *Energy and the Federal Government: Fossil Fuel Policies, 1900-1946* (Urbana and Chicago: University of Illinois Press, 1987), 100-101.

90 Federal Oil Conservation Board, Complete Record of Public Hearings, 1926, USGPO, IX.

91 *Ibid*., 11.

92 Erich Zimmermann, *Conservation*, 252 (cf. note 65).

93 Edward Constant, "Cause or Consequence: Science, Technology and Regulatory Change in the Oil Business in Texas, 1930-1975", *Technology and Culture*, vol. 30, no 2, 1989, 432.

94 *Ibid*., 38-39.

95 FOCB, *Complete Record*, 158-159 (cf. note 90).

96 Alfred White, "The Bureau of Mines Forecasts of Demand for Motor Fuel and Crude Oil", in National Resources Committee, Energy Resources and National Policy. 76th Congress, House Document 160 (Washington: USGPO, 1939), 403.

97 The Yale Law Journal Inc., "Proration of Petroleum Production", *The Yale Law Journal*, vol. 51, no 4, 1942, 608-628.

98 Matthew Huber, "Enforcing Scarcity: Oil, Violence, and the Making of the Market", *Annals of the Association of American Geographers*, vol. 101, no 4, 2011, 816-826.

37 In Zimmermann's view, pro-rationing meant "the petroleum industry had become ardent believers in what they chose to call conservation".[99] Writing in 1957, he acidly remarked that as a result. Conservation had become a "business proposition" rather than a government crusade. In the same stroke. The term no longer meant government intervention to avert wasteful competition, but light-touch regulation of the rate of petroleum production:

38 The meaning of conservation thus merges imperceptibly into that of the interdependent concepts of efficiency and economy, and in doing so, changes from a concept alien, if not hostile, to capitalistic thinking to one that fits painlessly into the ideology of capitalism.

39 But what were the conservational implications of this metamorphosis? Zimmermann left this question unanswered. But two decades later an oil industry lawyer gleefully asserted that, given the increased rate of extraction pro-rationing afforded in the long term, this policy had meant fifty percent *more* oil had been recovered than would have otherwise been achieved in an unregulated market.[100]

THE VEXED PROBLEM OF DEMAND

40 Writing in the 1950s, a period of historically unprecedented increases in the rate and scale of energy consumption,[101] Zimmermann lamented the care that had been taken to conserve oil at the production end when the energy consumer could still behave with careless profligacy. Nothing better demonstrated North America's commitment to thoughtless energy consumption than the heavy, under-occupied "gasoline guzzler" automobiles which increasingly populated the nation's highways. Was such freedom to waste energy "the crowning glory of all this conservation effort"?[102] In the U.S., where material and spiritual prosperity were seemingly intractably linked, he feared any attempt to constructively reduce energy consumption would provoke accusations that the government were interfering in the rights of the sovereign consumer. With heavy irony, and the wry perspective of a European émigré, he remarked that to do so "would be the end of the American way of life, the end of the American dream!"[103]

In fact, the impetus to address energy demand rather than supply would come from outside the U.S. rather than within. To understand how, it is necessary to look again at the work of the FOCB. In 1929 they had surveyed the global availability of oil and had concluded that "the development of foreign fields, through technical assistance and the further investment of American capital, would seem to be a logical conservation measure".[104] Concession agreements agreed between Anglo-American oil companies and oil-rich nations from Venezuela to Saudi Arabia in the decades after World War One had ensured that a growing stream of cheap foreign oil was being channeled into the U.S. and other developed nations. As a result, the FOCB believed a corresponding proportion of domestic reserves would be left in the ground. However, quite the opposite occurred. Between 1938 and 1955, the import of foreign oil grew from 54 to 454 million additional barrels of oil a year. While at the same time, the production of domestic crude doubled in the same seventeen-year timeframe, growing from 1.2 to 2.4 billion barrels per year.[105] An expansionist dynamic, enabled by the development of a planet-spanning infrastructure of tankers, canals, and pipelines, helped mitigate distance and drew in vast quantities of oil at a low cost.[106] 41

99 Erich Zimmermann, *World Resources and Industries*, 801 (cf. note 20).
100 Robert Hardwicke, "Adequacy of Our Mineral Fuels", *Annals of the American Academy of Political and Social Science*, vol. 281, no 1, 1952, 63.
101 Will Steffen, Wendy Broadgate, Lisa Deutsch, Owen Gaffney, Cornelia Ludwig, "The trajectory of the Anthropocene: The Great Acceleration", *The Anthropocene Review*, vol. 2, no 1, 2015, 81-98.
102 Erich Zimmermann, *Conservation*, 47 (cf. note 65).
103 *Ibid.*, 48.
104 US Senate, Regulating Importation of Petroleum and Related Products. Hearing before Committee on Commerce, 71st Congress. USGPO, 1931, 278.
105 Erich Zimmermann, *Conservation*, 351, 368 (cf. note 65).
106 Donald Worster, *Shrinking the Earth: The Rise and Decline of American Abundance* (Oxford: Oxford University Press, 2016), 142-143.

42 Demonstrating the retrenchment of national thinking, Zimmermann considered the importation of foreign oil a perfectly acceptable form of conservation.[107] He would pass away in 1961, meaning the subsequent and dramatic shift in the logics of energy resource conservation would not be subject to his analysis.[108] Accordingly, our story can continue only by extending his critical approach to the notion of energy resource conservation as it developed beyond his lifetime. In doing so, we will see how the fallacious use of oil importation to conserve domestic petroleum created the conditions from which a new, demand centered approach to energy saving would emerge.

MIDDLE EASTERN PRORATIONING

43 Of course, what looked like conservation to the Global North looked like wasteful expropriation to the oil-rich Global South. In 1960 the Organization of Petroleum Exporting Countries (OPEC) was formed by five major oil producing states, who recognized that their oil was a lever to fight back against exploitative concessionary agreements.[109] Agreed earlier in the century, these agreements had robbed developing nations of their right to impose taxes on oil, effectively allowing oil companies to act as sovereign states within their own borders.[110] Recognizing the iniquity of this arrangement, a counter-movement had formed which could be broadly termed “petronationalist” in so far as its objective was to channel the wealth afforded by oil to furthering the petrostates of the Global South rather than to the benefit of Northern, developed nations.[111]

44 In 1968 OPEC outlined its aims. It wanted its member states to participate in foreign oil companies’ decision-making regarding taxation and to ensure they had a role in influencing the agreed “posted” oil price. Often forgotten is that OPEC’s third aim was to ensure the “efficient development and conservation of petroleum.”[112] Attendees at the Sixth Arab Petroleum Congress in 1967 had been told that the “conservation of natural resources and pro-rationing of its production are an American invention”.[113] Its members were well aware that they could restrict their rate oil production, in order to raise prices, just as had been done in Texas and later across the U.S.[114] OPEC’s adoption of the logics of production rationing was no coincidence. Sheikh Tariki, the Saudi Petroleum Minister, had studied geology at the University of Texas.[115] While Venezuela’s government had hired Texas Railroad Commission Chief Engineer Jack Baumel to help implement pro-rationing in the 1950s.[116] But these conservation initiatives went beyond mere imitation. At a meeting between OPEC members in Tehran in 1971, the president of Iran’s National Oil Company Reza Fallah had suggested oil “should not be burnt up to generate energy, but conserved only for advanced technologies, as in the petrochemical industry”.[117]

45 As is well known, a more radical group of Arab member states formed a more radical Organization of Arab Petroleum Exporting Countries (OAPEC), who in October 1973 imposed an embargo on the export of oil to countries seen as sympathetic to Israel.[118] This did not stop Ali

107 Erich Zimmermann, *Conservation*, 354 (cf. note 65).
108 Stephen McDonald, “Erich W. Zimmermann”, 157 (cf. note 26).
109 Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela. Later joined by Qatar (1961), Indonesia (1962), Libya (1962), UAE (1967), Algeria (1969), Nigeria (1971), Ecuador (1973), Gabon (1975). On membership see Euclid A. Rose, “OPEC’s dominance of the Global Oil Market: The Rise of the World’s Dependency on Oil”, *Middle East Journal*, vol. 58, no 3, 2004, 424-443.
110 Giuliano Garavini, *Rise*, 31 (cf. note 11).
111 *Ibid.*, 39, 65.
112 John Vafai, “Production Control in the Petroleum Industry: A Critical Analysis”, *Santa Clara Lawyer*, vol. 189, 1971, 189-228.
113 *Ibid.*, 200.
114 David Prindle, *Petroleum Politics and the Texas Railroad Commission* (Texas: University of Texas Press, 1981); Giuliano Garavini, Rise (cf. note 11).
115 Fiona Venn, *Oil Crisis* (London, Longman, 2006) 36.
116 David Prindle, *Petroleum Politics*, 60 (cf. note 114); Ramón Rivas Aguilar, *Venezuela, apertura petrolera y geopolítica, 1948-1958* (Bogotá: Universidad de los Andes. 1999), 73.
117 Giuliano Garavini, *Rise*, 224 (cf. note 11); Fadhil Chalabi, *Oil Policies, Oil Myths: Observations of an OPEC Insider* (London: I.B. Taurus and co. ltd., 2010), 111-112.
118 Giuliano Garavini, *Rise*, 176 (cf. note 11).

Attiga, Libyan Secretary General of OAPEC, from appropriating the language of American conservationism to justify their actions. He later recast the embargo as a "wise decision" which had not only saved vast quantities of oil but also given "rise to an intensive worldwide search for appropriate energy policies".[119] Attiga's promotion of a vision of altruistic resource independence for both oil producer and consumer was timely. The globally influential and well-orchestrated *Limits to Growth* study, from the Club of Rome, had warned of societal collapse as a result of scarce resources.[120] As the global south effectively adopted something akin to U.S.-style pro-rationing, the growth-dependent logics of oil consuming states was shaken both by the embargo and the specter of long-term geophysical scarcity. In response to these shocks, the U.S. would begin to conserve energy from *within*, by addressing the vexed problem of energy demand.

CLOSING THE SYSTEM

46 In 1957 Zimmermann had hoped the "problem of inter-fuel relations and the still tougher problem of end uses" would eventually be addressed.[121] Not without irony, it took an external threat for North America's policy makers to begin to address energy consumption. From 1971 onward, the National Science Foundation's Research Applied to National Needs (RANN) program channeled funds into America's universities, national, and industrial laboratories in an attempt to alleviate various developmental problems, not least the seemingly inexorable increase in demand for energy that characterized the postwar period.[122] In early 1973, before the embargo, the largest tranche of RANN funding was earmarked for research into alternative forms of energy supply and determining the causes of demand.[123] As a more general energy crisis emerged, the years 1975 to 1985 were marked by unprecedented Federal investment in energy research.[124] The full story of this reorientation cannot be entered into here, but it will suffice to say that a wide range of disciplines, from physics to sociology, would take part in an indirect struggle to secure adequate energy supplies.[125] Science, as Zimmermann would no doubt have predicted, seemingly held the answer to the energy crisis.

New approaches to fuel efficiency, non-use, 47
substitution, and even reforms to the structure of the energy economy would find legitimacy under a set of science-derived policies that were concerned with saving energy at its point of use rather than at the site of its production. Central to this achievement was an idea. North America could become, in some sense, an energy autarky: a closed-system in which domestic energy supplies were consumed with ever increased efficiency. Under President Richard Nixon's *Project Independence*, economist Eric Zausner developed an econometric model which demonstrated how small increases in the efficiency of energy use, in aggregate, could allow North America's economic growth rate to decouple from growing energy consumption, eventually allowing the nation to become entirely energy independent by 1980.[126] Such thinking was reinforced by computer simulations which recast the energy economy as a closed system, in which energy demand could be manipulated as easily as lines of a computer program.[127] In such closed models, the conservational implications of efficiency increases could be clearly quantified.

119 Ali Attiga, "The Impact of Energy Transition on the Oil-Exporting Countries", *Journal of Energy and Development*, vol. 4, no 1, 1978, 41-48.
120 Giuliano Garavini, *The Rise*, 214-215 (cf. note 11).
121 Erich Zimmermann, *Conservation*, 388 (cf. note 65).
122 Richard Green, Wil Lepkowski, "A Forgotten Model for Purposeful Science", *Issues in Science and Technology*, vol. 22, no 2, 2006, 69-73.
123 'J.W', "NSF gets a record $768 million", *Science*, vol. 185, no 4156, 1030.
124 Daniel Kammen, Gregory Nemet, "Reversing the Incredible Shrinking Energy R&D Budget", *Issues in Science and Technology*, vol. 22, no 1, 2005, 84-88.
125 See Thomas Turnbull, *Paradox to Policy*, Ch. 4-6 (cf. note 14).
126 Andrew McKillop, "The Myth of Decoupling", in Andrew McKillop and Sheila Newman (eds.), *The Final Energy Crisis* (London: Pluto Press, 2005), 209.
127 Paul Edwards, *Closed World: Computers and the Politics of Discourse in Cold War America* (Massachusetts: MIT Press, 1994), 341.

48 Such idealised conceptions of energy demand were popularized by physicist-turned-environmentalist Amory Lovins who, toward the end of the decade, admitted having "shamelessly recycled" vast amounts of Federally funded research to demonstrate that U.S. energy demand could be reduced by thirty to forty percent by century's end.[128] RANN funded research had helped recast the energy consumer as the ultimate conservation actor, a move unimaginable to Zimmermann in 1957. To do so, as figures from Hotelling to Ciriacy-Wantrup had long suggested, it was argued that the energy economy would have to more closely cohere to an idealized conception of a free market. In his influential book, *Soft Energy Paths,* Lovins argued that energy could best be saved by harnessing the calculative capacities of the consumer, a decisionmaker whose manipulation of "a myriad of small devices and refinements" allowed for fine-grained informational feedback on energy demand. For this to work, he claimed, "institutional barriers", the very policies which in Zimmermann's time had been considered vital means of conservation, had to be removed.[129]

49 In the 1970s, the configuration of U.S. energy policy was somewhat contradictory. Nixon's government had introduced emergency oil and gas price controls in 1971, in a bid to diffuse forecast oil price rises. While in 1972, as part of *Project Independence*, the pro-rationing system had been hastily scrapped in an attempt to increase domestic petroleum production.[130] Looking to institute a more coherent program of market liberalization, in 1981 incoming President Ronald Reagan famously argued that the energy problem was not "a shortage of oil: so much as a "surplus of government".[131] His government scrapped emergency price controls in a move, it was claimed, that would save between 50 to 100 thousand barrels of oil per day thanks to consumption deterring price rises.[132] Far from mere symbolic changes, as some claim[133], the science and politics of energy saving had undergone a dramatic transition. The systemic approach to saving energy was clearly of consequence to the organizational principles of U.S. energy economy. The liberalization of the energy markets which would take place across the global North was in part justified in accordance with a belief in the conservative capacities of the market.

CONSERVATION ENCOUNTERS CLIMATE

The problem with this closed system conception 50 was that the consequences of fossil energy consumption exceeded such abstraction. As early as 1896, physical chemist Svante Arrhenius had surmised that the carbon emitted by fossil fuels could bind with atmospheric oxygen, creating a blanket of carbon dioxide that would retain a proportion of the sun's heat. Climatologists largely ignored the idea, believing that oceans could sequester vast quantities of carbon dioxide and that atmospheric water vapour made a greater contribution to heat retention.[134] It fell to steam power engineer Guy Stewart Callendar to resuscitate the idea. In 1938, he presented a paper to Britain's sceptical Royal Meteorological Society in which he empirically demonstrated the warming effect that the 150,000 million tonnes of carbon dioxide emitted in the past fifty years had engendered. Unexpectedly, from our perspective, Callendar hoped to accelerate this warming to delay the return of "deadly glaciers".[135]

128 Amory Lovins, *Soft Energy Paths: Toward A Durable Peace* (London: Friends of the Earth International, 1977), 147.
129 *Ibid*., 19.
130 Neil De Marchi, "Energy Policy under Nixon: Mainly Putting Out Fires", in Craufurd D. Goodwin (ed.), *Energy Policy in Perspective: today's problems, yesterday's solutions* (Washington DC: Brookings Institution, 1981), 497.
131 Michael Schaller, *Right Turn: American Life in the Reagan-Bush Era, 1980-1992* (New York/Oxford: Oxford, 2007), 28.
132 Erich Zimmermann, *World Resources and Industries*, 48 (cf. note 20).
133 Rüdiger Graf, *Oil and Sovereignty: Petro-Knowledge and Energy Policy in the United States and Western Europe in the 1970s* (Berlin: Berghahn Books, 2014), 186.
134 The following largely derives from Spencer Weart's *The Discovery of Global Warming* (Cambridge Mass: Harvard University Press, 2008).
135 Guy Stewart Callendar, "The Artificial Production of Carbon Dioxide and its Influence on Temperature" (1938), in Libby Robin, Sverker Sörlin, Paul Warde (eds.), *The Future of Nature. Documents of Global Change* (Connecticut: Yale University Press, 2013), 334.

51 Callendar's thesis was received with scepticism. It was only in 1950 that Canadian physicist Gilbert Plass made use of infrared spectroscopy to reveal a far dryer stratosphere than previously thought. The role of carbon dioxide in intercepting solar radiation became more tenable. Worse still, in 1958 oceanographer Roger Revelle discovered that oceans sequestered ninety percent less carbon dioxide than assumed. The final key came thanks to Revelle's employee, geochemist Charles Keeling, who accurately measured atmospheric carbon dioxide for the first time using infrared. Within two years, he had found clear increases in global mean temperature. Keeling saw no benefit in a warming world and joined forces with the nascent environmental movement of the 1960s, warning of the risks of glacier melt and sea level rise. His advocacy gradually filtered into public consciousness and an awareness that neither sea nor sky could absorb industrialism's excesses spread. [136]

52 By the 1980s, in contrast to the 1970s, it was clear that the greater risk was not so much a lack of fossil fuels so much as the climate's limited capability to accommodate the effects of their consumption. Given that this constraint was planetary, there was no longer an elsewhere to which the consequences of fossil fuel use could be outsourced, nor a future within which the sacrifice of conservation could be deferred. But for believers in the resource-conserving capacities of increased energy efficiency, this simply meant the closed system approach to saving energy should become a global endeavour.[137] Writing in 1981, energy analyst Amory Lovins was amongst the first to promote the optimistic idea that, simultaneously, scarce fuels could be conserved, industrial productivity increased, and climate change fought against.[138] Within the closed system of Earth's atmosphere, it was argued, energy efficiency would not only reduce the rate of fossil fuel consumption, it could also reduce carbon dioxide emissions.[139]

Critics saw no such benefit. In 1980, Iraqi-American economist Daniel Khazzoom criticised efficiency-based energy conservation, and its advocates who believed such a dynamic could be "mechanically" translated "from the laboratory to society".[140] In Jevons's formulation, he argued that such reasoning failed to account for the role of price as a demand accelerant. A second scholar, Leonard Brookes, former chief economist at the United Kingdom's Atomic Energy Authority, directed the same argument at those who believed climate change could be mitigated by increased energy efficiency. Citing Jevons, Brookes claimed increased energy efficiency would cause "a reduction in its implicit price with all that that implies for demand". If action were needed to fight climate change, a threat that Brookes was sceptical about, then he argued that this should involve "specific limitations on CO_2 emissions" or "worldwide agreement to place heavy taxes on the offending fuels."[141] 53

As policies to mitigate climate change became more widespread, in 1992 economist Harry Saunders termed the renewed doubt in the conservational implications of energy efficiency that were provoked, the "Khazzoom-Brookes postulate". As he noted, the widespread acceptance of an efficiency-based approach to conservation, which had taken hold in the 1970s, meant that once orthodox principles of neoclassical economics, namely the idea that efficiency increases induce demand, now looked like a "disturbing assault" on conventional wisdom.[142] 54

136 Spencer Weart, "The Discovery of the Risk of Global Warming", *Physics Today*, vol. 50, no 134, 1997, 39.
137 Bill Keepin, Gregory Katz, "Greenhouse warming: comparative analysis of nuclear and efficiency abatement strategies", *Energy Policy*, vol. 16, no 6, 1988, 538-561.
138 Amory Lovins, Florentin Krause, Wilfrid Bach, Hunter Lovins, *Least-Cost Energy: Solving the CO2 problem* (Baltimore: Brick House Publishing Company, 1981).
139 David Rose, Marvin Miller, Carson Agnew, "Reducing the problem of global warming", *Technology Review*, vol. 87, no 4, 1984, 48-57.
140 Daniel Khazzoom, "Economic Implications of Mandated Efficiency in Standards for Household Appliances", *Energy Journal*, vol. 1, no 4, 1980, ft. 5., 22.
141 Leonard Brookes, "The greenhouse effect: the fallacies in the energy efficiency solution", *Energy Policy*, vol. 18, no 2, 1990, 199–201.
142 Harry Saunders, "The Khazzoom-Brookes Postulate and Neoclassical Growth", *Energy Journal*, vol. 13, no 4, 1992, 131-132.

A science of energy resource conservation had developed which seemingly challenged the precepts of orthodox economics while also integrating aspects of economistic thinking. Amid this epistemological confusion, the conservational implications of increased energy efficiency have yet to be conclusively determined. A recent study explains the effects of energy efficiency increases as "an emergent property of a complex system".[143] Another study asserts that "the extent of rebound effects is, in practice, always an empirical issue".[144] The more data, the more evidence of rebound which can be found. In a sentiment Zimmermann would have applauded, another still argues that "the many impacts rippling through an economy" as a result of an increase in energy efficiency exceed the confines of economic reasoning and would do better to engage with psychology and sociology, amongst other disciplines.[145]

55 As it stands, the pursuit of energy efficiency remains based upon initiatives at the national or supranational scale, such as that of the European Union or signatories to the Paris Treaty. While commendable efforts have been made, such initiatives fail to fully account for the planetary implications of energy efficiency savings, in terms of the inducement of rebound effects and the degree to which supposed decoupling of energy and economic growth discounts the energy expended in producing imported goods.[146] Perhaps the growing ubiquity of digitalization can offer a suitable metrological infrastructure to better correlate data on energy consumption and atmospheric change at this scale, but the political will to act on such evidence remains absent.[147] At root, it seems a fundamental incommensurability remains between those who favor an interventionist approach to conservation and those who place their faith in the energy-conserving capacities of a free market. As Zimmermann would likely have guessed, a century of effort has failed to resolve this fundamental question. The dynamics of saving energy remain contested, and in this state of incommensurability they require sustained historical and humanistic inquiry.

CONCLUSION

56 By revisiting and extending the insights of resource economist Erich Zimmermann, this paper has sought to formalize a subfield of energy historical inquiry focused upon the contested notion of energy saving. Like conventional "material" transitions, attempts made to save and or use energy with greater efficiency have resulted in changes in the composition, pattern, or structure of societal energy use. Which is to say, past energy saving efforts, successful or otherwise, have created new constellations of energy use and their attendant material bases and infrastructures. One need only think of the growth of electrification in pursuit of coal conservation. Alongside which, the clear shift from an interventionist approach to energy saving to one predicated upon consumers acting efficiently in an unimpeded market clearly constitutes an important if largely unacknowledged transition. As the meaning of conservation has changed, its expected means of implementation has shifted from the state and industry to the consumer acting in a market. As a result, we are currently using policies to extend the supply of (artificially) scarce energy resources, developed in the 1970s in an attempt to reduce fossil fuel emissions. This presents a mismatch between

143 Frank Geels, Benjamin Sovacool, Steve Sorrell, "Of emergence, diffusion and impact: a sociotechnical perspective on researching energy demand", in Kirsten Jenkins, Debbie Hopkins (eds.), *Transitions in Energy Efficiency and Demand* (Abingdon: Routledge, 2019), 27.

144 Alan Grant, Michelle Gilmartin, Peter G. McGregor, J. Kim Swales, Karen Turner, "Modelling the Economy-Wide Rebound Effect", in Horace Herring, Steve Sorrell (eds.), *Energy Efficiency and Sustainable Consumption: The Rebound Effect* (London: Palgrave Macmillan, 2009), 72.

145 Reinhard Madlener, Karen Turner, "After 35 years of rebound research in economics", in Tilman Santarius, Hans Jakob Walnum, Carlo Aall (eds.), *Rethinking Climate and Energy Policies: New Perspectives on the Rebound Phenomenon* (Switzerland: Springer, 2016), 32.

146 Andreas Malm, "China as Chimney of the World: The Fossil Capital Hypothesis", *Organization & Environment*, vol. 25, no 2, 2012, 146-177.

147 Paul Edwards, "Knowledge Structures for the Anthropocene", *The Anthropocene Review*, vol. 4, no 1, 2016, 34-43.

policy and objective. As the notion of unburnable carbon demonstrates, hydrocarbons are overly abundant. As such, climate change mitigation requires a new approach toward energy saving which focuses upon dramatically reducing fossil fuel emissions in line with agreed limits to atmospheric concentrations of carbon dioxide. Such a goal will likely require large scale intervention in energy markets, a requirement that history suggests is not unthinkable.

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Journal of Energy History
Revue d'histoire de l'énergie

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POST DATE
20/03/2020
ISSUE NUMBER
JEHRHE #4
SECTION
Special issue
THEME OF THE SPECIAL ISSUE
Transitions in Energy History. History in Energy Transitions
KEYWORDS
Renewable, Transition, Knowledge, Geopolitics, Development
DOI
in progress

TO CITE THIS ARTICLE
Duccio Basosi, "Lost in transition. The world's energy past, present and future at the 1981 United Nations Conference on New and Renewable Sources of Energy", *Journal of Energy History/Revue d'Histoire de l'Énergie* [Online], n°4, published 20 March 2020 URL: energyhistory.eu/en/node/182.

Lost in transition. The world's energy past, present and future at the 1981 United Nations Conference on New and Renewable Sources of Energy

Abstract

After four years of preparations, in the summer of 1981 Nairobi hosted the United Nations Conference on New and Renewable Sources of Energy. A diplomatic exercise bringing together more than one-hundred governments from North and South and East and West, the conference did not produce either startling or binding decisions. However, the characteristics of the meeting were also such that the conference's final Programme of Action can be seen as a sort of *summa* of official thinking about energy at the beginning of the 1980s. After briefly presenting the making and the outcomes of the Nairobi conference, the article focuses on both the novelty and the limitations of the language of "energy transition" that was adopted on the occasion.

Plan of the article

ISSN 2649-3055

INTRODUCTION

1 Scholars have long dealt with the changes in the thinking about energy after the "oil shocks" of the 1970s.[1] This essay contributes to the literature by focusing on the United Nations Conference on New and Renewable Sources of Energy that was held in Nairobi in the summer of 1981. Usually the object of a short reference in the histories of renewable energies, the Nairobi conference is seldom mentioned in more general works on the UN or energy history. Such lack of attention is in many ways understandable: a diplomatic exercise bringing together more than one-hundred governments (not to mention the dozens of international organizations and UN agencies which took part in the works), the conference did not produce either startling or binding decisions. As is shown below, as far as the promotion of "new and renewable" sources of energy was concerned, to many observers the conference outcomes proved even below their already low expectations. Nevertheless, the Nairobi conference has at least two main reasons of interest. On the one hand, it was virtually the only attempt to tackle "energy" at the level of the entire "international community" – North and South, East and West – in the context of the deep changes produced in the international political economy by the hikes in oil prices of 1973 and 1979-1980. While its formal agenda included only the "new and renewable" sources of energy (a quite ambiguous terminology, by the way, as I will discuss below), *de facto* Nairobi was the only truly global forum at which governments debated the energy past, present and future of the planet in the wake of the "oil shocks". The making and outcomes of the conference are discussed in sections one and two below, on the basis of UN official documents, newspaper commentaries, and secondary literature.

On the other hand, it is precisely from its global nature that derives the second reason of interest of the Nairobi conference: the conference's resulting "Programme of Action", adopted by consensus, can be seen as a sort of *summa* of the official energy thinking of the time, a minimum common denominator of what was acceptable to all parties involved. Thus, a critical analysis of its language allows us to grasp how the world's energy situation was conceptualized in global official public discourse at the beginning of the 1980s. The third section of the article highlights how the Programme (and the conference works more broadly) reflected the change in the language about energy that had occurred during the 1970s, one for which the world's condition needed to be understood in terms of an "energy transition".[2] The adoption of such language in Nairobi provided a kind of stamp of global officialdom to the greater awareness of the historical contingencies governing energy which characterized the post-1973 years. But, as I will discuss in sections four and five, this also came with a set of ambiguities and contradictions that made the phrase "energy transition" little more than a buzzword good for any use. The sixth section concludes. 2

THE NAIROBI CONFERENCE AND ITS ORIGINS

Between 10 and 21 August 1981, the Kenyatta International Convention Centre in Nairobi hosted more than 4000 delegates from 125 countries and dozens of international organizations 3

1 A necessarily incomplete list of general references includes Jean-Claude Debeir, Jean-Paul Deléage and Daniel Hémery, *Histoire de l'énergie* (Paris: Flammarion, 2013 [original ed. 1986]), chap. 7; Vaclav Smil, *Energy in World History* (Boulder: Westview, 1994), chap. 6; Fiona Venn, *The Oil Crisis* (London: Routledge, 2002); Giuliano Garavini, *The Rise and Fall of OPEC in the Twentieth Century* (Oxford: Oxford University Press, 2019), chap. 4-6.

2 This aspect of the energy debates of the 1970s has been emphasized in Christophe Bonneuil and Jean-Baptiste Fressoz, *The Shock of the Anthropocene. The Earth, History, and Us* (London: Verso, 2016), chap. 5; Kathleen Araújo, *Low Carbon Energy Transitions. Turning Points in National Policy and Innovation* (Oxford: Oxford University Press, 2018); Duccio Basosi, "A Small Window. The Opportunities for Renewable Energies from Shock to Counter-Shock", *in* Duccio Basosi, Giuliano Garavini and Massimiliano Trentin (eds.), *Counter-Shock. The Oil Counter-Revolution of the 1980s* (London: IB Tauris, 2018). On the notion of "energy transition" in general: Jean-Baptiste Fressoz, "Pour une histoire désorientée de l'énergie", *Entropia*, vol. 15, 2013; Vaclav Smil, *Energy Transitions: History, Requirements, Prospects* (Santa Barbara: Praeger, 2010); Bruce Podobnik, *Global Energy Shifts: Fostering Sustainability in a Turbulent Age* (Philadelphia: Temple University Press, 2006), chapter 6.

for the United Nations Conference on New and Renewable Sources of Energy.[3] This was not the first UN conference entirely dedicated to energy (as sometimes mistakenly reported), but both the number of participants and the level of the delegations put it on a wholly different plane from its predecessor, held in Rome exactly twenty years earlier.[4] The UN Secretary General Kurt Waldheim opened the conference with an inspired speech, followed by a similar performance by Kenya's strongman Daniel arap Moi.[5] Four foreign heads of state and government, including India's Indira Gandhi and Canada's Pierre Trudeau, addressed the delegates, while other heavy-weights of world politics, including US President Ronald Reagan, China's Premier Zhao Ziyang and Mexican President José López Portillo, sent well-wishing messages.[6] Many national delegations were headed by ministers. Outside the conference center, local social movements – such as Wangari Maathai's Green Belt Movement – as well as representatives from international social movements and NGOs staged street demonstrations and held a parallel forum aimed at exerting pressure on the delegates for the adoption of clear objectives and financing schemes concerning both the promotion of "new renewables", such as solar and wind power, and the safeguarding of "old renewables", such as the forests which had come increasingly under threat in the context of the less affordable prices of petroleum products.[7]

"Energy" had quickly climbed up the interna- 4
tional agenda in the aftermath of OPEC's 1973 quadrupling of oil prices.[8] With oil then supplying roughly 50% of the world's total commercial energy, OPEC governments presented their organization as the developing countries' spearhead to redress the world's economy in their favor.[9] Their success was on display the following year, when a cohesive common front of Third World governments – oil importers and exporters alike – obtained the adoption by the UN General Assembly of two resolutions promoting the establishment of a New International Economic Order (NIEO).[10] As far as the capitalist "West" was concerned, in the same year 1974 a group of seventeen countries led by the United States founded the International Energy Agency (officially to promote mutual cooperation in the field, and possibly to serve as a counterweight to OPEC's power).[11] Starting in 1975, sections on "energy" of various length also featured regularly in the final communiques of the yearly summits of the seven most industrialized capitalist countries (the so-called G7, itself a product of

3 The list of the governmental delegations in attendance is in the official conference report: United Nations (UN), *Report of the United Nations Conference on New and Renewable Sources of Energy, Nairobi, 10 to 21 August 1981* (New York: United Nations, 1981), 48. As to the number of delegates, it was "about 5000" according to Nairobi's *Daily Nation*, while both *Le Monde* and the *Frankfurter Allgemeine Zeitung* gave the more conservative estimate of 4000. Respectively: "Sell us cheap oil, says Moi", *Daily Nation*, 11 August 1981; "Les deux crises", *Le Monde*, 11 August 1981; "Energie-Konferenz", *Frankfurter Allgemeine Zeitung*, 10 August 1981.

4 While featuring an address by Pope John XXIII, the Rome conference had had a mainly "technical" and academic character, and had seen the attendance of "447 persons from seventy-four countries and territories": UN, *New Sources of Energy and Energy Development. Report of the United Nations Conference on New Sources of Energy, Rome, 21 to 31 August 1961* (New York, United Nations, 1962).

5 UN, *Report*, 52-55 (cf. note 3).

6 *Ibid.*, 56, 110-114.

7 "More light than heat", *New Scientist*, 20 August 1981, 460; "Les pays en développement s'élèvent contre le prix excessif du pétrole", *Le Monde*, 12 August 1981. Also: Wangari Maathai, *Replenishing the Earth: Spiritual Values for Healing Ourselves and the World* (New York: Doubleday, 2010), 97

8 Recent assessments are in Elisabetta Bini, Giuliano Garavini and Federico Romero (eds.), *Oil Shock: The 1973 Crisis and its Economic Legacy* (London: IB Tauris, 2016).

9 Christopher Dietrich, *Oil Revolution. Anticolonial Elites, Sovereign Rights, and the Economic Culture of Decolonization* (Cambridge, UK: Cambridge University Press, 2017); Giuliano Garavini, "From Boumedienomics to Reaganomics: Algeria, OPEC, and the International Struggle for Economic Equality", *Humanity*, vol. 6, n° 1, 2015.

10 Giuliano Garavini, *After Empires: European Integration, Decolonization and the Challenge from the Global South, 1957 – 1986* (Oxford: Oxford University Press, 2012), chap. 5-6.

11 Henning Türk, "The Oil Crisis of 1973 as a Challenge to Multilateral Energy Cooperation among Western Industrialized Countries", *Historical Social Research*, vo. 39, n° 4, 2014. Two "classic" accounts are in Fiona Venn, *The Oil Crisis* (London: Routledge, 2002); and Daniel Yergin, *The Prize: The Epic Quest for Oil, Money and Power* (New York: Touchstone, 1991), chap. 29-33.

the "energy crisis" to an extent).[12] But the hike in oil prices also had reverberations in the "East", where energy-related trade was both a useful instrument in the Soviet "charm offensive" with Western Europe, and a reason of growing mutual bitter recriminations within the Eastern bloc.[13] In the latter half of the 1970s, against the backdrop of growing oil-imports-related indebtedness for many a Third World country, "energy" remained a major topic at the Conference on International Economic Cooperation (CIEC), which ran in Paris from 1975 to 1977 and supposedly incarnated a "North-South dialogue" between the (western) industrialized and the developing countries: to be sure, in the context of what proved to be a "dialogue of the deaf" on the general rules of the international economy, no agreement was found on substantial issues such as the principles on which to base oil pricing, the maintenance of OPEC's purchasing power, and financial assistance to oil-importing developing countries.[14] Nevertheless, CIEC participants were able to agree on the importance of energy availability and of cooperation in the energy field, with particular concern for the diversification of energy resources in the developing countries.[15]

5 Thus, at its 1978 session, the UN's General Assembly passed Resolution 33/148 "to convene an international conference on new and renewable sources of energy under the auspices of the United Nations in 1981".[16] The designation of Nairobi as the conference venue came at the following session of the General Assembly, together with the indication that ECOSOC's Committee on Natural Resources should act as the conference's preparatory committee.[17] In the same year, the Tunisian diplomat Mohamed Habib Gherab was chosen as the conference's secretary-general, a position in which he served until early 1981, when he was replaced by Uruguayan diplomat Enrique Iglesias.[18]

According to several commentators, the empha- 6
sis on "new and renewable sources" had been motivated by the desire to relaunch international dialogue and avoid the serious political confrontation that could be expected to occur over oil and oil prices.[19] In fact, it was precisely a new redoubling of oil prices in 1979-80 that lent the conference a greater political character, at a time when Mexico's President Portillo made bold proposals for a "World energy plan", the G7 promised to "break the existing link between economic growth and consumption of oil", and the Carter administration proclaimed that the Persian Gulf was a "vital interest" of the United States of America.[20] Not surprisingly, the conference was thus "welcomed" by the Non-Aligned Movement at its 1979 Havana summit, and looked at with hope in the well publicized report of the semi-official Independent Commission on International Development Issues chaired by the

12 Nicholas Bayne, "The foundations of summitry", *in* Emmanuel Mourlon-Druol and Federico Romero (eds.), *International Summitry and Global Governance: the Rise of the G7 and the European Council, 1974-1991* (London: Routledge, 2014).

13 Jeronim Perović, "The Soviet Union's Rise as an International Energy Power: A Short History", *in* Jeronim Perović (ed.), *Cold War Energy. A Transnational History of Soviet Oil and Gas* (London: Palgrave, 2017), 14-19; Andrei Keller, "'Muzhskaja druzhba'? Villi Brandt i Leonid Brezhnev v kontekste jenergeticheskogo dialoga mezhdu FRG i SSSR v 1970–1973 gg." ['Masculine Friendship'? Willy Brandt and Leonid Brezhnev in the Context of the Energy Dialogue between West Germany and the USSR, 1970–1973], *The Soviet and Post-Soviet Review*, vol. 44, n° 2, 2017.

14 Garavini, *After Empires*, chap. 6 (cf. note 10).

15 Jahangir Amuzegar, "A Requiem for the North-South Conference", *Foreign Affairs*, vol. 56, n° 1, 1977.

16 UN, General Assembly, Res. 33/148 of 20 December 1978.

17 UN, *Report*, 45 (cf. note 3).

18 *Id.*

19 "Les pays en développement" (cf. note 7); S. Odingo, "Prospects for New Sources of Energy", *GeoJournal*, vol. 3, supplement 1, 1981; Ursula Wasserman, "UN Energy Conference in Nairobi", *Journal of World Trade*, vol. 16, n° 1, 1982.

20 Portillo's bold energy speech at the 1979 UN General Assembly is briefly discussed in Guia Migani, "The road to Cancun. The life and death of a North–South summit", *in* Mourlon-Druol and Romero (eds.), *International Summitry* (cf. note 12). An intellectual history of "energy decoupling" is in Stephen Gross, "Reimagining Energy and Growth: Decoupling and the Rise of a New Energy Paradigm in West Germany, 1973-1986", *Central European History*, vol. 50, n° 4, 2017. On the "Carter doctrine" in the Persian Gulf, see Luis da Vinha, *Geographic mental maps and foreign policy change: re-mapping the Carter Doctrine* (Berlin: De Gruyter Oldenbourg, 2017).

former German chancellor, Willy Brandt.[21] But by 1981 the wind had also started to blow in a direction averse to gatherings like the one which was to take place in Nairobi: years of little progress over North-South issues had led to generalized weariness toward large UN conferences, US-Soviet relations had turned bitter again, and the coming to power of the new Reagan administration in the US promised to bring an even more radical wave of skepticism on the whole notion that "economic issues" should be settled in diplomatic forums.[22]

RESULTS AND ASSESSMENTS

7 As had occurred with similar conferences convened by the United Nations in the previous decade, the ten days of negotiations ended with the adoption by consensus of a "Programme of Action", which was devoted to "the Development and Utilization of New and Renewable Sources of Energy".[23] Later in the same year, the UN General Assembly adopted the Programme, again by consensus, with a resolution that "not[ed] with satisfaction the agreement reached on some issues", "express[ed] deep concern that no final decisions were taken on some other important questions", and urged in any case all governments "to take effective action" for its implementation.[24]

8 The Nairobi Programme was a 43-page document, divided in three main parts. The first part presented the intellectual and international political framework in which the conference had taken place and attempted – without much success, as I will discuss below – to frame a common language in which disparate national and regional priorities could be understood as part of a shared effort of the whole international community.[25] The second part listed the actual "measures for concerted action": for each of the fourteen sources of energy eligible as "new and renewable", the measures consisted in assessment and planning, research and development, and eventually technological transfer and adaptation, to be undertaken "at the national, subregional, regional and international levels".[26] The third part dealt with the identification of the areas of priority action and with the institutional arrangements for the implementation and monitoring of the program.[27]

This last part was the one that attracted most of the commentaries after the conference. As most commentators noted, despite the demands by Third World countries, no new international body was created to promote energy cooperation and financing, nor was there any financial target to meet by the member states in support of "new and renewable" energies. The *New York Times* wrote that the conference had ended "with a billion-dollar plan to end dependence on fossil fuels but no money to carry it out" and reported the comment of a delegate from an unspecified Third World country who allegedly dubbed the Programme "the Nairobi plan of inaction".[28] The Boston-based *Christian Science Monitor* confirmed that 9

> the agreement was hardly welcome to the third-world countries and their friends [who] had hoped for the setting up of a thoroughgoing UN energy secretariat and a financial energy institution (preferably linked to the World Bank) that would be able to channel large funds to poor nations for the development of suitable renewable energy sources.[29]

21 Respectively: *6th Summit Conference of Heads of State or Government of the Non-Aligned Movement* (Havana, Cuba, 3 – 9 September 1979), 112, available at http://cns.miis.edu/nam (accessed 4 July 2018); and *North/South: A Program for Survival* (Boston: MIT Press, 1980), 169-171.

22 A synthesis of the effects of these processes on the UN is in Mark Mazower, *Governing the World. The History of an Idea* (London: Penguin, 2012), chap. 12, which however does not mention the Nairobi conference. The changes are also discussed in Michael Schechter, *United Nations Global Conferences* (London: Routledge, 2005), 83-86.

23 Schechter, *United Nations*, 83 (cf. note 22). The full text of the Programme is reproduced in UN, *Report*, 1-43 (cf. note 3).

24 UN, General Assembly, Res. 36/193 of 17 December 1981.

25 UN, *Report*, 1-8 (cf. note 3).

26 *Ibid.*, 8-21.

27 *Ibid.*, 21-36.

28 "UN Energy Talk Ends with Plea for Money", *New York Times*, 23 August 1981.

29 "UN Energy conference fell far short of Third World expectations", *Christian Science Monitor*, 24 August 1981.

10 During the conference, some national delegations had made public announcements concerning their will to increase their international energy aid,[30] but the final document only stated that "investments in new and renewable sources of energy will account for a substantial and growing proportion of [energy] investment needs" (the latter were estimated to be "in the order of $54 billion" for the developing countries only).[31] In regard to the "measures for concerted action", the Programme indicated, in what was reportedly a last-minute deal, that "there should be an intergovernmental body in the United Nations specifically concerned with new and renewable sources of energy and entrusted with guiding and monitoring the implementation" of the recommendations included in the Programme itself, but left it to future arrangements to define its nature.[32] The conservative *Times* of London wrote of a "dawn stint" with "compromises" and the left leaning French *Le Monde* reported the comment of an unspecified "European diplomat" according to whom "the result was not glorious, but allowed everybody to save their face".[33] But the Jamaican *Kingston Gleaner*, which had followed the conference works with a keen interest in the performance of Prime minister Edward Seaga, wrote that it was not clear how "this plan of action [...] is to be implemented", and San Paulo's *Folha* was even more direct in writing of the "total collapse" of the UN conference.[34]

11 The press was also quick to recognize in the final outcome the visible hand of the US delegation, particularly averse to international bodies and public programs after the inauguration of the Reagan administration earlier in the year. The Soviet *Pravda* represented the US government as intent in putting "*opjat' palki v kolesa*" of the conference (literally "again the sticks in the wheels").[35] While not particularly surprising, given the bad state of US-Soviet relations at the time, such assessment was also somewhat hypocritical, since the delegations from the Eastern bloc had actually been in basic agreement with the US one, if with a lower profile.[36] But even the conservative Italian *La Stampa* wrote of Reagan's "veto".[37] On its part, the US delegation did little to conceal its satisfaction for the eventual minimalist arrangements: James Stromeyer, the US chief negotiator, was actually the only delegate claiming to be "very, very thrilled" at the outcomes.[38] As a confidential briefing paper for President Reagan spelled out some weeks after the conference:

> the success of UN conferences should not be measured in terms of new funds created. [...] The Principal value of the [Nairobi] Conference was in highlighting awareness of the current and potential use of [new and renewable sources of energy] and demonstrating that certain energy issues can be fruitfully discussed in UN forums. [...] It is particularly significant that the Program of Action [...] gives appropriate emphasis to the role of the private sector.[39]

In the following months, specialized magazines confirmed the basic disappointment expressed by the daily press, with the environmentalist UK-based *New Scientist* concluding that the whole effort, which had consumed "over 100 12

30 "Britain and Canada pledge energy aid", *The Times*, 12 August 1981.
31 UN, *Report*, 35 (cf. note 3).
32 *Ibid.*, 28.
33 "Dawn stint at energy conference", *The Times*, 22 August 1981; "La fin de la conférence de Nairobi", *Le Monde*, 24 August 1981.
34 "Carib. Energy Parley in the Making", *Kingston Gleaner*, 20 August 1981; "Conferência da ONU fracassa", *Folha*, 22 August 1981.
35 "Opjat' palki v kolesa", *Pravda*, 21 August 1981.
36 The position of the Bulgarian delegate, speaking for the entire Eastern block, is reported in UN, *Report*, 102-103 (cf. note 3). When the United Nations General Assembly, in 1982, created the Committee on the Development and Utilization of New and Renewable Energy Sources (Res. 37/250 of 21 December 1982), the Soviet Union and the United States were among the only ten countries to cast a negative vote. Voting record available at http://unbisnet.un.org:8080/ipac20/ipac.jsp?profile=voting&index=.VM&term=ares37250 (accessed 4 July 2018).
37 "Nairobi, tra ricchi e poveri nessun accordo sull'energia", *La Stampa*, 22 August 1981.
38 "UN Energy Talk" (cf. note 28).
39 Briefing paper on "Energy", attached to memorandum from Paul Bremer to Richard Allen, "Cancun Economic Summit Briefing Papers", 6 October 1981, Confidential, Ronald Reagan Presidential Library (RRL), Norman Bailey Files, Box 2, Cancun Summit.

billion sheets of paper", had been "a waste of energy".[40] For some years, invoking the Nairobi Programme remained a respected diplomatic activity: two years after the conclusion of the conference, the New Delhi summit of the Non Aligned Movement still lamented that "little progress" had been made on the subject[41], and the General Assembly of the United Nations passed another resolution (38/169) demanding the "immediate implementation" of the Programme.[42] After the mid-1980s, however, the Nairobi meeting fell into virtual oblivion for all practical purposes.[43]

ENERGY TRANSITION: A NEW PHRASE IN TOWN

13 Whatever its achievements (or lack thereof) in terms of actual cooperation in "new and renewable" sources, the Nairobi conference is an extremely interesting event in order to understand how the question of energy was thought about in the aftermath of the "oil shocks" of the 1970s. The result of an effort that was both more global in scope, and more specific in focus than the contemporary meetings of the "North-South dialogue", the conference stands out for its attempt to frame a new language on energy, in particular by providing the stamp of officialdom to the notion that the world was engaged in an "energy transition".[44]

14 In the 43 pages of the Programme, the term "transition" occurred 25 times (19 times in the phrase "energy transition"). Often – and, as will be discussed below, not without contradictions – the "energy transition" was presented in highly prescriptive terms, as a goal to be "ensured" through appropriate "technological, commercial, financial and monetary modalities".[45] Indeed, "achiev[ing] an orderly and peaceful energy transition" was presented as "the challenge and opportunity" of the time since the very first line of the document.[46] Borrowed from physics and re-signified to designate a change in the patterns of energy production and consumption of a given population, the phrase had showed up only sporadically in English from the 1950s to the early 1970s, mainly in publications intended to promote the civilian use of atomic energy.[47] In adopting it, Nairobi reflected and formalized at the highest international level the widespread change in the ways of thinking about energy that characterized the second part of the 1970s, after the 1973 "oil shock" had acted as an eye-opener into the temporary nature – indeed the frailty – of the previous energy order.[48]

15 The 1970s were not the first time when academics or policy planners reflected on the historically-contingent nature of the human use of specific energy sources: from William Stanley Jevons's *The Coal Question* (1865) to the OEEC's "Robinson report" (1960), such considerations

40 "Waste of Energy", *New Scientist*, 27 August 1981, 506; Odingo, "Prospects" (cf. note 18); Ursula Wasserman, "UN Energy" (cf. note 7); André van Dam, "Renewable energy: renewable hope", *Futures*, February 1982.

41 *7th Summit Conference of Heads of State or Government of the Non-Aligned Movement* (New Delhi, India, 7-12 March 1983), 79, available at http://cns.miis.edu/nam (accessed 4 July 2018).

42 UN, General Assembly, Res. 38/169 of 19 December 1983.

43 The conference is briefly mentioned in Bernd Hirschl, "International renewable energy policy—between marginalization and initial approaches", *Energy Policy*, vol. 37, 2009; Johannes Urpelainen and Thijs Van de Graaf, "The International Renewable Energy Agency: a success story in institutional innovation?", *International Environmental Agreements*, vol. 15, 2015; Peter Dauvergne, *Handbook of Global Environmental Politics* (Cheltenham: Elgar, 2012), 80-81; Sylvia Karlsson-Vinkhuyzen, "The UN, Energy and the Sustainable Development Goals", *in* Thijs Van de Graaf *et al.* (eds.), *The Palgrave Handbook of the International Political Economy of Energy* (London: Palgrave, 2016). All these works cite Nairobi either as an event of no consequence, or as the far antecedent of later gatherings. In this same spirit, IRENA's website traces the agency's origins back to "the proposal for an international agency dedicated to renewable energy" made in Nairobi in 1981: see **http://www.irena.org/about/aboutirena/history** (accessed 1 Macrh 2020). As for (the lack of references in) general histories of energy, see for example: Smil, *Energy in World History* (cf. note 1); Debeir, Deléage and Hémery, *Histoire* (cf. note 1).

44 *Energy Transition* was the title of the Programme's first chapter: UN, *Report*, 3 (cf. note 3).

45 UN, *Report*, 5 and 3 (cf. note 3).

46 *Ibid.*, 3.

47 See, for example, Harrison Brown, *The Challenge to Man's Future* (New York: Viking, 1954).

48 "The eruption of oil prices since 1973 [...] had shattered the settled regime of cheap and reliable energy as an unfailing resource", in the words pronounced by the Jamaican Prime minister Seaga in Nairobi: UN, *Report*, 57 (cf. note 3).

punctuated the history of the modern uses of energy.[49] But rarely did they step into the limelight outside of specialist or government circles, and even more rarely were they conceived as systematic reflections on world energy history.[50] After 1973 instead, the studies of energy in the past began to flood history journals, the field of "energy policy" quickly became a hot topic in ordinary debates, and publications envisioning some "energy future" attracted wide readerships in multiple languages: less radical than "energy revolution" and less technical than "energy substitution" (two expressions with which it often came in association), in such a context "energy transition" became the key phrase to indicate both that energy practices had often changed in the past, and that they could – or should – change again in the present and in the future.[51]

16 The United States, the country where the phrase first gained wide circulation, was also the one where it first became part of the political jargon: on 18 April 1977, the democrat President Jimmy Carter used it in a televised speech to the nation, during which he told the public that "twice in the last several hundred years, there has been a transition in the way people use energy" (from wood to coal in the 19th century and from coal to oil in the 20th), and that "we must prepare quickly for a third change".[52] In the same months, 1970 "Earth Day" promoter Denis Hayes set up to organize a "Sun Day" aimed at ensuring a "transition to a post-petroleum world" based on what, in a successful book, he had called "the rays of hope".[53] By the end of the decade, several countries saw equivalent expressions appear in national political debates.[54]

Three documents testify to the spreading of the term in international forums before Nairobi: José Lopéz Portillo's aforementioned 1979 "energy plan", where he proposed "the adoption of a world energy plan that covers all nations […] and has as its fundamental objective the assurance of an orderly, progressive, and just transition from one age to man's history to the next";[55] the same "Brandt report" cited above, presented to the UN Secretary General in February 1980, which recommended "an orderly transition […] from high dependence on increasingly scarce nonrenewable energy sources";[56] and finally, the General Assembly's Resolution 35/56 of 5 December 1980, which affirmed that "the international community will have to make substantial and rapid progress in the transition from the present international economy based on hydrocarbons".[57] 17

In view of the Nairobi conference, government officials from all over the world, as well as representatives from international organizations and NGOs were thus explicitly invited to think in terms of the "awareness of the role of new and renewable sources of energy in the energy transition of mankind" during the sessions of the Preparatory Committee.[58] In that connection, the Group of 77 submitted a proposal that the 18

49 A survey of early 20th century critics of the reliance on fossil fuels is in Hermann Scheer, *Energiautonomie* (München: Verlag Antje Kunstmann, 1999), chap. 2; an analysis of the "scarcity syndrome" in the US is in Roger Stern, "Oil Scarcity Ideology in US National Security Policy, 1909-1980", Oil, Energy & the Middle East Program, Working Paper, Princeton University, 2012; commentary about the 1950s debates in the OEEC up to the "Robinson report" is in George Gonzalez, *Urban Sprawl, Global Warming, and the Empire of Capital* (New York: SUNY Press, 2016), 78-81.

50 As concerns the latter point, a possible exception from the first half of the 20th century is Lewis Mumford, *Technics and Civilization* (London: Harcourt, 1934).

51 A survey is in Basosi, "A Small Window" (cf. note 2).

52 Jimmy Carter, "Address to the Nation on Energy", 18 April 1977, available at **https://www.presidency.ucsb.edu/documents/address-the-nation-energy** (accessed 1 March 2020). Also: "Excerpts From 'Overview' Section of President's National Energy Plan", *New York Times,* 30 April 1977.

53 "'Earthday' backer planning 'Sun Day'", *New York Times*, 16 October 1977. Hayes would soon be called by Carter to direct the Solar Energy Research Institute.

54 See for example "Controle da política energética", *Folha*, 4 November 1978; "Nucléaire: le gouvernement français est moins seul", *Le Monde*, 12 June 1979; "Jansen fordert 'Energiewende'", *Frankfurter Allgemeine Zeitung*, 5 September 1979.

55 Address by Mr. José Lopéz Portillo, *United Nations General Assembly, Official Records, Thirty-Fourth Session, 11th Plenary Meeting,* 27 September 1979, 202.

56 *North/South,* 171 (cf. note 21).

57 UN, General Assembly, Res. 35/56 of 5 December 1980.

58 Such was the invitation by the conference's Secretary-General Enrique Iglesias at the third session of the preparatory committee, which was held in early spring 1981: UN, *Report of Preparatory Committee for the United Nations Conference on New and Reneawable Sources of Energy* (New York: United Nations, 1982), 7.

conference promote the "concerted action of the international community in order to contribute to the process of energy transition".[59] The delegation of the Netherlands, speaking on behalf of the European Community, similarly stressed "the importance of energy transition, a concern common to the whole of the international community",[60] and the US delegation submitted a proposal to rephrase the objectives of the conference so as "to increase the quantity of energy that can be derived from new and renewable sources of energy and the pace of transition to those technologies".[61] So widespread had become the circulation of the expression, that in Nairobi virtually all major speeches spoke that language, while the speakers who did not use it – the Soviet delegation and the OPEC representative, for instance – did not object to its use.[62] In a sense, at the beginning of the 1980s, the "international community" formalized nothing less than its acceptance of the historicity of the human use of energy: this was no longer to be thought of as a transcendent phenomenon, but as a fully historical one, evolving along with needs, science, technology, and availability of resources.

DUBIOUS CERTAINTIES

19 On a more critical note, Jean-Baptiste Fressoz has written that the phrase became popular in the mid-1970s to ward off the much more depressive notion that an "energy crisis" had taken hold of the oil-importing countries.[63] Indeed, it is difficult to put in doubt that its success owed much to the oil price shock of 1973, the evident critical consequences of which it contrasted with the positive language of opportunity and change. But the language of "the energy transition" came also embedded with a problematic assumption that was typical of the 1970s: coming on top of a new redoubling of oil prices in 1979-80, the Nairobi conference did not only promote the abstract notion that social arrangements concerning energy were transient, but also the much more specific notion that "the transition" was necessitated by the prevailing high prices of "conventional" resources.[64]

20 This was a view that compounded in a single conclusion two distinct forecasts about the future that were popular in the 1970s: that oil prices would remain high forever, and that their increase reflected the coming scarcity of the precious hydrocarbon. The Programme spelled out the problem clearly in its first pages:

> In view of the often wasteful and inefficient utilization of hydrocarbon resources by some countries as well as their finite supply and depletable nature it has become clear that the previous assumption of abundant and cheap energy is not valid any longer.[65]

21 Today, standard textbooks on energy history recognize that many factors contributed to the steep price increases of the 1970s much more than their "finite supply".[66] But one need only to take a rapid look at the official conference report to notice that there was a common thread running through the debate in Nairobi:

> It was underlined that the world had entered a period of transition during which concentrated efforts at all levels, national and international, would be needed to lessen the consequences of the diminishing resources of conventional and traditional energy, especially of hydrocarbons, and to pave the way for effective new sources of energy. [...] The view was widely held that the limited resources of fossil fuels constituted a problem of global dimensions and may produce unforeseen global consequences. [...] It was recognized that, without a similar concentration of

59 *Ibid.*, 17.
60 *Ibid.*, 19.
61 *Ibid.*, 20.
62 Summaries of the speeches given in Nairobi by heads of state or government and delegates are in UN, *Report*, 52-62 and 67-77 (cf. note 3).
63 Fressoz, "Pour une histoire", 173-187 (cf. note 2).
64 By an established convention, "conventional" resources are to be intended here, quite paradoxically, as the hydrocarbons and nuclear energy that had fueled the industrialization of a portion of world since the 19th century.
65 UN, *Report*, 3 (cf. note 3).
66 Francisco Parra, *Oil Politics. A Modern History of Petroleum* (London: IB Tauris, 2004), 175-276.

> efforts at the international level, the shortage of energy resources might have the consequence of accentuating world economic disorder.[67]

22 Several of the major speeches explicitly made the same point. For instance, UN Secretary-General Waldheim opened his inaugural speech by declaring that "until recently, supplies of energy had been taken for granted [...], the underlying assumption being that of a cheap and inexhaustible supply of oil and gas. The reality had disproved the assumption".[68] The host, Daniel arap Moi claimed that "a great deal had changed" since the 1961 Rome conference, when "oil had been cheap and seemingly plentiful".[69] In what the Nairobi *Daily Nation* hailed as "a frontal attack to the rich nations", Indira Gandhi charged that "as a consequence of excessive exploitation the supplies of fossil fuel – a depleting asset – ha[ve] become precarious".[70] In opening the general debate, the Director General of the UN's Committee for Development and International Cooperation claimed that "according to various studies, a continuation of current energy consumption policies would lead to serious scarcity of oil and to mounting uncertainties regarding assured supplies at required levels".[71] In short, the language at the conference – providing the rationale both for "the energy transition" and for the conference itself – was to a large extent that typical of most of the literature of the 1970s, which interpreted the "oil shocks" mainly as a symptom of the coming exhaustion of oil (and other hydrocarbons in perspective).[72]

23 In reality, the 1970s debate was more composite. The notion that the United States had reached its "peak oil" and that the world was about to follow, famously advanced by geologist M. King Hubbert, was severely criticized by other specialists who noted that the regime of low oil prices of the pre-1973 period had dramatically slowed down the pace of exploration, implying that the latter would catch up in a high price context.[73] According to such critics, several reasons, other than exhaustion, justified using the prevailing high prices of the time as a springboard for "the transition": these included considerations of "energy security" (given the uneven distribution of known oil reserves on the world map), the need to shift to "modern renewables" (solar and wind, in particular) to counter the observed "greenhouse effect" and "acid rains" deriving from the burning of (actually overabundant) hydrocarbons, the premium associated with the "democratic" nature of dispersed energy sources, the doubts about the longer term prospects of relying on finite energy sources.[74] In some cases, these same motives appeared next to the "coming exhaustion" argument, but it was nevertheless the latter that caught the spirit of the time.[75]

24 In Nairobi, a note of caution on the subject came by the Soviet delegation, whose technical paper deposited with the conference materials included, quite ironically, a straightforward lesson in market economics: "high world oil prices create economic conditions propitious to developing that part of the resources of 'ordinary'

67 UN, *Report*, 67-68 (cf. note 3).
68 *Ibid.*, 52.
69 *Ibid.*, 53.
70 *Ibid.*, 56. And "Indira calls for energy revolution", *Daily Nation*, 11 August 1981.
71 UN, *Report*, 66 (cf. note 3).
72 A survey of the international literature is in Basosi, "A Small Window", 348-350 (cf. note 2).
73 See in particular: Tyler Priest, "Hubbert's Peak: The Great Debate over the End of Oil", *Historical Studies in the Natural Sciences*, vol. 44, n° 1, 2014.
74 "Energy security" considerations (for the US) were prominent, for example, in the widely read Ford Foundation Energy Policy Project, *A Time to Choose: America's Energy Future* (Cambridge, MA: Ballister, 1974). The "energy democracy" and "global warming" rationales were already prominent in the works of ecologists, such as Barry Commoner, *The Poverty of Power* (New York, 1976), chap. 3, but it took the 1990s for such themes to break into mainstream international politics. See Spenser Weart, *The Discovery of Global Warming* (Cambridge MA: Harvard University Press, 2003), chap. 7.
75 Matthew Connelly, "Future Shock. The end of the world as they knew it", *in* Niall Ferguson, *The Shock of the Global* (Cambridge, MA: Harvard University Press, 2010). One of the most sophisticated and influential works of the 1970s aimed at promoting solar energy, *Rays of Hope* stressed the risks stemming from the accumulation of CO_2 in the atmosphere from the burning of fossil fuels, but with an awkward language also concluded that "regrettably, America's oil is now almost certainly half gone": Denis Hayes, *Rays of Hope. The Transition to a Post-Petroleum World* (New York: Norton, 1977), 35.

oil fields which are not extracted by conventional oil production methods".[76] On that basis, the Soviet paper announced that "in the USSR preparations are being made for the industrial implementation of several methods for improving oil output".[77] Eventually, the Programme avoided making clear statements, such as those that Jimmy Carter had openly made in the US, about when the effects of "scarcity" would actually be felt in terms of exhaustion.[78] In partial contradiction with the urgency communicated by the opening lines, a passage in the Programme even took the more relaxed view that, even if with problematically high prices, "in the foreseeable future, hydrocarbon supplies will continue to play a very important role in meeting the global energy demand".[79] Yet, in hindsight, having chosen a rigid conception of "transition", which posited so strongly one and only one rationale for the effort, the Nairobi Programme also laid the bases for its own demise after 1985, when a true "oil glut" and a price "countershock" on the world market came to last until the beginning of the 21st century.[80]

ONE, NONE, AND ONE-HUNDRED THOUSAND TRANSITIONS

25 The greatest paradox of the language of "the transition" of the 1970s was that the more it was used, the less its content was defined.[81] While most of those who used it agreed that "the energy transition" would imply a lesser role for conventional oil in the future, disagreement reigned on virtually every other aspect of the supposedly shared concept. Environmentalists would usually indicate solar and wind energy as their preferred endpoints, but influential think tanks with widespread global reach campaigned for coal, nuclear, or simply for "non-conventional" oil. Combinations of all the above were often to be found in influential policy prescriptions. Careful government planning was required according to some authors, while the process would proceed almost spontaneously according to others. The time horizons for the process to be completed varied from extremely detailed to completely absent. As also noted by Fressoz, few publications bothered to clear whether by "transition" from one energy source to another they implied an absolute "substitution" or simply a relative one (which could be obtained by an actual "addition" of new sources to the existing mix, without necessarily reducing absolute consumption levels of any one source).[82] From this standpoint, Nairobi only compounded the ambiguities of the intellectual debate, by carefully avoiding to make a clear choice for any of the divergent available conceptions of "the transition". If anything, the globalization of a phrase that had originally been re-signified in "western" industrialized countries led to further inconsistencies when applied to Third World countries, for most of which hydrocarbons covered only a minor portion of national energy consumption. In short, it seems possible to extend to the 1970s the judgment reserved to a later phase by political scientist Joseph Szarka, according to whom "energy transition" is a particularly "problematic example of the vagueness that surrounds much of the energy lexicon".[83]

The opening statement of the Programme indicated that the world was up to achieving an "energy transition from the present international economy based primarily on hydrocarbons to 26

76 *Nacional'nyj doklad, predstavlennyj Sojuzom Sovetskih Socialisticheskih Respublik* [National report, submitted by the USSR], 10 June 1981, available at **https://digitallibrary.un.org/record/22577/files/A_CONF-100_NR_51-RU.pdf** (accessed 1 March 2020), 13.

77 *Id.*

78 In Carter's presidential address: "Each new inventory of world oil reserves has been more disturbing than the last. World oil production can probably keep going up for another 6 or 8 years. But sometime in the 1980's, it can't go up any more. Demand will overtake production. We have no choice about that". See Carter, "Address to the Nation" (cf. note 52).

79 UN, *Report*, 5 (cf. note 3).

80 On the "glut" of the 1980s Garavini, *The Rise*, chap. 7 (cf. note 1).

81 A more detailed analysis of the international literature synthesized in this paragraph is again in Basosi, "A Small Window" (cf. note 2).

82 Fressoz, "Pour une histoire" (cf. note 2).

83 Joseph Szarka, "Towards an evolutionary or a transformational energy transition? Transition concepts and roadmaps in European Union policy discourse", *Innovation*, vol. 29, n° 3, 2016, 223.

one based increasingly on new and renewable sources of energy".[84] But, on the one hand, it was impossible to find in the Programme any clear indication of what "increasingly" meant, or of the deadlines after which the "increase" could be measured. On the other, to the extent that Nairobi did promote "new and renewable" energies as part of a not-better-specified "more balanced energy mix", the list of fourteen energy sources considered at the conference came immediately into conflict with the opening statement: as noted, perhaps ironically, in a paper prepared by the Economic Commission for Western Asia, with fuel-wood, charcoal, peat, energy from draught animals, oil-shale and tar sands all included in the list, "clearly not all sources are new, and equally clearly, not all sources are renewable".[85]

27 Nor did the conference ever confront – at least explicitly – the question whether there would be a true "substitution" of hydrocarbons or a simple "addition" of other energy sources to an expanding mix. Given that "the transition" rested ostensibly on the increasing price and growing scarcity of hydrocarbons, one would expect an emphasis on their actual substitution. In reality, with the lonely exception of the Swedish Prime minister, Thorbjörn Fälldin, who celebrated his country's attempts "to reduce the consumption of oil" (as opposed to vague talk of "efficiency"),[86] the entire conference and preparatory works were geared toward redoubling the "efforts designed to explore and develop conventional energy resources".[87] As far as new and renewable energies were concerned, they could "make a significant contribution, but their role and potential in the short term should not be overstated".[88] If there was to be a "transition", it was *obtorto collo*.

Of course, one could expect that it would be difficult to design a common "energy future" for so many countries, which not only started from very diverse conditions but had often also identified different energy sources as strategic for their own national energy policies. If one looks at the energy policies that were being pursued at the national level by some of the main participants in the Nairobi meeting, it is hard to see how any specific indication could come out of the conference: the Soviet Union aimed at completing its domestic transition from coal to oil and gas[89]; France had invested heavily in nuclear energy, Brazil had made a substantial bet on nuclear and bio-ethanol, the Scandinavian countries pushed for "green" technologies as wind and geo-thermal power[90]; Japan's "Sunshine program" included heavy investments in solar research next to those in nuclear energy[91]; China was about to pass its Sixth Five-Year Plan, keenly focused on energy conservation and mostly aimed at the substitution of coal for oil;[92] the Third World governments, which depended on "old renewables" for most part of their energy needs, showed interest for the technologies of what we would call today the "new renewables", but also consistently used their periodic summits to affirm their right to the peaceful development of civilian nuclear energy.[93] 28

Echoes of such different situations and choices resounded throughout the conference, and brought to light the obvious political and power-related aspects of any official international discourse on energy: on the one hand there were 29

84 UN, *Report*, 3 (cf. note 3).

85 Economic Commission for Western Asia, *Regional Preparatory Expert Group Meeting for the United Nations Conference on New and Renewable Sources of Energy*, 20 March 1981, 1, available at **https://digitallibrary.un.org/record/25399?ln=es** (accessed 1 March 2020).

86 UN, *Report*, 58 (cf. note 3).

87 *Ibid.*, 7.

88 *Ibid.*, 5.

89 Perović, "The Soviet Union's Rise" (cf. note 13).

90 A recent work on these cases is in Araújo, *Low Carbon* (cf. note 2).

91 See Daniel Yergin, *The Quest: Energy, Security and the Remaking of the Modern World* (New York: Penguin, 2011) 534-536.

92 In a significant passage the Plan read that "oil consumption in 1985 is to be 10 million tons less than that of 1980. To substitute coal for petroleum in the power stations, the state plans to increase coal supply in the five years and appropriate funds to expand related engineering work": "The Sixth Five-Year Plan (1981-85) for the National Economic and Social Development of the People's Republic of China", *Chinese Economic Studies*, vol. 17, n° 1, 1982, 25.

93 See for example: *6th Summit Conference*, 73-74 (cf. note 21); and *7th Summit Conference*, 166-168 (cf. note 41).

countries that could plan an "energy transition" away from hydrocarbons with relative ease; on the other end of the spectrum, in Indira Gandhi's words, the calls for a more balanced energy mix "should not be an excuse for diverting attention from the immediate task of the equitable sharing of conventional energy".[94] Similarly, in conclusion of a lengthy passage in which he warned that "the destruction of the forests and of the natural vegetative cover [...] would disrupt the cycles and balances of the biosphere", Daniel arap Moi formulated a proposal for "a two-tier price system which would enable the poor countries to import oil at lower prices than those charged to industrialized ones", synthesized by Nairobi's *Daily Nation* under the title "Sell us cheap oil".[95]

30 Finally, a position *sui generis* on "the transition" was the one expressed by the US delegation after the switch from Carter to Reagan. Headed by a republican lobbyist without any experience in the field of energy, Reagan's team in Nairobi was entrusted with one main task, which it pursued relentlessly: to celebrate the contribution that the "private sector" and "the market" could make to a "successful transition".[96] In practice, of course, this meant that the US government was pursuing in Nairobi the international portion of its domestic agenda of cancellation of any form of public support to renewable energies.[97] More generally, it could also be said that Nairobi was a first testing ground for the US administration's "neoliberal" shift over international economic issues, that the President would soon personally promote at the "North-South summit" which took place in Cancún only weeks after the energy conference.[98] But in this connection the Reagan team also operated on a "philosophical" plane: by definition, a "transition" left to private actors could only be intended as an open-ended process, irrespective of what the Programme said about the goal to promote "new and renewable" sources.[99]

CONCLUSIONS

There are three main conclusions from the analy- 31
sis conducted above. The first is that Nairobi, as a major event organized by the United Nations, reflected and formalized a new language about energy that had begun to spread in the 1970s and which presented the post-1973 world energy condition as one of "transition". To the extent that this implied greater awareness of the "historicity of energy" (in policy-making as well as in individual or corporate decisions), this was by no means a minor fact. The second is that the conference reflected a typical misconception of much of the literature and the political discourse of the 1970s about energy, which affirmed the necessity of "the transition" on the basis of the widespread expectation that oil prices would remain high forever (ostensibly reflecting

94 UN, *Report*, 57 (cf. note 3).

95 "Sell us cheap oil, says Moi" (cf. note 3). To be sure, while most likely instrumental, Moi's words expressed the ideas elaborated by several social movements in Third World countries in those years: if promoting "renewables" as an alternative to oil meant to rely on fire-wood, the ecological consequences of renewables could be even more devastating than those of burning hydrocarbons. Also thanks to a large street demonstration in the conference days, these reflections impressed the international press, which dedicated several reports and articles to the topic: "Zwei Milliarden Menschen brauchen täglich Brennholz", *Franfurter Allegemeine Zeitung*, 25 August 1981; "Quest for future energy puts biology in harness", *The Times*, 17 August 1981. Eventually, the conference passed a resolution presented by Kenya and India which called for "the immediate acceleration of programmes of reforestation and afforestation [...] as part of the effort to achieve a fivefold increase in the annual tree-planting rates by the year 2000", possibly the only portion of the Programme with a clear objective-cum-deadline: UN, *Report*, 40 (cf. note 3).

96 *Summary of the National Report Submitted by the United States of America*, 2 July 1981, available at https://digitallibrary.un.org/record/22567?ln=en (accessed 4 July 2018). The speech by the head of the US delegation is reproduced in "Ambassador Stanton Anderson, 13 Aug. 1981", *Department of State Bulletin*, vol. 82, n° 2058, 1982, 63-66.

97 See Victor McFarland, "The United States and the Oil Price Collapse of the 1980s", *in* Basosi, Garavini and Trentin, *Counter-Shock* (cf. note 2).

98 Vanessa Ogle, "State Rights against Private Capital: The ''New International Economic Order'' and the Struggle over Aid, Trade, and Foreign Investment, 1962–1981", *Humanity*, vol. 5, n° 2, 2014; and, again, Migani, "The road to Cancun" (cf. note 20).

99 On neoliberal "rationality": Pierre Dardot, Christian Laval, *La nouvelle raison du monde. Essai sur la société néolibérale* (Paris: La Découverte, 2009). More specifically: Szarka, "Towards an evolutionary" (cf. note 83).

an incipient scarcity of the raw material, even though the Programme was not very clear as to what this meant in practice): four decades later, with concerns for "global warming" quickly on the rise, historians correctly see the 1970s as a period when the awareness of the link between fossil fuels consumption and the "greenhouse effect" became popular among environmentalists, but "official" international politics at the time expressed little interest in this topic and the Nairobi conference was no exception. Finally, while extremely prescriptive in indicating the rationale for "the transition", the conference language was much more indeterminate in pointing out what "transition" actually meant in practice. Ostensibly the world was engaged in a shift from hydrocarbons toward "new and renewable" energies, but the term "transition" came with multiple and potentially contradictory meanings (and the ambiguity of the phrase "new and renewable" did not help). The *koiné* with which the international community tried to speak in Nairobi was largely superficial, and concealed the reality of extremely diversified national conditions and intentions with respect to energy and energy policy.

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JEH RHE

Journal of Energy History
Revue d'histoire de l'énergie

Reconfiguring technologies by funding transitions: priorities, policies, and the renewable energy sources in the European Community funding schemes

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POST DATE
27/07/2020

ISSUE NUMBER
JEHRHE #4

SECTION
Special issue

THEME OF THE SPECIAL ISSUE
Transitions in Energy History. History in Energy Transitions

KEYWORDS
Research, Politics, Renewable, Solar, Eolia

DOI
in progress

TO CITE THIS ARTICLE
Efi Nakopoulou, Stathis Arapostathis, "Reconfiguring technologies by funding transitions: priorities, policies, and the renewable energy sources in the European Community funding schemes", *Journal of Energy History/Revue d'Histoire de l'Énergie* [Online], n°4, published 27 July 2020 URL: energyhistory.eu/en/node/212.

Abstract

The article examines the changes in the European Community (EC) research funding priorities and how they determined the character of the photovoltaic and wind technologies developed between 1975 and 2013. We address two research questions: What role has the EC's energy policy played in directing research policy? How did the EC's research funding priorities define the character of wind and photovoltaic technologies? We argue that EC energy policy directed research policy, even in unintentional ways. Furthermore, we argue that the politics of scale, for wind technologies, and material politics, for photovoltaics, had a prominent role in defining the priorities and shaping their technical characteristics.

Acknowledgments

We are grateful for the valuable comments and suggestions we received by the anonymous reviewers. Also, we are grateful to the participants of the Energy Transitions Conference that took place in Milan, most specifically to Anna Guagnini, Yves Bouvier, Léonard Laborie and Yannis Fotopoulos. Part of the research has been funded by the State Scholarships Foundation (IKY) in the "Strengthening Human Resources Research Potential via Doctorate Research" (MIS-5000432) funding scheme.

Plan of the article

INTRODUCTION

Aim and Approach

1 The paper focuses on the European Community (EC) research funding priorities in the field of non-nuclear energies (NNE), particularly for solar photovoltaic (PV) and wind energy (WE) technologies.[1],[2],[3] The analysis covers the period from 1975 to 2013. It focuses on the EC research funded and promoted through the Research and Development programmes (R&D) and the corresponding NNE sub-programmes.[4] We argue that changes in EC funding priorities shaped the technical characteristics of both PV and wind turbines (WTs). We analyse the aims and objectives of EC R&D programmes and of the NNE sub-programmes between 1975 and 2013, tracking shifts in energy technology-related research priorities, the meanings attributed to the developing technologies, and the characteristics of various renewable energy sources (RES).[5] We claim that studying the political economy of research as well as the strategies and dynamics of shaping research policy in the RES industry is important in exploring how the EC energy policy directed research policy. We consider research policy as something that is shaped and structured through pressures by the EC energy priorities, national priorities, transnational competitions and the research networks.

The two case studies were chosen because of the determinant role of these two technologies in shaping EC research policy for the promotion of energy technologies that are considered 'environmentally friendly' and key contestants of the hydrocarbon energy policies developed at European level. The importance of both PV and WE technologies in EC research policy is also reflected by the level of funding they received from EC R&D programmes. PV ranked first in funding among all RES from 1975 until 2002, when biomass took the lead. WE ranked second and third in funding during the same period, but gradually lost its privileged status between 2003 and 2013. 2

Thus far, scholars in the history of science and technology and environmental history have examined the role of experts, legislation, non-governmental organisations, and citizen activism in energy transitions. They have showed that different political, ideological and cultural conditions can affect technological styles both at the level of innovation and at that of technological networks.[6],[7] They have compared various energy programmes within national contexts and examined the impact of international treaties and agreements as well as the specific conditions that foster varieties of styles. Scholars have argued that various cultural particularities and needs can deeply influence the adopted style and energy system. In particular, Sovacool deploys the concept of research styles to denote the cultural differences that shape and direct research and result in different technologies.[8] He has 3

1 RES fell under the NNE field.

2 For simplicity reasons we employ the term EC to denote the European Economic Community (EEC)/EC. The EEC was renamed to EC when the Maastricht Treaty entered into force in 1993 and became one of the European Union pillars. All R&D programme Decisions made direct references to European Community R&D, including the FP7 Decision that was issued in 2006. Since 2009, when the Lisbon Treaty entered into force, the EC pillar was abolished.

3 Throughout the article when referring to Europe or European we refer to EC funding, unless stated otherwise.

4 First Energy R&D Programme (1975-1978); Second Energy R&D Programme (1979-1983); FP1 (1985-1988); FP2 (1988-1991); FP3 (1990-1994); FP4 (1994-1998); FP5 (1998-2002); FP6 (2002-2006); FP7 (2007-2013).

5 By 'meanings of technologies' we refer to how the epistemic communities assessed or attributed value on the developing technologies with the potential of efficiency increases (for PV) and scale up (for WTs).

6 Matthias Heymann, "Signs of hubris: The shaping of wind technology styles in Germany, Denmark, and the United States, 1940-1990", *Technology and Culture,* vol. 39/4, 1998; Ulrick Jørgensen, Peter Karnøe, "The Danish Wind-Turbine Story: Technical Solutions to Political Visions?" *in* Arie Rip, Thomas Misa, and Johan Schot (eds.), *Managing Technology in Society. The Approach of Constructive Technology Assessment* (London: Pinter, 1995).

7 The term 'technological styles' used draws from Heymann's work (cf. note 6). It is employed to describe technological developments or changes directed by cultural, socio-economic and political conditions, which influence the technical characteristics and result in different technologies.

8 Benjamin Sovacool, "The importance of open and closed styles of energy research", *Social Studies of Science*, vol. 40/6, 2010.

approached research conducted in emerging innovations in energy regimes as a dynamic system of relations among companies, users, governments, engineers and other stakeholders. His unit of analysis are state-bounded energy regimes. While all the above approaches are very important and contribute to the understanding of energy transitions, this paper aims to shift attention towards research conducted on energy technologies and its importance in defining the technical characteristics of energy innovations. Furthermore, by focusing on the political economy of R&D at an EC level, we unravel this entity's role in shaping, directing and controlling technological change in energy technologies.

4 Thus, our story goes beyond the existing national historiographies by studying the socio-political dynamics that have shaped EC research policy in the field of RES technologies. Our approach has been influenced by the work of Mazzucato and Semieniuk who have stressed the importance of studying the ways in which choices concerning funding affect the direction of innovation in the field of RES; in our analysis, the focus is on the EC R&D funding schemes for RES technologies.[9] Our research, resonates with their approach by identifying a) research strategies that linked research, experimentation and production in the making of energy innovations, b) mission-oriented energy innovations, and c) research policies, research programmes and funding schemes that invested in risky technologies that had not been tested and were still far from deployment.

5 By conducting an in-depth historical analysis of the role played by R&D funding in the introduction of RES technologies and in shaping the EC energy markets, we contribute to the existing scholarship, which has studied energy transitions by focusing on the socio-political and financial dynamics of the energy regimes at national and transnational level.[10] We argue that we need to look at the funding flows and their direction in the making of the technologies and thus we seek to link funding schemes with the technical characteristics of 'green' technologies. Towards this end, the article addresses the following research questions: What role has the EC's energy policy played in directing research policy? How did the EC's research funding priorities define the character of wind and photovoltaic technologies? Throughout the examined period –1975-2013– there have been several changes in the EC energy policy strategy and the research priorities, both in general and specifically for RES. In sections 2.1 and 2.2, we discuss some of these major changes and landmarks in regards to the EC energy policy strategy and energy research priorities, which have had significant bearing on the EC research priorities in the domain of RES technologies.[11] Studying the impact of research funding and research policies in the technological change of RES technologies, we have identified two major periods. During the first period –1975-1998– the research agenda was characterised by technological pluralism and continuous experimentation. Research policy advocated the pursuit of varied energy technologies but

9 Mariana Mazzucato, Gregor Semieniuk, "Financing renewable energy: Who is financing what and why it matters", *Technological Forecasting and Social Change*, vol. 127, 2018; Mariana Mazzucato, Gregor Semieniuk, "Public financing of innovation: new questions", *Oxford Review of Economic Policy*, vol. 33/1, 2017.

10 Ronan Bolton, Timothy J. Foxon, "A socio-technical perspective on low carbon investment challenges - Insights for UK energy policy", *Environmental Innovation and Societal Transitions*", vol. 14, 2015; Ronan Bolton, Timothy J. Foxon, "Infrastructure transformation as a socio-technical process: Implications for the governance of energy distribution networks in the UK", *Technological Forecasting and Social Change*, vol. 90, 2015; Adrian Smith, Andy Stirling, Frans Berkhout, "The Governance of Sustainable Socio-Technical Transitions", *Research Policy*, vol. 34/10, 2005; Frank W. Geels, "From sectoral systems of innovation to socio-technical systems: insights about dynamics and change from sociology and institutional theory", *Research Policy*, vol. 33/6-7, 2004; Frank W. Geels, Johan Schot, "Typology of sociotechnical transition pathways", *Research Policy*, vol. 36/3, 2007; Timothy J. Foxon, Peter J. G. Pearson, Stathis Arapostathis, Anna Carlsson-Hyslop, Judith Thornton, "Branching points for transition pathways: assessing responses of actors to challenges on pathways to a low carbon future", *Energy policy*, vol. 52, 2013.

11 The sections provide a brief analysis of some of the main changes in EC energy policy and research priorities; they are not exhaustive.

with clear funding frontrunners (i.e. research on several solar cells but dominance of c-Si in the first period and thin films in the second period). During the second period –1998-2013– research shifted towards industrial exploitation of near-market products and large-scale production, with research on the integration of RES technologies to the electricity grids, accompanied by a thrust towards boosting the EC's global industry competitiveness, and research on the design of the technologies.

Methodology and Data Analysis

6 The material for the present study consists of various published yet hitherto unstudied sources. We analysed the first two energy R&D programmes, the seven Framework Programmes (FPs), their respective NNE sub-programmes, the funded projects for PV and WE technologies for electricity production, as well as various assessments, reports, legislative material and secondary sources. The FPs, sub-programmes, and projects were retrieved through advanced searches at the "Europa" website.[12] From Europa, booklets that contain the funded projects were retrieved. These booklets contain information regarding the exact funding each project received, the contractors' names, as well as a presentation of each project (aims, objectives, description etc.).[13] Additional information for the funded projects was obtained through the Cordis database.[14] Cordis does not always offer all necessary information (e.g. funding may be missing for some projects) and it is up-to-date only for projects funded since FP5. Thus, we used Cordis only as a supplementary source of information, especially for projects from FP5 onwards.

7 All the funded projects that correspond to the sub-programmes, for both PV and WE, were examined and analysed. Projects using PV and WTs for non-electricity production purposes were excluded from our analysis. Moreover, our analysis does not include the analysis of the demonstration programmes. Our calculations for the funding of the projects were based on the information provided in the above-mentioned material. The evaluations, assessments and reports were also retrieved from Europa, as well as FP-specific sites. These sources were used to enrich the analysis with further information and to help us contextualise our story and research material. To further assist the analysis, we used the legislative material accessible via the EUR-lex website.

ENERGY POLICY AND ENERGY RESEARCH PRIORITIES: FROM 1975 TO 2013

From Energy Strategy to Common EC Energy Policy

Until 1993, the EC had no concrete common energy policy and it lacked the institutional power to establish the requisite institutional, legislative and policy tools for implementing a common EC-wide energy policy across the member states. Moreover, the member states had conflicting interests, which led them to having opposing stances as regards energy policy issues and the means of dealing with them.[15] Thus, what existed were national energy policies –either fragmented or coherent– and an EC energy policy strategy.[16],[17] The lack of a common energy policy was acknowledged by the EC. Only a few domains like the Energy R&D programmes consisted of a 8

12 https://europa.eu/european-union/index_en

13 By contractors' name we mean all the information about the project leader (name, institution name etc.); the same information is provided for all partners involved in the project(s).

14 https://cordis.europa.eu/

15 Alberto Tonini, "The EEC Commission and European Energy Policy: A Historical Appraisal", *in* Rosella Bardazzi, Maria Grazia Pazienza, Alberto Tonini (eds.), *European Energy and Climate Security: Public Policies, Energy Sources, and Eastern Partners* (New York, London: Springer, 2016).

16 *Id.*

17 Both strategy and policy set targets to be achieved through objectives. The two terms are used to indicate the changes in the acquired institutional powers of the EC. Thus, we employ the term strategy to denote the lack of 'tools' required and/or presupposed to reinforce the necessary actions taken towards achieving the targets at an EC level (i.e. the EC did not have the institutional tools to implement the objectives in the member-states). In contrast, policy indicates that the required 'tools' for implementing the actions necessary exist (the EC acquires more powers that enable the implementation of the objectives in the member states).

common action (i.e. consensus amongst member states to undertake joint research at the EC level).[18,19]

9 The first EC energy policy strategy objectives were set to address the challenges deriving from the 1973 oil crisis. In particular, the objectives consisted of measures to reduce oil dependency and to ensure energy security and energy supply.[20] These objectives, which arose in response to the oil crisis of 1973 and were further boosted during the oil crisis of 1979, aimed to quell the uncertainty, unease, and urgency to secure an energy supply for Europe. It was within this context of uncertainty that the first Energy R&D Programme launched in 1975 to explore potentially viable energy options such as RES. However, the EC's energy policy strategy objective to decrease imports of oil products in order to ensure the security of the energy supply, was to be met primarily via nuclear energy and natural gas, not RES.[21,22] The pathways towards oil substitution varied, depending on cultural, geographical and political specificities, as well as on the availability of energy resources. For example, Germany opted for coal, and later for nuclear energy.[23] France launched a massive nuclear energy programme in 1974, whereas Denmark prioritised coal in combination with natural gas.[24,25] Accordingly, the national R&D programmes on RES also had varying priorities. Germany, France and Italy dedicated funds both for PV and WE, whereas Denmark and the Netherlands prioritised WE.[26] From 1986 and throughout the 1990s, apart from the Chernobyl disaster that briefly boosted RES R&D efforts, public funding for RES declined worldwide.[27]

A common energy policy slowly took form with the 1992 establishment of the European Single Market (SEM). Additionally, SEM gave more power to the EC and helped harmonise energy policies across the member states.[28,29] The energy policy-relevant actions concerned setting up of 'common rules for the internal market in electricity'. A major trigger behind a common energy policy was climate change.[30,31] The objective of CO_2 emissions reduction played a significant role in (re)defining the European energy policy and its objectives. For example, the 1997 Kyoto Protocol and Energy White Paper called for reductions in greenhouse gas (GHG) emissions, setting specific reduction targets expressed in percentages in relation to the baseline year 1990 (for the EC, 8% reduction of the six GHGs within the first commitment period of 2008-2012).[32] This overall target was divided into country-specific targets via a European Union (EU) burden-sharing agreement. Country-specific targets varied widely from one country to another, depending on each country's wealth as well as its earlier energy efficiency and emission reduction 10

18 Neil Nugent, "Policies", *in* Neil Nugent, William E. Paterson (eds.), *The Government and Policies of the European Union* (Basingstoke: Palgrave Macmillan, 2006).
19 Commission of the European Communities, *Energy in Europe: Energy policies and trends in the European Community* (Luxembourg: Office for Official Publications of the European Communities, 1989), 6.
20 Council Resolution, of 17 December 1974 concerning Community energy policy objectives for 1985 (*Official Journal of the European Communities*, 1975).
21 *Id*.
22 Council Resolution of 16 September 1986 concerning new energy policy objectives for 1995 and convergence of the policies of the Member States (No C 241, 25.09.198) (*Official Journal of the European Communities*, 1986.
23 Frank Laird, Christoph Stefes, "The diverging paths of German and United States policies for renewable energy: Sources of difference", *Energy Policy*, vol. 37/7, 2009.
24 Miriam J. Boyle, M. E. Robinson, "French Nuclear Energy Policy", *Geography*, vol. 66/4, 1981.
25 Mogens Rüdiger, "From import dependence to self-sufficiency in Denmark, 1945–2000", *Energy Policy*, vol. 125, 2019.
26 Maarten Wolsink, "Dutch wind power policy: Stagnating implementation of renewables", *Energy Policy*, vol. 24/12, 1996.
27 Ch. Breyer *et al.*, "Research and Development Investments in PV: a limiting factor for a fast PV diffusion?", *25th European PV Conference*, 2010.
28 Tonini, "The EEC Commission and European Energy Policy", *op. cit.* 13-35 (cf. note 15).
29 SEM was to create a unified European market by deregulating. It provided the EC with more powers and, along with the Single European Act, 'allowed' regulating energy policy.
30 Directive 96/92/EC (*Official Journal of the European Communities*, 1996).
31 Jegen Maya, "Energy policy in the European Union: The power and limits of discourse", *Les cahiers européens de Sciences Po*, n°2, 2014.
32 European Commission, Energy for the Future: Renewable Sources of Energy White Paper for a Community Strategy and Action Plan, COM (97)599 final, 1997.

measures. These GHG emission reductions were accompanied by EC policies and measures that were to be undertaken to reach the targets.

11 Similar goals regarding RES share in energy consumption were integrated into EC legislation. The 2001 Directive set the goal for an indicative share of 22.1% electricity from RES by 2010.[33] The 2009 Directive established an overall binding target of 20% contribution of RES energy to final energy consumption by 2020, which was followed by national binding targets for each member state.[34] These aims and objectives in the EC legislation and policy were influenced, especially during the 2000s, by environmental concerns (relating to, for example, fossil fuels and nuclear power). Moreover, it was the Lisbon Treaty (2007) that defined energy policy "[...] as an area of priority action by primary (i.e. treaty) law [...]", hence a common EC energy policy, centrally regulated.[35] These legislative changes, which facilitated further integration of RES in the national electricity grids, drew attention towards RES. During this period, financial incentives were adopted to facilitate the integration of RES into the electricity grids. For example, feed-in-tariffs were introduced in several countries like Germany, France, Greece, Italy, and the UK.[36] These incentives were accompanied by programmes such as the 1998 German 100.000 roofs programme and the 2001 Italian 10.000 rooftops programme.[37]

12 Therefore, in 1993 a common and centrally driven EC energy policy began to shape and direct national energy policies. Member states agreed to relinquish a (small) part of their sovereignty as they adopted the more-or-less binding joint measures concerning energy policy that were indicated in EC regulations and directives. Within this framework, a common vision was created, and energy policy was shaped by specific environmental challenges and problems. From 2001 onwards, the EC has encouraged further energy production by RES, moving from indicative to binding targets concerning the share of RES in electricity generation. These binding targets helped to steer development towards the goals of the energy policy, notably those relating to RES and emission reductions. At the same time, as will be illustrated in section 2.2, the character of EC research policy became less experimental and explorative, and more focused on the integration of RES technologies into the electricity grids. At the EC level, this shift was accompanied by environmental concerns (e. g. climate change, GHS emission reductions) that provided political legitimization to public policies that supported the investments in RES technologies.[38] Hence, energy and environmental policy were moving in the same direction, both calling for further integration of RES technologies into the electricity grids. It was believed that this could be achieved by following supportive research policies.[39] Three sets of EC policies—energy, environmental, and research—were aligned in that they pursued similar energy policy goals by reinforcing the further development and integration of the RES technologies to the electricity grids. This synergism of energy, environmental, and research goals helped the EC to achieve its

33 Directive 2001/77/EC (*Official Journal of the European Communities*, 2001).

34 Directive 2009/28/EC (*Official Journal of the European Communities*, 2009).

35 Jale Tosun, Sophie Biesenbender, Kai Schulze (eds.), *Energy Policy Making in the EU: Building the Agenda* (London: Springer, 2015), 22.

36 Luigi Dusonchet, Enrico Telaretti, "Comparative economic analysis of support policies for solar PV in the most representative EU countries", *Renewable and Sustainable Energy Reviews*, vol. 42, 2015.

37 Ahmad Zahedi, "Solar photovoltaic (PV) energy; latest developments in the building integrated and hybrid PV systems", *Renewable Energy*, vol. 13/5, 2006.

38 Climate change became a policy priority soon after the Kyoto Protocol (see: Tim Rusche, "The European climate change program: An evaluation of stakeholder involvement and policy achievements, *Energy Policy*, vol. 38/10, 2010), and the same applies for GHG emission reductions (see: European Commission, Report from the Commission to the European Parliament and the Council Progress Towards Achieving the Kyoto and EU 2020 Objectives, COM(2014) 689 final).

39 Research, both for PV and WTs, was supporting the integration of RES into the electricity grids (e.g. through funding problems that addressed the resolution of connectivity issues). Such research themes can be traced already from the first pilot projects but it was-especially-in the late-1990s that such topics gained prominence in the R&D programmes.

targets for GHS emissions and RES integration to the electricity grids and to enhance the sustainability of its energy policy.

Energy and Research Policy Alignment

13 Throughout the examined period, there were several important changes in the EC research priorities; we will briefly touch upon three changes that are of major importance. The first change was introduced by the Single European Act in 1987, which provided a new legal basis for R&D and redefined the aim of the research activities.[40],[41] Within this framework, R&D was instrumental for strengthening European industry and its international competitiveness. The second change was introduced by the establishment of the European Research Area in 2000, responsible for aligning EC and member state research activities, programmes and policies. The ERA was envisioned to become the equivalent of the SEM but for research; create an integrated space for science and technology. With the ERA, alignment was pursued through joint research ventures under the EC R&D umbrella, accompanied by funding increases (3% of GDP goal), to overcome fragmentation across Europe, between different countries.[42] The third important change was introduced by the implementation of the Strategic Energy Technology Plan (SET-Plan) in 2007, which emphasised low carbon technologies and coordinated the criteria for research and innovation. SET-Plan essentially called for better coordination and alignment between energy policy and research policy for RES technologies, towards achieving the 2020 goals. This was to be achieved through the creation of the European Technology Platforms (ETPs), introduced in 2004. ETPs are industry-led fora that publish Strategic Research Agendas, which connect visions to challenges and suggest responses to the latter by outlining research priorities to infiltrate the EC R&D priorities.[43]

In 1998 the R&D and Demonstration (RD&D) sub-programmes were merged. The R&D sub-programmes were managed by the Directorate General for Research and Development, responsible for research policy, and the Demonstration sub-programmes were managed by the Directorate General for Transport and Energy, responsible for energy policy. The importance of this merger lies in its impact on research. Research that could narrow down the gap between research and market was prioritised, as well as projects that could resolve connectivity issues for the integration of RES to the electricity grids. 14

An important question needs to be addressed before examining the changes in energy and research policy: in which ways, if any, did the consecutive EU enlargements influence energy R&D funding? As illustrated in Figure 1, during FP1, NNE received significant funds, showing the influence of the 1970s oil crises. In FP2 and FP3, NNE received a smaller portion of funds as compared to those dedicated to nuclear energy, clearly indicating the high priority of nuclear energy. This significant funding increase allocated for nuclear energy can be attributed to the Chernobyl nuclear disaster, which was the major trigger behind increased nuclear funding – especially on nuclear safety. During FP4 and FP5, NNE funds were almost equal to the funds for nuclear energy. Therefore, when compared to the funds NNE received during the previous two FPs, during this period, NNE gained prominence. The variability in funding between NNE and nuclear energy between FP1 and FP5 seems to have been influenced by broader energy issues and pressures. Critical events such as the oil crises and the Chernobyl disaster were the driving force behind changes in energy funding, rather than the enlargements. 15

40 Single European Act (*Official Journal of the European Communities*, 1987).

41 Dan Andree, Priority-setting in the European Research Framework Programmes (Stockholm: VINNOVA, Swedish Governmental Agency for Innovation Systems, 2009), 17.

42 Thomas Banchoff, "Politic Dynamics of the ERA", *in* Jacob Edler, Stefan Kuhlmann, Maria Behrens (eds.), *Changing Governance on Research and Technology Policy: The European Research Area* (Cheltenham, U.K. and Northampton, Mass: Edward Elgar, 2003).

43 For more information on ETPs see **https://etip-pv.eu/** and **https://etipwind.eu/**.

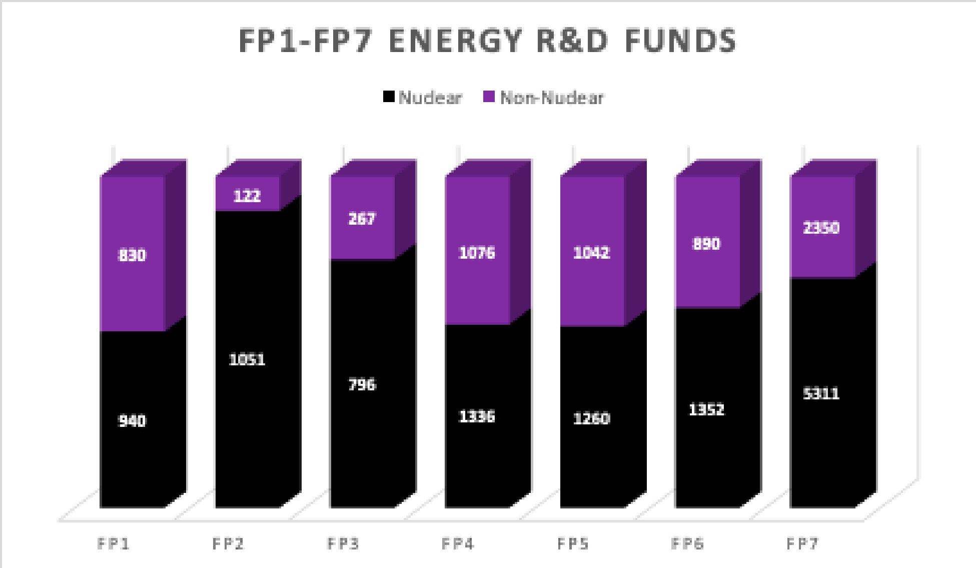

Figure 1: FP1-FP7 Energy R&D Funds (in EUR million). Adapted from: Vilma Radvilaite, "EU budget 2014–2020 deal: opportunities for wind energy", *European Wind Energy Association*, 2013, 3.

In FP6, funding for NNE declined, whereas the NNE funds during FP7 almost tripled and funding for nuclear energy nearly quadrupled. The 2004 and 2013 enlargements included the accession of several countries with nuclear power stations (Lithuania, Hungary and Bulgaria). The Kyoto protocol required GHG emission reductions, sustainable energy production figured amongst the EC's energy priorities, and the nuclear industry sought to rebrand nuclear energy as a safe and clean energy source.[44] The EC invested both in NNE and nuclear energy in its attempt to balance between energy security, energy efficiency and sustainable energy production. Global trends, competition with the USA and China, as well as the energy crises like the January 2006 gas conflict between Russia and Ukraine, also spurred funding for NNE and nuclear energy in the last period of our study.[45]

BLOWING THE WIND WHILE SEEKING THE SILICON: EC RESEARCH POLICY ON WIND TURBINES AND PHOTOVOLTAICS

We distinguish two periods for both case studies; the first from 1975 to 1998 and the second from 1998 to 2013. The reasoning behind this periodisation lies in the overall rationale underpinning research policy, its aims and objectives and, by extension, the specific choices for both PV and WTs. 16

During the first period, research aimed to support the European industry's international competitiveness. Towards this aim, research was designed to strengthen the industry's scientific and technological basis. The R&D programmes aimed to provide a basis for cooperation among member states and their various actors (e.g. universities and research centres). Research was to support the overall EC energy policy strategy goal of securing energy supply and decreasing energy imports. The research agenda of the EC was characterised by technological pluralism and continuous experimentation. EC research policy advocated the pursuit of varied energy technologies but with clear funding frontrunners (e.g. research on several cells but with a clear dominance of crystalline Si cells). 17

44 Andrei Stsiapanau, Lithuania-Short Country Report, HoNESt Project, 2018; Mathew Adamson, Gábor Palló, Hungary-Short Country Report, HoNESt Project, 2017; Ivan Tchalakov, Ivaylo Hristov, Bulgaria-SCR, HoNESt, 2019.

45 Frank Umbach, "Global Energy Security and the Implications for the EU", *Energy Policy*, vol. 38/3, 2010.

18 During the second period, research was (re) directed at solving new problems and this resulted in both its role and use being re-casted. R&D sought to foster economic development, sustainable development, and solving environmental and societal problems whilst aiding the European industry's global competitiveness. The systematic emphasis given to economic development was directly in line with the "Lisbon agenda" (2000), which sought to turn the EU into "the world's most competitive and dynamic knowledge economy."[46] Environmental objectives, especially CO_2 emissions were highlighted, especially for the RES-related activities. Moreover, research was envisioned as the focal point of innovation and knowledge-production, and R&D programmes portrayed research as a means of achieving these economic objectives. Within this context, there was a constant effort to narrow the gap between research and market, aiding the commercialisation of products which emerged from the research. This shift became evident as R&D programmes came to increasingly value and foster innovation and economic applications. Furthermore, energy policy was strongly geared towards addressing environmental challenges. As such, energy policy clearly affected research policy. During this period, research shifted towards industrial exploitation of near-market products and large-scale production, the resolution of connectivity problems that would aid the integration of RES technologies to the energy grids, and research on the design of the RES technologies.

19 In other words, during the two periods, research had to respond to different problems, had distinct roles and was used differently. The targeted problems and solutions from each period corresponded to different ideologies concerning the political economy of research. In turn, this resulted in different visions for the role of research and the character of the specific energy technologies. In the first period, the aims and objectives of research were informed by EC energy policy, which was oriented to resolve the corresponding energy challenges. During the second period, research policy was harnessed to reflect the emergent needs of the EC's energy policy, which had reoriented to address environmental and economic challenges. The alignment and reorientation of energy and research policy influenced the kinds of technologies and the character of those technologies that were developed through these programmes.

As was illustrated in section 2.1, several important changes occurred in energy policy from the first to the second period. All these changes were configured within different ideological frameworks and therefore the visions that were embedded in the research priorities for each period differ. In the second period, the Lisbon agenda gained prominence and its vision to turn the EU into a leading knowledge-based economy in the world prevailed.[47] The resulting socio-political and economic changes were also reflected in the aims and objectives of the EC research policy, which was now designed to increase production capacity, which would assist the large-scale deployment of energy technologies, create products that are near market implementation, etc. While occurring within the same policy landscape, each case study has its own particularities owing to the differences between the technologies. The WE case study is characterised by constant upscaling of WTs (in MW terms), whereas the PV case study is characterised by transnational competition for determining the 'dominant' raw materials used for the solar cells. 20

Funding the wind: from replacing fossil fuel power plants to the creation of wind power plants

The WE case study begins in 1979, with the second Energy R&D programme and concludes with FP4.[48] This period can best be described as one of experimentation, exploration, research primarily on onshore WTs, and several pilot projects. The second period includes FP5 to FP7. This period includes further design improvements, 21

46 Decision No 1513/2002/EC (*Official Journal of the European Communities*, 2002), 1.

47 *Id*.

48 It was proposed in the first energy R&D programmes' assessment to include WE research in the second energy R&D programme.

and implementation and integration of both offshore and onshore WTs. R&D gradually shifted to offshore WTs, accurate short-term forecasting, and optimal installation locations. Both periods exhibit the constant upscaling of WTs (in MW terms). However, the rationale for their upscaling differs, with each period's rationale reflecting its own distinct ideologies and visions. In the first period, R&D on WTs was justified as an investment that would bolster energy supply security and ensure the competitiveness of wind power with fossil fuel power plants. During this period, WE development aimed to upscale WTs, reaching the policy goal of large WTs with a capacity of 1-2 MW. In the second period, further WT upscaling was justified as a response to growing demand for more energy and concern for sustainable development. Research focused on large onshore WTs – up to 12 MW – and large offshore WTs – reaching 20 MW - primarily in wind farms known as 'wind power plants'. The further upscaling of WTs in this period was accompanied by the additional aim of integrating them into existing electricity grids. In order to address connectivity problems, research was redirected to enable more accurate short-term weather predictions and optimal installation locations for WTs, and to assess their integration and contribution to the electricity grids.

Experimentation: wind turbines as competitors to fossil fuel plants

22 The main drivers for research at the beginning of this period were the oil crises, the consequent need for security of energy supply accompanied by the need to decrease oil imports, and the desire to enhance the European industry's competitiveness. The second Energy R&D programme had a highly exploratory character.[49] It focused on the creation of wind atlases, collection of the corresponding data and figuring out possible installation locations.[50] During this programme, large 'wind machines', in the 1,5-2MW range were deemed competitors of conventional fossil fuel plants.[51] Hence, WE was to become competitive with fossil fuel plants and the integration of WE into the electricity grids was to be achieved through R&D of large wind machines. Towards this end, research projects focused on the development of 630kW wind turbine prototypes, small-scale WTs in the 10-55kW range, and wind farms of medium-sized WTs in the 300-500kW range.[52]

Research efforts during FP1 focused on completing the wind atlases and wind resource assessment(s), determining the optimal installation locations and experimenting and developing several prototypes. The rationale for funding the development and use of large WTs was based on economies of scale that contend 'when producing in series the costs will decrease'.[53] Throughout this programme, research focused on large WTs (around 1MW), small and medium WTs (up to 750kW), whereas research on offshore WTs was also pursued. 23

Research during FP2 focused on measurements, modelling, and experimentation in design. During this period, research on large-scale WE exploitation focused primarily on the potential of wind farms; following visions from the EC energy policy. Moreover, the research projects focused on cost reduction, wind predictability, modelling and operational problems. Research on large scale WTs was a way of sharing the risk with industry, particularly the risk concerning the commercialisation of a given technology.[54] 24

49 C. Boffa, *et al.*, *Evaluation of the Community cost-shared research programme on solar, wind and biomass energy and of the Joint Research Centre's programme on non-nuclear energies (1979-1985)* (Luxembourg: Office for Official Publications of the European Communities, 1987), XV.

50 *Ibid.*, 84.

51 We employ the term of competitors to denote the economic viability of the technologies.

52 For more detailed information on the projects see **https://cordis.europa.eu** and **https://publications.europa.eu/en/home**.

53 Hermann Bondi H., *et al.*, *Evaluation of the R & D programme in the field of Non-Nuclear Energy (1985-1988)*, (Luxembourg: Office for Official Publications of the European Communities, 1988).

54 Throughout the article we use the terms 'risk' and 'risky' to denote the character of the EC R&D. These terms were deployed by the EC itself to express the uncertainty in the outcome of the research undertaken, as well as the timeframe (10-15 years) needed for the research to materialise in something concrete. What this means is when

25 During FP3 and FP4, research efforts focused primarily on design and manufacturing improvements. The rationale for R&D of RES, and especially WE, was to advance the future large-scale applications of wind installations in electricity grids. Towards this end, R&D of such technologies was coupled with terms like 'Renewable Energy Power Plants' and the aims focused on their introduction into the EC's electricity grids. RES was intended to contribute to the long-term EC energy security, and therefore, research focused on the industrial deployment of 1-2 MW range WTs, whereas several projects for offshore WTs in wind farms were also included.

Implementation and integration: the wind power plants

26 The second period's (1998-2013) research rationale was to increase WE capacity, reduce the cost of WE production, and integrate WE into the electricity grids on a large-scale. R&D pursued these goals through the implementation of large onshore and offshore WTs, primarily as wind farms.

27 FP5 aimed to strengthen the European industry's global competitiveness and provide technically and economically efficient energy to a competitive EC. This goal was to be achieved through the large-scale use of RES and large-scale generation of electricity, hence the focus on large-scale WTs. Main research themes of this programme were short-term forecasting, more accurate mapping to reduce operational and investment risks, resolution of problems regarding transportation and erection of WTs (especially in complex terrains), aerodynamics and aeroelasticity, and decreasing the noise caused by WTs (primarily caused by the rotors). During this programme, R&D concentrated on the development of 1,3-5 MW range onshore WTs, as well as offshore WTs for areas of greater sea depth.

and whether a technology or the processes, methods etc. employed for its development will lead to an end-product that can/will become commercial. Moreover, these terms were used by the EC to justify why publicly funded R&D was/is needed, since the private sector was/is not willing in partaking in long-term research on its own.

During FP6 and FP7 (2002-2013), sustainable development was framed as a contribution to economic development and the global competitiveness of the European industry. Moreover, terms like 'sustainable energy economy' gained prominence in the EC research policy. These terms were coined with the aims and objectives of helping the European industry to compete globally, the large-scale deployment of WE, and creating the conditions for the successful grid connection of WTs. Projects during this period sough to clear roadblocks to the integration of WE into the electricity grids, such as the intermittency of WE production, short-term wind forecasting predictions, foundation and support structure (offshore WTs), design limitations of large on and offshore WTs, and issues regarding aerodynamics and aeroelasticity. Throughout this period, very large offshore WTs of up to 20 MW were being researched. The majority of the projects focused on wind farms that could help WE reach higher levels of market penetration. Additionally, research for offshore WTs and the resolution of the problems with their integration into the electricity grids were steadily gaining attention. 28

Powered by the sun: a tale of competing materials

In the PV case, two themes recur throughout both periods: a) increasing the cell efficiency b) decreasing the cell costs.[55] Both periods are also characterised by transnational competition between Europe, USA, Japan, and during the 2000s, China. Throughout the entire period examined (1975-2013), both c-Si and thin film cells received funds. The main shift in these two periods is in the R&D funding prioritisation of the materials used for the cells. The first period is characterised by intense experimentation and exploration of the PV potential, research on different techniques and methods for increasing the cell efficiencies and several pilot projects. The cell material that prevailed during this period was crystalline Silicon (c-Si). The second 29

55 Cell efficiencies are expressed in percentages that correspond to the amount of sunlight the cell can convert into electricity.

period was characterised by industrial exploitation and large-scale production of PV, research had a strong industry-led character and thin film cells took the lead in R&D funding.[56]

The crystalline-silicon solar cell 'era'

30 Throughout the first period, PV received the largest share of the funding, among all other RES.[57] PVs were understood as a long-term solution that could reach their potential towards the electricity needs of Europe in the 21st C.[58],[59]Although both c-Si and thin-film PV were researched, the former prevailed, and especially single-crystalline silicon (sc-Si) cells. Sc-Si solar cells were described by the EC as 'conventional' because of the materials' extensive use for space applications since the 1950s.[60] On the other hand, multi-crystalline silicon cells (ms-Si) were known but not considered conventional. Thin film cells like amorphous silicon (a-Si), Cadmium Sulphide ($CdS-Cu_2S$), and Cadmium Selenide (CdSe) were all categorised as 'alternative cells.'[61]

31 From 1975 to 1983, the projects funded focused on the exploration of various techniques intended to increase cell efficiencies and reduce related costs. Funding decisions prioritised the 'most promising cells and their development' in order to enhance European international competitiveness in the c-Si field, especially with the USA.[62],[63],[64] During the first period, the motivations for competing with the USA and Japan were entirely different from those prevailing during the second period. During the first period, the main driver for PV R&D was energy security. R&D endeavoured to strengthen the scientific and technological basis of the European PV industry, as well as to aid the European industrial actors in establishing a place in the newly formed PV market. During the second period, the main motivation was to help the European industry to maintain its existing market share, whilst assisting its further expansion.

Throughout the first period, the USA and Japan interchangeably led global PV cell/module production, swapping the leading position. The USA led PV cell/module production until the late 1980s and then again during 1993-1998. The USA's leading role in PV during the 1980s has largely been attributed to Jimmy Carter who dedicated funds towards PV R&D during his presidency (1977-1981).[65] Between those periods when the USA led PV cell/module production, from 1988 to 1992, Japan assumed the leading role.[66] This shift can be attributed to Japan's strong national R&D programme promoting PV, the 'Sunshine' programme.[67] Japan dedicated research funds primarily to a-Si but also for c-Si, with the rationale that the former was "[...] better suited for mass production."[68] Therefore, Japan developed c-Si but strong emphasis was put on a-Si development. In 1993, Japan began the 'New Sunshine' programme, providing initiatives for PV and specific targets for installation, which, along with 32

56 Industry-led refers to the efforts in narrowing the gap between R&D and the market.

57 Based on the authors' own calculations of the funded projects.

58 Ugo Farinelli, *et al.*, *The evaluation of the Communities' energy conservation and solar energy R&D sub-programmes* (Luxembourg: Office for Official Publications of the European Communities, 1980).

59 Based on forecasts about the member states' energy requirements and PV corresponding contribution to the said requirements (i.e. electricity production), PV were expected to contribute 'significantly' from the year 2000.

60 Boffa, *et al.*, *Evaluation of the Community cost-shared research programme*, *op. cit.*, 55 (cf. note 49).

61 *Id.*

62 Paul Maycock, "The world photovoltaic market 1975-1998", *PV Energy Systems*, 2002.

63 Ronald H. Brown, Jeffrey E. Garten, *U. S. Industrial Outlook* (DIANE Publishing: 1994).

64 c-Si is divided into sc-Si and mc-Si. sc-Si and mc-Si differ in certain, crucial, aspects: a. efficiencies achieved; sc-Si cells have the largest efficiencies (e.g. 22% for sc-Si modules vs 18% for ms-Si for 2018), b. cost of cells; sc-Si are more expensive ($0.165 per watt for sc-Si vs $0.133 per watt for ms-Si for 2018). The above examples are based on the same basis (maximum efficiencies and cell prices for 2018). However, given the differences per manufacturer and each country's legal basis the numbers may vary.

65 Wolfgang Palz, *Power for the World: The Emergence of Electricity from the Sun* (Pan Stanford Publishing Pte. Ltd., 2011).

66 Arnulf Jäger-Waldau, *PV Status Report 2008* (Luxembourg: Publications Office of the European Union, 2008).

67 *Id.*

68 Palz, *Power for the World op. cit.* (cf. note 65).

low interest rates, helped Japan regain its leading role in 1999.[69]

33 During FP1, the largest share of R&D funding was dedicated to a-Si research, although c-Si cells continued to receive funding. Funding for a-Si cells was prioritised in order to become competitive with Japan, then the leader in the a-Si research and production.[70],[71] Within this programme, two companies coordinated/led the a-Si research.[72] These companies were Messerschmitt-Bölkow-Blohm, of the Federal Republic of Germany, and Solems, of France.

34 For the remainder of the first period, R&D was reoriented towards c-Si, which seemed to offer efficiency improvements. The a-Si field was deemed ‘somewhat disappointing’, because it had not delivered the expected efficiency improvements, while c-Si cells seemed more promising in this regard and became the primary object of R&D.[73] Towards the end of this period, there were some new cell entrants (e.g. dye-sensitised nanocrystalline, molecular plastic and organic), which received R&D funding during the subsequent period but were not the main recipients of PV funding.

‘Silicon Crisis’ in PV: thin-film cells take the funding lead

35 During the second period, thin-film cells gradually took the lead in R&D funding: in FP5 thin film R&D received approximately 18% of the total PV R&D funding, whereas c-Si received around 28%. Correspondingly, for FP6, thin films received approximately 35%, while 29% was dedicated to c-Si. In FP7, the corresponding numbers were approximately 44% for thin films and 12% for c-Si. We argue that an important event—the silicon crisis in PV—played a crucial role in the changing of research priorities. The silicon crisis in PV lasted from 2004 to 2008. Shortages in purified silicon feedstock made it difficult for the PV industry to meet its needs for feedstock. Concomitantly, silicon prices skyrocketed from approximately 24 USD per kilo in 2003 to 500 USD per kilo in 2008.[74] Soon after silicon prices steeply rose, they started to decline: in 2009 the price dropped to 50-55 USD per kilo, and in 2014 reached 14-16 USD per kilo.[75] At the same time, the world PV cell/module production significantly increased from 744,1 MW in 2003 to 1195 MW in 2004, and further to 7350 MW in 2008 and 23500 MW in 2010, with a continuous increase thereafter.[76]

The silicon crisis resulted from the increasing demand for silicon feedstock from the PV industry, a demand that silicon manufacturers could not fulfil. This increase in demand was caused by the constant growth of the PV industry, both in terms of its production capacity and the number of PV companies. This can be partly attributed to the entrance of Taiwan and China into the PV market: their PV cell/module production was 124 MW in 2004, 1070 MW in 2007, and approximately 5.6 GW in 2009.[77] Between 1999 and 2006, Japan led global PV cell/module production, until China assumed the lead.[78] China has steadily led PV cell/module production at such an unprecedented pace that there is a large divide between their productive outputs and those of all other PV-producing nations. Global PV cell/module production measured approximately 11,5 GW in 2009, 50% of which was produced in China and Taiwan.[79] By 2016, China had further consoli- 36

69 Arnulf Jäger-Waldau, *PV Status Report 2010* (Luxembourg: Publications Office of the European Union, 2010).

70 Data drawn from: Arnulf Jäger-Waldau, *PV Status Reports 2003-2017* (Luxembourg: Publications Office of the European Union).

71 Boffa, *et al.*, *Evaluation of the Community cost-shared research programme, op. cit.*, 57-58 (cf. note 49).

72 Only these two companies participated in the EC-funded a-Si research; the other contracts signed were coordinated by Universities and Research Centres/ Organisations.

73 Roger Booth, *et al.*, *Evaluation of the JOULE Programme (1989-1992)* (Luxembourg: Office for Official Publications of the European Communities, 1994).

74 The 2008 USD price corresponds to 260 EUR and the 2014 USD price corresponds to 12-14 EUR.

75 Arnulf Jäger-Waldau, *PV Status Report 2016* (Luxembourg: Publications Office of the European Union, 2016).

76 Data drawn from: Arnulf Jäger-Waldau (cf. note 70).

77 Data drawn from: Arnulf Jäger-Waldau, *PV Status Reports*, issued by the JRC (2008 and 2010).

78 Jäger-Waldau (cf. note 66).

79 Jäger-Waldau (cf. note 70).

dated its leadership; global production measured approximately 81,9 GW, of which approximately 60 GW were produced in China and 11 GW in Taiwan.[80]

37 Glimmers of the impeding silicon crisis were foreshadowed in the early 2000s. The European Solar PV Conference is a conference of central importance for the European and global PV communities which draws attendance from politicians and policy makers. During the 2001 European Solar PV Conference, industry stakeholders raised issues surrounding silicon feedstock supply.[81] For example, two Bayer executives made direct reference to an impeding silicon crisis whilst highlighting the need for new Si-feedstock.[82] Furthermore, a 2002 article in Solar Energy Materials & Solar Cells, a journal of central importance in the field of solar PV, notes: "[…] the feedstock used to date […] is already limiting the PV market expansion even if a true shortage is not expected before 2004-2005 according to a 'low growing PV market scenario'. This conclusion implies that a new silicon feedstock not depending on electronic grade silicon production chain must be available on the market from the years 2004 to 2005".[83] Silicon feedstock shortages were also stressed in research proposals submitted during FP5. These project proposals made direct references to the forthcoming silicon feedstock shortages and proposed various ways to overcome them, such as new production methods and processes, and the embrace of techniques that consume less silicon feedstock.[84] Worries concerning shortages of silicon feedstock were reflected in the character and themes of the projects funded. Concerns arising from the silicon crisis shifted research priorities for both thin-film and c-Si cells. Ultimately, this crisis shifted research priorities in favour of thin-film cells.

38 While the funding of research utilising thin-film cells became prioritised, research utilising c-Si still garnered significant amounts of funding. Yet, the silicon crisis had a major impact on c-Si research. During this period, the divide between RD&D begun to blur, largely attributed to the convergence of energy and research policy. Furthermore, the potential of large-scale production became a central 'evaluation' criterion guiding the selection of projects.

39 During FP5, mc-Si was first in funding, but thin-film cells also had a strong funding presence. Under FP5, micromorph Si (a-Si/μc-Si) made its debut, mainly explained by the desire to narrow down the gap with Japan that was leading in this materials' research and production front. During FP6, thin-film cells prevailed in R&D funding, and research efforts focused on thinner and larger area thin film cells. Thin film cells also enjoyed increased efforts from private industry. From 2005 to 2009, the number of thin film companies significantly increased from 130 in 2007 to over 200 in 2009.[85] At the same time, their respective market share increased from 6% in 2005 to 10% in 2007 to 16-20% in 2009.[86] It is worth noting that beginning in this period and extending through the present day, c-Si has maintained the largest market share (approximately 90%) and a significant share of R&D. C-Si research shifted to alternative techniques for processing the feedstock and reductions in the Si consumption for the production of the cells. Additionally, c-Si research included the use of different substrate materials, decreases in the wafers' thickness and the development of larger area cells.

40 During FP7, thin-film cells still had prominence as a recipient of R&D funding. However,

80 Jäger-Waldau, *PV Status Report 2017* (Luxembourg: Publications Office of the European Union, 2017).

81 Hubert Aulich, Friedrich-Wilhelm Schulze, "Silicon feedstock for the photovoltaic industry", *17th European Photovoltaic Solar Energy Conference and Exhibition,* 2001, Munich.

82 Wolfgang Koch, Peter Woditsch, "Solar grade silicon feedstock supply for PV industry", *17th European Photovoltaic Solar Energy Conference and Exhibition*, 2001, Munich.

83 Peter Woditsch, Wolfgang Koch, "Solar grade silicon feedstock supply for PV industry", *Solar Energy Materials & Solar Cells*, vol. 72/1-4, 2002, 11.

84 For example, see FP5 PV projects: SOLSILC, SPURT and NESSI.

85 Data drawn from: Arnulf Jäger-Waldau, *PV Status Reports*, issued by the JRC (2008-2012).

86 *Id*.

concentrator photovoltaics (CPV) gained the second highest share of PV R&D funding, 31% of the total. Under FP7, several collaborative projects with Japan, India, and Mediterranean countries on CPV were funded. CPV had been known for several decades, as demonstrated by the existence of research projects beginning with the first R&D programme. CPV had also earned the attention of private industry, with several companies worldwide working on CPV. Isophoton, a Spanish company, had specialised in CPV for several decades, whereas CPV was also developed in California and by Sharp in Japan. Therefore, further research that will determine why CPV gained prominence during FP7 is required.

CONCLUSIONS

41 Our research has shown that the EC energy policy directed research policy and the research priorities, partly unintentionally. Research priorities and strategies were configured and reconfigured in response to either energy policy targets or to energy crises and the challenges that they imposed on national and transnational energy systems. Our approach has stressed the importance of researching the funding scheme and the political economy dynamics in the making of the technologies. Research capabilities and choices significantly shaped the market of RES technologies by setting the technological characteristics of the innovations, and by legitimising certain technical options while excluding others (e.g. prioritising the cell materials for PV and the scale for WT). We argue that market interests and transnational competition, especially during the second period, drove the innovation of RES technologies. The funding schemes developed by the EC configured knowledge networks that create knowledge, social and cultural capital, and that directed technological change in the RES technologies along specific technological styles.[87]

42 The first R&D programme was created shortly after the first oil crisis to explore other potentially viable energy options. However, it was not until FP5 that energy policy was truly shaped in tandem with research policy. Since FP5, the EC's energy policy objectives have slowly come to influence the research objectives and define the research priorities of funded projects. During the second period, the EC funded research that assisted the RES transition in response to various problems and concerns (e.g. environmental, societal). This choice was deeply influenced by energy policy, which cast the vision for the RES transition. The close relationship between energy and research policies can also be traced to the merger of the RD&D sub-programmes.[88] This merger, in turn, strengthened the integration of energy and research policies, as well as the changing research priorities for RES. Moreover, with the merging of the two sub-programmes, research that could shorten the value chain was prioritised (i.e. develop near-market products directly from research projects). This was primarily expressed through the continual emphasis placed on innovation and the interconnection of research with the market and industrial production. This also becomes evident in the RES research policy by the recurrent efforts to facilitate the integration of RES technologies to the electricity grids and the implementation of both PV and WTs (i.e. wind power plants and increase in cell efficiencies).

Throughout this paper we have argued that 43
changes in the funding priorities affected the selection and the character of the specific technologies both for WTs and PV. We have argued that these changes were directly associated with the changing political economy of research and the corresponding visions that favoured specific technological choices in each period. During the first period, research was aiding the industry's competitiveness by strengthening its scientific and technological basis. During

87 See the introduction.

88 RD&D refers to the merge of the R&D and Demonstration programmes in the second period; the importance of the merger lies in how it impacted research and the corresponding themes, as well as the technologies (e.g. prioritising research that could narrow down the gap between research and market). For further information see pages 7 and 15.

the second period, the priorities of EC-funded research changed as it responded to a plethora of environmental and economic challenges. This resulted in various changes in the research priorities both for PV and WTs. For PV, research priorities shifted towards large-scale production and had a strongly industry-led character (i.e. decreasing the time from research to market). Additionally, emphasis was given to projects that promised to deliver applicable end-products and not merely research results (i.e. applied research rather than «open skies» research), which could be directed towards assisting the industry's global competitiveness and increasing its manufacturing capacity. WT research shifted its focus to large wind farms and their integration into energy supply systems, in order to facilitate the transition towards RES.

44 In both cases, we illustrated that a crisis can significantly impact the selection of research pathways and, thus, of the relevant technologies. For WE, the oil crises influenced the selection of large-scale WTs which could compete with fossil fuel power plants. The silicon crisis in PV (2004-2008) significantly impacted both the selection and prioritisation of thin-film cells and the research priorities of the formerly dominant c-Si cells. Even though thin-film PVs still hold a modest market share, during the years of the silicon crisis their market share and pace of diffusion increased, although c-Si remained dominant. Our work has shown that there was an emphasis on funding research projects that would reduce the time needed to turn research and experimentation into innovations. That means that the emphasis was on provisions that would facilitate the market deployment of research results.

Furthermore, our research corroborates Mazzucato and Semieniuk's argument that stresses the importance of mission-oriented innovations. We have shown that funding schemes promoted mission-oriented RES innovations since they were steered by the oil crises, energy supply security and, later, were influenced by energy policy and the fast implementation of the RES transition. Public financing, in the form of EC R&D funding schemes, has been highly risky.[89],[90],[91] In the case of WE, this was illustrated by the consistent funding of constantly upscaled, and larger, WTs. The larger scales funded were not yet commercial nor was their 'successful' commercialisation certain. In the case of PV, even when the R&D programmes favoured c-Si, they nevertheless continued to fund other materials as well. During the second period, the EC took a huge risk by devoting the bulk of its funds to thin-film cells, which were a high-risk investment because they did not yet have a significant market presence. Yet, our research goes beyond the types of innovation activities promoted through public funding schemes identified by Mazzucato and Semieniuk, by stressing the importance of transnational competition in shaping funding priorities and thus innovation pathways. 45

89 Booth, *Evaluation of the JOULE Programme*, *op. cit.*, 130 (cf. note 73).

90 Directorate General for Research and Innovation, *Non-nuclear energy programme (1990-94) JOULE II – Vol 1* (Luxembourg: Office for Official Publications of the European Communities, 1997), 75.

91 Nicholas Chrysochoides, *et al.*, *Clean, Safe and Efficient Energy for Europe: Impact assessment of non-nuclear energy projects implemented under the Fourth Framework Programme* (Luxembourg: Office for Official Publications of the European Communities, 2003), 8.

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Journal of Energy History
Revue d'histoire de l'énergie

VARIA

ISSN 2649-3055

JEH RHE

Journal of Energy History
Revue d'histoire de l'énergie

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POST DATE
22/09/2020

ISSUE NUMBER
JEHRHE #4

SECTION
Varia

KEYWORDS
Gas, Territory, Pollution, Capitalism, Sustainability

DOI
in progress

TO CITE THIS ARTICLE
Nicholas Z. Muller, Joel A. Tarr, "The McKeesport Natural Gas Boom, 1919-1921", *Journal of Energy History/Revue d'Histoire de l'Énergie* [Online], n°4, published 22 September 2020 URL: energyhistory.eu/en/node/225.

The McKeesport Natural Gas Boom, 1919-1921

Abstract

This article explores a short-lived but major natural gas boom in the area of McKeesport, Pennsylvania. The discovery and exploitation of natural gas resources often displays a boom and bust cycle characterized by a rush of investment and production followed by resource exhaustion and falling prices. The McKeesport boom was especially noteworthy not only because of the copious production of the initial big well but also because the field was quite short-lived due to the closeness of the drilling and herd behavior of the drillers. Drillers and investors disregarded expert warnings about the limits of the resource. An enduring legacy of the McKeesport boom was a long-term environmental hazard of orphan wells. The lessons of this analysis of the McKeesport boom may provide guidance for current environmental regulators facing the promises of promoters of unlimited natural gas resources.

Plan of the article

ISSN 2649-3055

INTRODUCTION

1 Natural resource extraction often follows a boom-and-bust cycle. A new discovery or technological innovation leads to a rush of investment and production. In time, falling prices or dwindling reserves result in stalled activity. The cycle repeats with new discoveries, innovations, or rebounding prices. One such event, triggered by discovery of a major natural gas well, occurred in the McKeesport area just south of Pittsburgh, Pennsylvania from 1919 to 1921. While natural gas booms were not necessarily unique, the McKeesport boom was especially dramatic not only because of the production of the initial big well but also short-lived because of the closeness of the drilling and herd behavior of the drillers. As the unusual and detailed quantitative historical record shows, the gusher erroneously convinced property owners and investors alike that exorbitant profits awaited the investor who sunk the next well. The rush was on.

2 The present paper uses a unique database, digitized from historical field performance data, to quantify the frenzy. More specifically, a detailed production chart first published in the February 1921 issue of *Natural Gas*, a trade journal, has been digitized for the quantitative analysis executed in this study. These data include daily and total field production, as well as the number of dry, producing, and total wells. This dataset provides a unique, micro-level depiction of the performance profile of the field and evidence of its rapid exhaustion. Within the current generation, the Pittsburgh region is experiencing a boom in natural gas production caused by the application of hydraulic-fracturing and horizontal drilling technology[1]. This more recent episode is far larger in scope and its consequences, both financial and environmental, considerably more far-reaching.

3 Though the two episodes are separated by nearly a century, and they differ in important ways, this article emphasizes three features of the McKeesport boom that may help inform present decision-making. First, we document the extent to which herding behavior, rather than reasoned investment, governed decision-making during the McKeesport boom. This involves three points. The rate at which new wells appeared in the field was associated with recent drilling, whether the recent wells were successful or not. (This aspect of the analysis is enabled by the new, digitized data noted above.) Even early in the boom, cost and revenue estimates suggest the rate of return on new wells was negative. And, official forecasts by state geologists of the field's limited capacity and short remaining life were ignored.

Second, we argue that land use, specifically densely sub-divided land, exacerbated over-investment. Drilling decisions by individual leaseholders and landowners neglected the negative depressurization externalities that coordinated management could have avoided. Third, the McKeesport boom left an enduring environmental hazard in the form of orphaned wells. In the throes of the frenzy, considerations of long-term impact were absent. All three of these features have clear connections to the present. 4

Other boom and bust cases of natural gas development reinforce the conclusions of this paper regarding exaggerated forecasts of future supply, disregard of expert warnings, concern over site development, the failure of governmental regulation and improper capping plugging of wells, leading to methane leakage. 5

NATURAL GAS IN PENNSYLVANIA AND THE MCKEESPORT POOL

The discovery and exploitation of natural gas in the Pittsburgh region began in the late 1870s and extended into the 20th century. Drillers seeking oil and salt in the northwestern corner of Pennsylvania had discovered natural gas in the 1860s and occasionally used it to heat boilers and power drilling equipment. However, gas was largely flared, or burned off, because of a lack of demand. In the mid-and-late 1870s, drillers found substantial gas supplies in Butler, Armstrong, and Clarion Counties closer to industrial users. 6

1 See, "Fracking in Pennsylvania", *Ballotpedia, Digital Encyclopedia of American Politics and Elections*. URL: https://ballotpedia.org/Fracking_in_Pennsylvania.

Iron manufacturers in the Pittsburgh region began bringing gas into their mills by pipeline. The use of natural gas rather than coal to provide heat had cost and convenience advantages, and other mills and glass works soon followed[2].

7 In the late 19th century, Pennsylvania was the largest producer of natural gas in the nation. In the 1880s, drilling for natural gas increased throughout the state with most wells located in southwestern Pennsylvania where geological features were conductive to the pooling of gas. By 1897, there were 2,467 gas wells in the state operated by 176 producers: a number that increased to 12,255 wells with 1,174 producers in 1913. The state reached its maximum total gas production in 1906, a year when residential and industrial consumption exceeded state production. Intuitively, prices rose. In 1906, the average price per thousand cubic feet of natural gas was 13.4 cents. It increased to 18.25 cents in 1913, as demand continued to exceed supply[3].

8 Many of the wells drilled in western Pennsylvania were located in the Pittsburgh Quadrangle, a geological area of 227 square miles that includes most of southeastern Allegheny County and small sections of Washington and Westmoreland Counties. Drillers included both small operators and large, such as the Philadelphia Company, the Peoples Natural Gas Company, the Carnegie Natural Gas Company and the Manufacturers Light and Heat Company. These firms sought oil as well as natural gas. Extensive drilling in this quadrangle took place in the late 19th century and into the 20th but declined considerably because of lower prices. After approximately 1912, however, and after the beginning of World War I in 1914, gas prices increased as did the pace of drilling[4].

Natural gas is commonly associated with anticlines, roof-shaped folds of the containing rock. The McKeesport gas pool was located on the Murrysville anticline and was part of the historically productive Murrysville field. Natural gas and oil deposits are located in what geologists called sands, some identified by the name of the sand's discoverer. The most productive sand in this anticline was the Speechley sand. This deposit was between 20 and 50 feet thick, located at a depth of 2,325 to 3,000 feet. It had a porosity of approximately 5 to 18 per cent. Between 1915 and 1919, extensive gas drilling developed in several western Pennsylvania sands including the Speechley, Hundred-foot, Murrysville and Elizabeth sands in North Versailles Township and Versailles borough in Allegheny County. Drilling in the deeper Speechley sand began in 1919[5]. 9

DRILLING, FIELD PRODUCTION, AND HERD BEHAVIOR

On April 19, 1919, the Philadelphia Company, a major natural gas utility, was drilling on a farm in the Snake Hollow district of North Versailles when it struck a well that initially produced approximately 1,500,000 cubic feet (cf) of gas[6]. While a large producer, this well was soon exceeded in production by the "Big Well," drilled on a nearby site on August 23, 1919 by wildcatters David A. Foster and Samuel J. Brendel. The Foster and Brendel well struck gas at 2,239 feet and had an initial production of 4,000,000 cf per day, increasing to a maximum of 56,117,000 cf. The well was quickly connected to the nearby pipeline of the Peoples Natural Gas Company at a contract price of 17 cents per thousand cf, reducing the amount of wasted gas. In November of 1920, over one year after it was sunk, about one third of the total gas extracted from the McKeesport pool had been produced by the "Big Well."[7] 10

2 Joel A. Tarr, Karen Clay, "Boom and Bust in Pittsburgh Natural Gas History: Development, Policy, and Environmental Effects 1878-1920", *Pennsylvania Magazine of History and Biography*, vol. 139, 2015.

3 Pennsylvania Topographic and Geologic Survey Commission, *Oil and Gas Map of Southwestern Pennsylvania. 1915* (Harrisburg, Pa: Wm. Stanley Ray, State Printer, 1916), 16-18.

4 Meredith E. Johnson, *Geology and Mineral Resources of the Pittsburgh Quadrangle* [hereafter cited as Johnson, *Pittsburgh Quadrangle*]. *Pennsylvania Geological Survey Atlas of Pennsylvania, n°27* (Harrisburg, Pennsylvania: Bureau of Topographic and Geological Survey, 1929).

5 Johnson, *Pittsburgh Quadrangle*, 120-123.

6 A.M.T., L.B. & J.J.M, "McKeesport Gas Field Snake Hollow District, May 12, 1920", (Harrisburg: Bureau of Topographic and Geological Survey, mimeo)

7 Johnson, *Pittsburgh Quadrangle*, 123.

11 The magnitude of the gas produced by the "Big Well" and several other nearby wells was especially significant because of a national fuel crisis provoked by World War I and a growing natural gas shortage. In late 1918 the Public Service Commission of Pennsylvania published a report on the "Present and Prospective Supply of Natural Gas Available in Pennsylvania". This report warned that demand for gas from both domestic and industrial users was increasing as the volume of gas from producing wells declined and fewer new wells were drilled[8]. In the context of rising gas prices and reduced supply, the discovery of the "Big Well" set off a frenzy of wildcat drilling in North Versailles, Versailles, and other townships in the McKeesport region. (Figure 1 shows the density of drilling in McKeesport.)

12 William Alvin White wrote in *Collier's Magazine* that "Instantaneously and simultaneously every person became gas crazy" as an epidemic of "gas fever" spread throughout McKeesport and beyond[9]. Hundreds of companies selling gas stocks formed, and they marketed securities in barbershops, department stores and on street corners (see figure 1). The *Pittsburgh Post-Gazette* wrote that "scores of bunko men and clever swindlers" selling gas stocks were operating in the city. By Jan. 10, 1920, 297 companies had been formed to drill in this district. Churches and school boards leased land for wells and large sums were offered for leases a mile or so from the gusher. Two daily newspapers focusing on gas issues began publishing in McKeesport and a weekly gas magazine started in Pittsburgh[10].

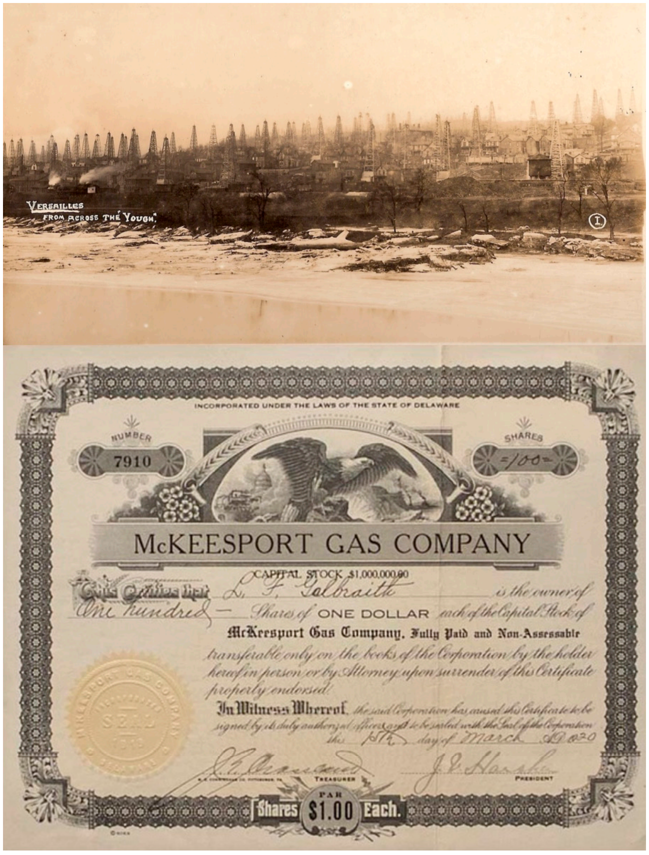


Figure 1: Wells in the McKeesport Pool and Stock Certificate. Source: Top Panel: McKeesport Historical Society. Bottom Panel: "McKeesport Natural Gas Boom and Stock Certificate," used with permission of the American Oil and Gas Historical Society.

DETERMINANTS OF DRILLING

13 To quantify drilling and extraction behavior, figure 2 plots three time series: the number of productive, dry, and capped wells. These data are a digitized version of Chart No. 1 from *Natural Gas* of February, 1921[11]. From the summer of 1919 until the spring of 1920, there were fewer than 50 dry and producing wells. Drilling then ramped up quickly. By the summer of 1920, over 300 wells had been drilled. By late 1920, there were more than 600 wells, with roughly one-third producing and the remainder dry. Ominously, from April of 1920 onward, the rate of increase in additional dry wells far exceeded that of successful wells. Further evidence of the futility of drilling evinces in the rate of increase in the number of capped wells. In the late spring of 1920, the count of capped wells surpassed that of both dry and productive wells. Figure A1 in the appendix demonstrates that from autumn of 1919 onward, the rate of successful wells in the McKeesport pool was lower than the statewide average success rate for Pennsylvania between 1908 and 1913.

8 Samuel S. Wyer [Chief Natural Gas Conservation, U.S. Fuel Administration], *Present and Prospective Supply of Natural Gas Available in Pennsylvania* (Washington DC: Dec. 28, 1918), 3-4.

9 William A. White, "McKeesport - A City Aflame", *Collier's Magazine*, vol. 65, Mar. 27, 1920, 15.

10 *Pittsburgh Post-Gazette*, April 4, 1920.

11 J. French Robinson, "Production of the McKeesport Gas Pool", *Natural Gas*, vol. 2, 1921, 3-6.

14 Figure 3 plots the daily production from the field. In 1919, daily production increased, with some variation, as the few new wells drilled were productive. However, production quickly plateaued at about 60 million cf. This level of output was maintained for only a few months, before daily yield dropped precipitously. By the summer of 1920, production was roughly 20 million cf. More modest declines in production occurred throughout 1920 to 1921. Combining figures 2 and 3 reveals that average production dropped even more rapidly, as daily production fell while the well count climbed.

The data plotted in figure 2 are next used to explore the determinants of drilling. Table 1 reports the results of a series of regression analyses intended to characterize the factors affecting the field-wide well count. The models employ first-differenced data because the well series exhibit non-stationarity over the approximately 450-day sample period. All three series are stationary in first-differences, which enables inferences as to the relationships among the series. 15

Each of the models control for time trends, and effects specific days of the week, and the days 16

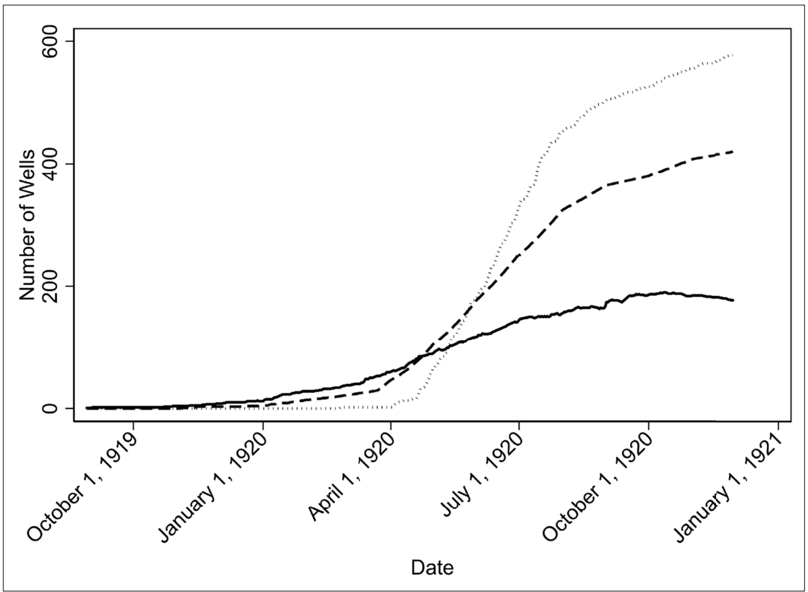


Figure 2: Drilling in the McKeesport Pool.
Solid: Producing Wells.
Dash: Dry Wells.
Dot: Capped Wells.
Source: Natural Gas, 1921; Authors' calculations.

Well Control	One Week	Two Weeks	Three Weeks	Four Weeks
Producing	-0.22[A]	-0.387	-0.811	-0.851
Well	(0.191)[B]	(0.347)	(0.475)	(0.542)
Dry	1.045***	1.036***	1.072***	0.993***
Well	(0.199)	(0.248)	(0.301)	(0.363)
Capped	0.029	0.048	0.077	0.049
Well	(0.077)	(0.108)	(0.12)	(0.157)
Time Trend	Y[C]	Y	Y	Y
Day of Week	Y	Y	Y	Y
Day of Month	Y	Y	Y	Y
Season	Y	Y	Y	Y
R^2	0.679	0.704	0.735	0.758
Obs	452	445	438	431

Table 1: Determinants of New Well Drilling.
A = sum of coefficients over lags of length indicated in each column heading.
B = robust standard errors in parenthesis.
Dependent variable is first difference in total wells drilled.
All well controls first-differenced.
* = p < 0.10; ** = p < 0.05; *** = p < 0.01.

of the month during which drilling occurred. Of central interest is how the well count on a particular day (t) corresponds to lagged measures of drilling activity. The columns in table 1 correspond to different lag lengths for measures of both producing and dry wells. For example, column (1) includes the count of producing, dry, and capped wells within the past week. This model shows that the number of recently drilled productive wells (those drilled within the last week) has no significant effect on whether new wells are drilled. The negative sign on the productive well coefficient is particularly interesting. This may suggest that a new well sent a discouraging signal to market participants. Perhaps recognizing the finite nature of the field, a new "wet" well implied an incremental reduction in the likelihood of hitting the next gusher.

17 In contrast, the number of dry wells does significantly affect the count of new wells ($p < 0.01$). The coefficient suggests that for every one dry well sunk in the past week, investors were likely to drill an additional well. This result reveals an important aspect of investor and driller behavior. Simply the fact that others were sinking new wells into the field stimulated additional drilling. More dry wells meant that the next big strike could still be on the horizon. To make that strike, one simply had to keep drilling.

The remaining three columns of table 1 reinforce this finding. When the lag length is extended to two, three, and four weeks, the same result holds. New productive wells did not significantly influence the decision to drill. Dry wells did. An additional failed investment (a dry well) erroneously bolstered investors' sense of their chance of hitting the next gusher. These econometric results convey the essence of the race that characterized the boom. 18

COSTS, REVENUES, AND THE RATE OF RETURN ON WELLS

The preceding sections demonstrate that the majority of wells drilled after June of 1920 were not productive. This section collects available cost and pricing data and combines that with the production data in figure 3 to estimate the time needed for investors to break even on investments in drilling. Here, we use the average productivity of a well and calculate the total revenue as the product of the price of gas times average daily production. We then report when total revenue equals initial cost. This clearly differs from the perspective of market participants. For example, drillers may have estimated investment recovery periods assuming average productivity *at the time of drilling* would continue at that level into the future. This stands in contrast to 19

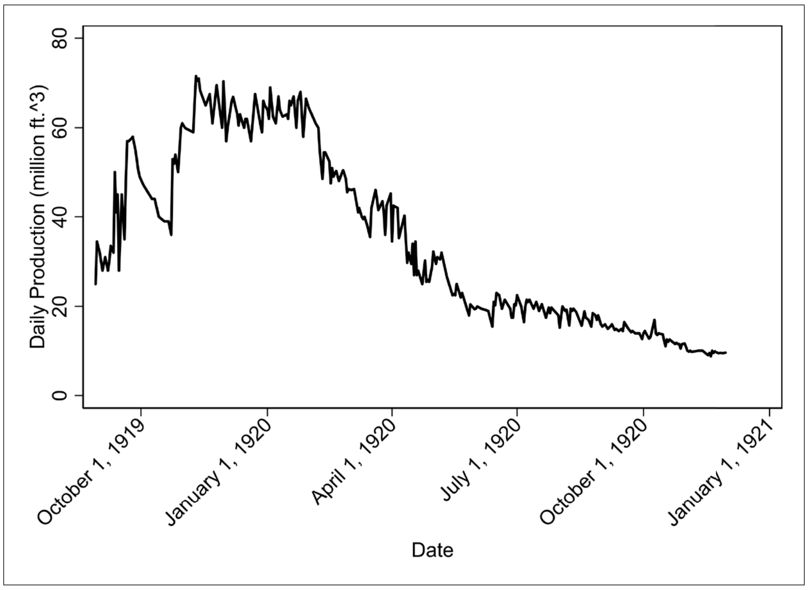


Figure 3: Daily Production from the McKeesport Pool.
Source: Natural Gas, 1921; Authors' calculations.

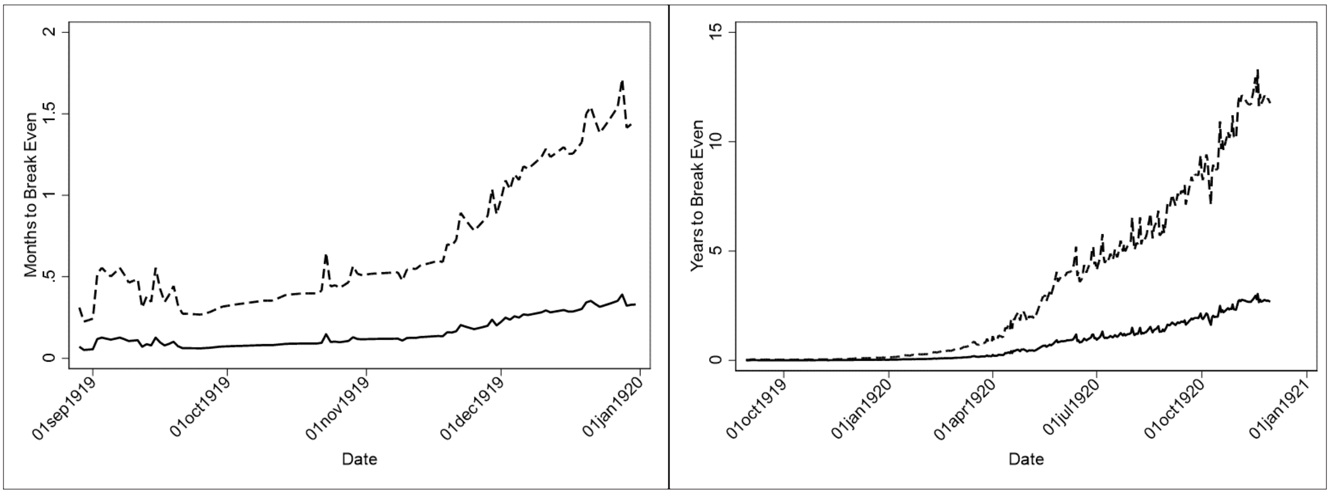


Figure 4: Net Revenues and Break Even Points.
Left panel: months to zero net revenue assuming high fixed costs (dashed line) and low fixed cost (solid line).
Right panel: years to zero net revenue assuming high fixed costs (dashed line) and low fixed cost (solid line).
Source: Authors' calculations.

actual production subsequent to drilling which, as figure 3 shows, fell quite quickly throughout much of the sample. Because of a lack of available data, we assume zero variable cost. As such, these estimates are biased downwards. That is, our estimates will tend to suggest shorter than actual breakeven times.

20 The initial costs of the first wells were relatively low – the "Big Well" cost approximately $8,000 and many of the early wells cost less than $15,000. As drilling increased, however, drilling contractors doubled and tripled their fees as the boom increased. By January 1920, most wells were capitalized at between $30,000 and $40,000. The gas was sold at prices from 10-18 cents per thousand cf with an estimated average of 15 cents[12].

21 Figure 4 shows the estimated time to recovery of fixed cost. The left panel focuses on the first four months of data. From late August, 1919 to January 1920, at a capital cost of $8,000, payback took less than one month. Even assuming the much higher investment cost of between $30,000 and $40,000 per well, during the early life of the pool, payback occurred in under two months. Despite these seemingly promising conditions, state geologist George H. Ashley predicted that wells sunk after January 1, 1920, four months after the initial gusher, would not produce enough gas to pay dividends[13].

The right panel of figure 4 encompasses the full 450-day time series. Using the high capital cost assumption suggests that payback times had stretched to over 5 years by June, 1920. For wells drilled later in 1920, breakeven would not have happened until over ten years. Given that the effective life of the field ended prior to the projected payback period, the rate of return on such wells drilled late in the field was assuredly negative. 22

It is highly unlikely that rational investors would have elected to keep sinking wells given these market conditions. These data build the case that reasoned balancing of probabilities, benefits, and costs did not have an appreciable role in extraction decision-making. Market participants were in the throes of a frenzy. 23

The gross inefficiency of this behavior is best summarized in the following way. J. French Robinson, former state geologist and later geologist for the Peoples Natural Gas Company, 24

12 Johnson, *Pittsburgh Quadrangle*, 131.

13 George H. Ashley, "Development and Probable Life of Gas Pool at McKeesport, Pennsylvania", *Bulletin n°3*, Bureau of Topographic and Geological Survey, Harrisburg, Pennsylvania 1919, 3.

estimated in 1925 that the field's total production, with the aid of pumps, was 21 billion cf. Using the estimated average price of 15 cents, the total value of gas extracted was $3,500,000. The estimated cost of drilling the roughly 600 wells in the digitized data averaged out to approximately $13 million dollars[14]. This immense loss to investors in the field was concentrated among those who were latecomers. One natural gas expert noted that over-drilling had resulted in twenty times the amount of money being spent that was necessary to develop the field[15]. Clearly, the productive labor and capital deployed after the middle of 1920 would have been better used elsewhere.

25 It is of interest to know how the McKeesport experience influenced natural gas markets at the time of the boom. For instance, an extraction pattern characterized by boom-and-bust rather than steady rates of production may yield excessive price volatility which would adversely affect consumers *and* investors. Unfortunately, we lack the fine-grained pricing, production and cost data (beyond McKeesport) to quantitatively determine whether the boom affected prices, exploration, and investment in other fields. We can reasonably conclude that gas prices in and around the Pittsburgh market were affected. This claim rests on two facts. First, extraction from the "Big Well" comprised an appreciable share of regional production. And two, is quite likely that the large quantity of gas produced in the early days of the boom would have alleviated the supply shortage experienced by both domestic and industrial consumers.

26 The present analysis demonstrates how one well influenced drilling behavior within the field. We cannot conclusively say how McKeesport affected investment in other fields. However, news of the "Big Well" did reach national media markets. Hence, there was at least the potential for broader effects on the supply-side of the natural gas industry.

14 Johnson, *Pittsburgh Quadrangle*, 127.
15 "McKeesport's Gas Spectre", *Gas Age*, Jan. 25, 1921, 65.

THE ROLE OF EXPERTS

Rampant drilling occurred despite attempts from government experts to manage the boom. State Geologist Ashley noted that properly drilled wells should be on sites of 80 acres or more and warned in both state reports and the newspapers in November and December of 1919 that over-drilling would exhaust the gas field in less than two years. In a report published in late November, 1919, Ashley noted that "the practice of punching the sand as full of holes as a colander" would accelerate the inevitable decline of the field. This warning seems to have been, according to Ashley, either "overlooked or purposely suppressed". A statement implying that the field might last "a dozen or a score of years" replaced it[16]. Ashley again predicted that subsequent wells would result in significant financial losses. He buttressed this prediction with pressure measurements from the pool showing declines of roughly five pounds per day[17]. 27

Despite this official guidance, within a period of fifteen months after Ashley's warnings over 600 wells were drilled in an area that ten could have drained. Many in the gas business questioned Ashley's predictions, noting that he had failed to anticipate the boom and was possibly wrong in his predictions regarding its longevity[18]. However, while some of the early wells were productive, most were quickly exhausted as maximum daily output of the field at around 70 million cf was maintained for only about one month. Even with productive wells, the forecasted production was usually double the actual production. This fact 28

16 George H. Ashley, "Decline of McKeesport Gas Pool", *Bulletin n°4*, Pennsylvania Bureau of Topographic and Geologic Survey, Harrisburg, Pennsylvania, December 26, 1919; George H. Ashley, "Decline of McKeesport Gas Pool", *Bulletin n°4*, Pennsylvania Bureau of Topographic and Geologic Survey, Harrisburg, Jan. 12. 1920, rev. June 1922. These are consecutive Bulletins issued by the Pennsylvania Bureau of Topographic and Geologic Survey each with a title and date, as indicated.
17 George H. Ashley, "The McKeesport Gas Pool Allegheny County, Pennsylvania", *Bulletin n°5*, Pennsylvania Bureau of Topographic and Geological Survey, Harrisburg, Jan. 12. 1920, rev. June 1922, 4.
18 "Antagonism to State Geologist," *The Gas Age*, 1920, 234.

underscores the apparent divergence between our calculations of the time to investment recovery and the records showing continued rampant drilling. Hence, Ashley's predictions, while both ignored, and derided, were borne out, leading the most prominent journal in the field, *The Gas Age*, to note that, "It doesn't do to laugh at the experts, who generally have the last laugh[19]."

29 The preceding three subsections make clear the inefficiencies and irrational behavior associated with the McKeesport boom. The first conclusion drawn from the McKeesport experience relevant to decision-making today is that initially high returns to investment can so enthrall market participants as to seemingly suspend rational choice. State Geologist Ashley, in his report of January, 1920, described McKeesport after the first major strike as having a "wild-west stock selling boom." Pittsburgh newspapers were filled with ads for gas stock, with promises of "phenomenal returns on small investments".[20] The returns to the "Big Well" convinced investors that the next mother lode was there for the taking, new dry wells somehow meant greater chances for success; that negative net revenue did not matter; and that expert advice was wrong. In short, the behavior of market participants in the McKeesport boom argues for a robust regulatory role in natural resource extraction. Allowing market forces to operate in an unfettered fashion led to huge financial inefficiencies.

THE ROLE OF LAND USE

30 One of the unusual characteristics of the McKeesport site was that in the previous three decades much of the land near the location of the "Big Well" had been subdivided into small lots (see figures 1 and 5), often only 25 feet wide, and sold at low prices. Much of the Speechley Sand was located in the township of North Versailles, and Allegheny County real estate records show that of the 5,293 total building lots recorded in the 8.03 square mile township of North Versailles in 1936, 3,980 had been recorded between 1896 and 1915. Only 23 were recorded from 1916-1925, suggesting heavy residential subdivision and building before the gas boom[21]. This land use context contributed to the over-investment in the field in two ways. First, the autonomy of multiple landowners meant that no one manager or firm optimized efficient investment and extraction decisions *at the pool level*. The externality imposed by each additional well in terms of lowered pressure and reduced yields was ignored. Had drilling occurred on much larger plots (as in a rural setting) it is likely that fewer wells would have been sunk. Multiple wells on larger plots would internalize the costs of lowered pressure, decreasing the incentive to drill. This would mitigate pool-level inefficiency.

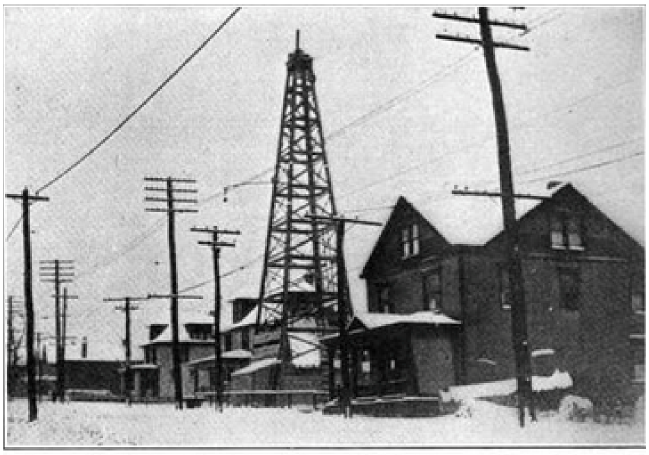
Second, wells drilled in close proximity to one another meant that new wells were common knowledge. Derricks were visually obvious (see figures 1 and 5). Fear that one's neighbor might hit the next big well no doubt fueled the rush particularly given the adherence to the Rule of Capture in Pennsylvania. This controversial but widely accepted rule in the U.S. maintained that the owner of a tract of land acquires title to the oil and gas produced from wells drilled there but not to the oil and gas that migrates to an adjacent location. 31

The influence of Foster and Brendel's "Big Well" cannot be overplayed. The success of the "Big Well" resulted in gas companies, both new and old, frantically seeking leases on nearby sites. With no overarching management, the 864-acre Speechley sand began to resemble a pincushion of derricks with the more than 600 wells averaging 1.3 acres per well. Close proximity to a 32

19 Ibid.

20 George H. Ashley, "The McKeesport Gas Pool Allegheny County, Pennsylvania", *Bulletin n°5,* Bureau of Topographic and Geological Survey, Harrisburg, Pennsylvania, Jan. 12 1920, rev. June 1922.

21 *Real Estate Statistics for Allegheny County, Pennsylvania Base Book, 1936* (Pittsburgh, Pennsylvania: University of Pittsburgh Press, 1936), 10; George H. Ashley, J. French Robinson, *The Oil and Gas Fields of Pennsylvania* (Harrisburg: Bureau of Topographic and Geological Survey, 1922), 66. A striking example of excessive subdivision of the land and drilling for oil on small plots with disastrous results was in Galicia in the 1870s and 1880s. See Alison Fleig Frank, *Oil Empire: Visions of Prosperity in Austrian Galicia* (Cambridge: Harvard University Press, 2005), 61-68.



New Well in McKeesport

Figure 5: Example of Proximity of Drilling to Residential Real Estate in the McKeesport Pool.
Source: Jennings, E. C., "Newton Gets the Gas Fever," *The Gas Age*, 1920, 130.

producing well, however, did not guarantee gas, since the Speechley sand lacked connectivity of its pools and uniformity of its reservoirs[22]. Hence, as depicted by figures 2 and 3, the vast majority of wells drilled subsequent to Foster and Brendel's well were unsuccessful.

33 Herein lies the second important lesson drawn from the McKeesport experience for current decision-makers. Allowing unmanaged extraction in dense urban or suburban land uses is especially likely to yield inefficient extraction and significant external cost.

ENVIRONMENTAL EFFECTS

34 The state of Pennsylvania began regulating natural gas drilling to a limited extent in the Natural Gas Act of 1885. Companies organized under the act had the right of eminent domain. The Act contained specific terms regarding the sealing and plugging of abandoned wells, with a $200.00 fine if the regulations were not followed. While no governmental agency was tasked with its enforcement, the Act provided that if a well was left unplugged the owner of adjacent lands or "in the neighborhood" of the well could plug it at the cost of the original owner. The motivation for this feature appears to have been to avoid waste and to prevent flooding of adjacent wells. In 1891, the state legislature passed another act requiring the plugging of wells that were abandoned or not operating. Violation of the act was a misdemeanor. In 1921, the legislature passed further legislation regarding plugging well and protecting existing wells from water entering from new drilling[23].

Little enforcement of these regulations seems to have taken place. The rapid expansion of well digging in the McKeesport pool resulted in a failure by many companies to satisfactorily case their wells. Many wells flooded with water. Other drillers who found only limited gas abandoned their wells and neglected to plug them according to state law. Gas leakage fouled the air and well fires were frequent[24]. By the end of the period under examination, Pennsylvania natural gas production was sharply down. 35

An enduring legacy of the McKeesport boom is continued methane leakage from well sites, pipelines and other gas appliances. The current concerns are two-fold: methane is a potent greenhouse gas, and continued leaks pose safety and health risks. Concern in the past, however, related primarily to the fact, as the 1927 *Natural Gas Handbook* noted, "gas leaking into the atmosphere means a continual loss in money," although gas explosions were also an issue[25]. 36

22 George H. Ashley, "The McKeesport Gas Pool Allegheny County, Pennsylvania", *Bulletin n°5,* Bureau of Topographic and Geological Survey, Harrisburg, Pennsylvania, Jan. 12, 1920, rev. June 1922, 6.

23 Tarr, Clay, "Boom and Bust in Pittsburgh Natural Gas History".

24 Johnson, *Pittsburgh Quadrangle*, 129. A document in the archives of the Pennsylvania Geological Survey, located in Pittsburgh, entitled, "Plugging of Wells in McKeesport Gas Field", lists approximately 500 wells that were plugged mainly in 1920. The entries for each well include information such as the name of the well owner or lessee, the name of the plugger, the date of the plugging, the depth of the well, and some information about casing. There is no information on the document about who compiled it but is can be assumed that the Pennsylvania Geological Survey collected and compiled the information.

25 Ramón A. Alvarez, *et al*. "Assessment of Methane Emissions from the U.S. Oil and Gas Supply Chain", *Science*, vol. 361, n° 6398, 2018; John C. Diehl, *Natural Gas Handbook* (Erie, Pa: Metric Metal Works, 1929), 330.

37 Methane leakage was an especially serious problem in natural gas fields located near and in residential areas such as McKeesport and Versailles. The worst problems in regard to methane leakage occurred in the post-World War II period. Many well bores that were never properly plugged had been covered by structures or filled by landowners. In addition, scavengers removed many casings to sell as scrap metal and methane leaked into structures, creating air pollution and explosion hazards. In 2005, problems with methane leakage in Versailles resulted in Congressman Mike Doyle securing federal funding for an investigation by the National Energy Technology Laboratory (NETL). The NETL report identified three types of abandoned wells at the Versailles site: wells never cased; wells with only surface conductors left; and wells with the surface conductors and some casing remaining. The NETL researchers performed geophysical surveys using seismic and magnetic technologies, performed gas analyses from existing vents and wells, and searched for unknown gas leaks and hidden wells. They concluded that "improper well abandonment for many of the 175 [Versailles] gas wells drilled in the Borough provides a mechanism of migration for stray gas detected at the surface[26]." The report concluded with a number of recommendations for identifying gas leaks and remediating them. The NETL investigators, however, only examined the sites of the 175 Versailles wellbores although NETL also estimate that over 1,000 wells were drilled in the McKeesport field. The remainder of the well sites have been left for future study.

38 The third lesson from McKeesport relevant to the current natural gas boom is that insufficient regulatory enforcement may result in enduring environmental hazards. The myopic behavior so pervasive during the boom fundamentally neglects future impacts, either financial (as demonstrated above) or environmental. The result is a future stream of costs ultimately reflected in suppressed property values, required mitigation measures, and non-pecuniary effects. Again, the issue here is an externality produced by extraction; in this case an intertemporal externality rather than the contemporaneous externality of depressurization raised earlier. The regulatory role, then, is a common one: to mitigate the harmful effects on third parties produced by the actions of self-interested market participants.

In the current context, where extraction has evolved from vertical to horizontal drilling and the use of hydraulic fracturing, leakage rates remain a concern. Given the magnitude of natural gas production in the 21st century, the ramifications of leakage are global in reach. Further, the enduring effects of gas field development and production on water quality, disturbances from new rights of way, and ecosystem fragmentation pose significant costs to affected communities. Though the scope and techniques have changed from the McKeesport era to the present, the clear role for regulatory management of externalities remains. 39

CONCLUSIONS

This paper argues that natural resource extraction cycles, which often follow a boom-and-bust pattern, should be regulated. The justification for government intervention stems from two areas. First, there are contemporaneous externalities from pool depressurization and potentially long lasting externalities from environmental damage. Second, the irrationality that seemingly grips market participants yields over-investment and, hence, waste of productive labor and capital. The McKeesport experience highlights both in hyperbolic fashion. Our fixed cost estimates conservatively suggest investment exceeded revenue by nearly a factor of five. This omits variable costs, losses to some shareholders, and the value of leaked gas. Thus, the inefficiency in McKeesport was likely many times greater. Our newly digitized data reveals new wells were drilled when the expected payback period approached ten years. Further, these data show that investors interpreted failed wells as a signal to drill more, expecting the next great strike to be around the corner. 40

26 National Energy Technology Laboratory, *Methane Emissions Project Borough of Versailles, Pennsylvania Final Report* (Pittsburgh, Pa: National Energy Technology Laboratory, 2007).

41 What does McKeesport potentially convey to the present gas boom in the U.S.? We distill three central lessons that are pertinent to current situation. First, large initial returns may induce irrational behavior leading to inefficient outcomes. In the present, this pertains to both firms and private lessors who contract with drillers, allowing extraction on their land holdings with anticipated returns in the form of royalties. Second, unmanaged extraction in dense urban or suburban areas is especially likely to cause inefficient investment and significant external cost. Fortunately, the current boom is focused in rural and ex-urban areas[27]. And third, sub-optimal oversight will generate long-term environmental degradation. Today the focus is on local air pollution, water quality impacts, and the contribution to long-term climatic change. Each of these aspects of the McKeesport experience may inform how firms, communities, and regulators choose to act in the present phase of the natural resource extraction cycle.

27 Erin N. Mayfield, *et al.*, "Cumulative Air, Climate, and Employment Impacts of Natural Gas Systems", *Analysis: Nature Sustainability*, vol. 2, 2019.

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ENERGY SOURCES

ISSN 2649-3055

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Journal of Energy History
Revue d'histoire de l'énergie

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POST DATE
19/12/2019

ISSUE NUMBER
JEHRHE #4

SECTION
Energy sources. News from the Archives and Heritage

KEYWORDS
Knowledge, Electricity Production, Politics, Data

DOI
in progress

TO CITE THIS ARTICLE
Daniela Russ, "The World Energy Council as an Archive for Research on Energy History", *Journal of Energy History/Revue d'Histoire de l'Énergie* [Online], n°4, published 19 December 2019 URL: energyhistory.eu/en/node/147.

The World Energy Council as an Archive for Research on Energy History

Abstract

This paper presents the World Energy Council (WEC) as an archive for research on the history of energy. Since its foundation in 1924, this non-governmental, technical, international organization, organized more than thirty congresses and meetings, published numerous proceedings, statistics, and reports and conducted a couple of major studies and surveys in the field of energy. Stretching over almost one hundred years and covering all technical forms of energy, the WEC constitutes a unique archive for researching energy history today. The purpose of this paper is, firstly, to provide an overview of the variety of material produced by the World Energy Council. Secondly, I identify ways in which historical scholarship can approach this material and benefit from it. Drawing on the experience of textual analysis in the social sciences, the paper distinguishes four approaches. The documents can be approached as a (1) source of information for the history of energy, or be seen as (2) strategic interventions in a debate. Moreover, they can become the basis for an (3) archaeology of knowledge focusing on how they came to be authoritative statements in a discourse on energy. Lastly, they can serve to explore (4) the relation between the making of documents and their function in a discourse.

Plan of the article

INTRODUCTION

1 The World Energy Council (WEC)[1] is a non-governmental, technical, international organization in the field of energy. In 1924, Daniel N. Dunlop, a British electro-technical engineer and director of the British Electrical and Allied Manufacturer's Association (BEMA), initiated the first World Power Conference in the wake of which the organization was founded. Since that time, the WEC has organized more than thirty congresses and meetings, published numerous proceedings, statistics, and reports and conducted a couple of major studies and surveys. Stretching over almost one hundred years and covering all technical forms of energy, the WEC makes for a unique archive for energy history. The main aim of this paper is, firstly, to provide a brief overview of the variety of material – publications and administrative documents – produced by the World Energy Council over the course of the last century. In a second step, I identify ways in which historical scholarship can approach and draw from this material. This paper does not provide a comprehensive overview; instead, I understand this as the beginning of a more systematic approach towards the documents published by the WEC.

2 Scholars working in the field of energy history have likely come across the World Energy Council at some point in their research; they might even have worked with WEC publications. In general, however, historical research has tapped the WEC archive only in a selective and unsystematic manner. One challenge in using WEC documents is that the use of primary sources in historical research requires their critical assessment: who created them, by which means, and for which purpose? However, scholarly work on the WEC as such –its organizational structure, decision making procedure, and its various activities– is still very limited. The two histories on the WEC have been commissioned by the organization itself on occasion of its anniversaries.[2] Wright, Shin and Trentmann's *From World Power Conference to World Energy Council* stands out for how well it embeds the organizational history in the broader historical context. Elsewhere, I have tried to complement these works with a view on the emergence of a global energy economy.[3]

In the following, I give an introduction to the various documents that have been produced by the WEC over the last century. As the largest and longest-ranging series of publication, I focus particularly on conference proceedings and digests. Along with this overview, I provide a table on Github (**https://github.com/Ueberdruss/World-Energy-Council**), which gives the date and topic of the conferences, their table of contents, and information on where they can be accessed. In the second part of this paper, I identify the scope of topics and research questions that can be addressed on the basis of the variety of material published by the WEC by analytically distinguishing four approaches. I conclude that further research on organizational practice, including interviews, would be helpful to situate the documents and understand their origins. 3

THE VARIETY OF PUBLICATIONS

Over the last century, the WEC has published a broad range of material that differs widely in form and content (see Table 1). 4

Three of the publications cover almost the entire period of time: the conference proceedings, the minutes of the International Executive Council (IEC, the WEC's authoritative body, which meets 5

1 The organization changed its name twice from World Power Conference to World Energy Conference in 1968 and to World Energy Council in 1992. Throughout this paper I use only its current name – World Energy Council.

2 Rebecca Wright, Hiroki Shin and Frank Trentmann, *From World Power Conference to World Energy Council: 90 Years of Energy Cooperation, 1923-2013* (London: World Energy Council, 2013). Ian Fells and World Energy Council, *World Energy 1923-1998 and Beyond: A Commemoration of the World Energy Council on Its 75th Anniversary* (London: World Energy Council, 1998).

3 Daniela Russ, "Speaking for the World Power Economy: Electricity, Energo-Materialist Economics, and the World Energy Council (1924-1978)", *The Journal of Global History*, vol. 15, n°2, 2020.

Field of Activities	Documents	Date or Period of Publication
Administration	Minutes of the International Executive Council	1930-1931,1933-2017**
	Minutes of sub-commissions and Working Groups	Depends
Conferences	World Energy Congress*	1924-today**
	Sectional Meetings	1928-1968
Standardization	Survey of International Standardization	1936
	Technical Data on Fuels***	1930, 1955, 1962, 1977
	Standard Terms of the Energy Economy	1978
	Substitutions between Forms of Energy	1985
Statistics	Power Resources of the World	1929
	Statistical Yearbook	1936-1958**
	Survey of Energy Resources	1962-today
	International Energy Data	1990
Journals/Studies/Reports	World Survey	1934
	Forecasts	1974- ca. 1993
	Scenarios	ca. 1998-today
	Energy Trilemma Index	2011-today
	Energy Issues Monitor	2012-today

Table 1: The main activities of the WEC's central office, excluding publishing activities by National Committees. *under various names: World Power Conference, World Energy Conference, World Energy Congress **excluding 1939-1945 ***published by the British National Committee of the World Power Conference

annually), and the statistical survey on power resources. Other publications were temporarily limited, such as surveys on standardization, the results and minutes of sub-commissions and working groups, or the short-lived journal *World Survey*. Recently, the WEC began publishing an annual ranking of energy policy performance, the *Energy Trilemma Index*, and the *Energy Issues Monitor* –a publication that seeks to feel the pulse of the 'global energy economy'.

6 Even though the WEC was renamed World Energy *Council* in 1992 to highlight its broad range of activities, the organization of the World Power Conferences (now 'congresses'), remains the core of the WEC's activities. It is the only time when the organization makes it into the news, and many of the organizational activities are structured around and geared towards the rhythm of the conferences. In the beginning, there were two types of conferences: World Power Conferences and Sectional Meetings. Sectional Meetings were regionally or thematically limited gatherings, which had initially been introduced to "keep up the interest" between the full conferences taking place only once every six years.[4]

4 Polytechnische Schau: Weltkraftkonferenz, *Polytechnisches Journal*, n° 340, 1925, 200-1. Url: **http://dingler.culture.hu-berlin.de/article/pj340/ar340058** (13/11/2019).

In 1968, Sectional Meetings were abolished and full conferences began to be organized in a more standardized fashion every three years.[5] The early conference proceedings came in few, heavy volumes, resembling other documentations of scientific conferences. In the mid-20th century, the WEC experimented with multiple, smaller volumes that could be purchased separately, but still included every single conference paper. It was only in the 1970s that conferences were beginning to be documented in digests, roundups or chronicles –focusing on the glaring moments and 'factual' outcomes.[6]

7 These changes in publication form are interesting in themselves from a media-historical point of view (the discussions touch upon printing costs and technology, the wider circulation of smaller volumes and digests, etc.). However, they also affect the ways in which the conference proceedings can inform historical research. Where full technical papers are given, the proceedings can complement studies in the history of electrification, technology and energy politics. Protagonists that have long been at the heart of national histories of electrification, such as Herbert Hoover, Samuel Insull, Georg Klingenberg, and Aleksandr Kogan, presented at the early conferences. Digests, in contrast, reflect a primacy of organization over individual contributions. They were put together with a view on the entire conference and the intervention the WEC –or the National Committee organizing the meeting– intended to make in a more general discussion. Digests mark the turn from a scientific conference to an organization representing an ever more self-aware industry. From this follows that technical papers, welcoming speeches, and discussions, are comparable to a different degree over the entire period of time.

The second series of publications ranging from the earliest years of the organization until today are the statistics on energy resources, published as *Statistical Yearbook of the World Power Conference* from 1936-1958, and as *Survey of Energy Resources* from 1962-today. From its foundation, the WEC strove to become a "center of calculation"[7] for a world power (later: energy) economy. The idea was pervasive in Dunlop's early plans for the organization and translated into a durable focus on resource statistics. Between 1936 and 1958 the WEC had published nine issues of the *Statistical Yearbook*. However, when the United Nations began to issue its "J" series of Statistical Papers in 1952, the WEC reviewed its statistical work to avoid overlap between the two publications. Starting from 1962, the new publication called the *Survey of Energy Resources* focused solely on resources and – as this information was more long-lived – was issued only once every six years. In the 1970s, the rhythm of publication was synchronized again with the triennial rhythm of World Energy Congresses. 8

Another long-term form of documentation are the minutes of the WEC's International Executive Council (IEC). These are not officially published, but can be accessed through the WEC London Headquarters. The minutes are available for almost the entire period from 1930-2017, with only minor exceptions (see Table 1). Like with other publications, the form of the minutes – their structure, layout, and print– changes over the time, reflecting waves of rationalization and professionalization of the organization. The minutes give information on attendance, speakers, 9

5 World Energy Conference, *Minutes of the Meeting of the International Executive Council*, 1969, Annex 8.

6 By focusing on the documentation of the conferences *in text*, I omit two aspects that would also be interesting for historical research. Firstly, many proceedings contain photographic documentation of the conference highlights, the opening and closing session, dinners and excursions. Secondly, the conferences were often accompanied by excursions to the most notable sights of the 'energy economy', i.e. dams, power plants, mines, etc. in the respective countries. At some occasions, there was an exhibition of the 'national' power technology along with the conference. I did not come across any substantial documentation of these travels or exhibitions (some of the proceedings include a few pages), but I assume there could be more to find with the National Committees organizing the respective conference. For a brief overview of the conferences and excursions see Fells and World Energy Council, *World Energy 1923-1998 and Beyond.*

7 Bruno Latour, *Science in Action: How to Follow Scientists and Engineers Through Society* (Cambridge, MA: Harvard University Press, 1987).

topics, and decisions. Thus, they are especially interesting to study the WEC's own organizational history, as well as its relation to corporations, industries, and (inter)national administration.

10 Starting from the 1970s, the WEC complemented its two major publications –the conference proceedings and resource statistics– with more project-based brochures and reports. There had always been temporally limited publications, such as the short-lived journal *World Survey* (1935), a report on *Power Resources of the World (Potential and Developed)* (1929), a *Survey of National and International Standardization* (1936), or the handbook *Substitutions between Forms of Energy and How to Deal with Them Statistically* (1985) published in cooperation with the Union Internationale des Producteurs et Distributeurs d'Energie Electrique (UNIPEDE). Beginning in the 1970s, the WEC began to organize its work in sub-commissions and working groups. Through the work of the Conservation Commission set up in the wake of the oil crises in 1975, the WEC became for the first time involved in actual studies of the 'energy economy'. The forecasts and energy balances worked out in this commission were published in three reports, *World Energy: looking ahead to 2020* in 1979, *Energy 2000-2020: World Prospects and Regional Stresses* in 1983, and *World Energy Horizons (2000-2020)* in 1989. The Conservation Commission turned into the Study Commission in the 1990s; around 2000 its focus shifted from forecasting to scenario-building.

11 Recently, the WEC initiated two new surveys that are published in short annual reports: The *Energy Trilemma Index* and the *World Energy Issues Monitor*. The *Energy Trilemma Index* ranks countries according to their performance in three dimensions of the 'energy challenge': energy security, energy equity, and environmental sustainability. Apart from the annual reports, there is also an interactive online tool that makes the ranking's variables transparent.[8]

The *World Energy Issues Monitor*, in contrast, is an annual survey among public officials, chief executives and 'leading experts' conducted in the WEC member countries.[9] These experts give their views on the 'world energy agenda', focusing on "macroeconomic risks; geopolitics; business environment; and energy vision and technology".[10] The *Issues Monitor* can also be tailored to match the informational needs of specific industries or regions.[11]

While covering the most important projects, this overview of the WEC's publications is incomplete in two ways. Firstly, the WEC embarked on many different study projects with various cooperation partners, often focusing on a specific industry or problem and resulting in single reports. Not all of these reports have been mentioned here. Secondly, the activities of the national committees are not taken into account here, even though they undertook their own studies and reports. 12

THE SCOPE OF TOPICS AND RESEARCH QUESTIONS

What kind of questions can be asked on the basis of the WEC's documents and what is the scope of research topics that can be addressed? Understanding texts not merely as a source of information, but as discursive documents, shaped by and intervening in a discourse on energy, the WEC's documents can inform very different research questions. Drawing on Lindsay Prior's (2008) categorization of textual material in social research, I lay out four ways in which the WEC documents can be approached (see Table 2).[12] Prior distinguishes on the one 13

8 World Energy Council, *Energy Trilemma Index*. Url: **https://trilemma.worldenergy.org/#!/energy-index** (accessed 13/11/2019).

9 World Energy Council, *World Energy Issues Monitor: Managing the grand transition*, 2019. Url: **https://www.worldenergy.org/publications/entry/world-energy-issues-monitor-2019-managing-the-grand-energy-transition** (accessed 13/11/2019).

10 World Energy Council, *World Energy Issues Monitor: What keeps energy leaders awake at night?*, 2014, 7. Url: **https://www.worldenergy.org/assets/downloads/World-Energy-Issues-Monitor-2014.pdf** (accessed 13/11/2019).

11 Ibid.

12 Lindsay Prior, "Repositioning Documents in Social Research", *Sociology*, vol. 42, n°5, 2008, 821–36.

Focus of Research	Document as resource	Document as topic
Content and Form	(1) What can we learn about the personal and organizational connections between different national and international organizations in the field of energy?	(3) How are the WEC documents created through practices of negotiation, standardization, and quantification?
Use and Function	(2) How are the WEC documents used by actors to advocate for a certain energy policy?	(4) What is the function of the WEC documents in the field of global energy policy and how does it affect their making? How are the documents shaped by and have impact on the field?

Table 2: Systematization of research questions that can be pursued on the basis of WEC material, based on the distinctions developed in Lindsay Prior, "Repositioning Documents in Social Research", *Sociology*, vol. 42, n°5, 2008.

hand between the form and content of a document, as well as its use and function. On the other hand, documents can be understood as a mere source of information, or a 'topic' themselves. Treating documents as 'topics' means to investigate their own making. Documents, in other words, can become a research object in their own right. Drawing from Prior's distinctions, the WEC's documents can (1) be seen as a source of information and (2) a source through which we can learn about the strategic use or function of the publication. What is more, they can become the material of (3) a more 'archaeological' endeavor to study how their specific content came into being. (4) Lastly, we can extend this approach to the use of these documents, asking about their specific function in the discourse.

Documents as Source of Information

14 Most of the above-mentioned documents published by the WEC are intended to give information on some aspect of the 'world energy economy'. Insofar as historical research is interested in precisely this information, such as historical data on resources, numbers on national energy supply and consumption, or the state of international standardization etc., the documents can be used as a source of information in a straightforward way. However, assessing the accurateness of the information is not always so simple.[13] Apart from the information the WEC's documents are supposed to give, they contain plenty of by-information that can become valuable in historical and sociological research. To give an example, a thorough analysis of different WEC documents could inform a history of how an international network of energy politics emerged. Most conference proceedings give information on the speakers, their country of origin and organizational affiliation. The minutes of the IEC also provide a list of attendees (and their status) and document all contributions to a discussion. Since the second half of the 20th C., delegates of international organizations regularly take part in the meetings, without being official WEC members. In turn, WEC delegates represent the organization at the meetings of other international organizations. So, in principle, these documents allow to trace the personal and organizational links between several organizations in the field. While some of the involved organizations have received scholarly attention, they have never been studied with a focus on

13 Nowadays, however, the most important sources for energy information are the International Energy Agency and BP Energy Statistics. When WEC data is used and compared to or combined with data from other sources, it should also be taken into account, that the units, conversion factors and statistical methodology applied differs between different organizations.

their personal and organizational interrelations.[14] By combining these archives, the emerging network of international energy politics could be traced from the time of the League of Nations, through the post-war organizations of economic recovery, the United Nations regional organizations and technical assistance program, to the institutions set up during the oil crisis of the 1970s.

The Function and Strategic Use of Documents

15 The WEC always claimed to be a clearing house for energy information, and a platform to exchange experiences between people working in the 'field of energy'.[15] Neither representing the interests of a particular nation nor industry, the organization declared itself neutral. However, this is not to say that the organization's documents cannot be studied as strategic interventions in a political debate. In the 1930s, for instance, the WEC developed a position toward international standardization, which is mirrored in the form and content of its publications. An even better example is the WEC's reaction to the oil crises of the 1970s. Having both oil-consuming and oil-producing countries among its members, the WEC found itself in a peculiar position. The political conflict around national sovereignty and petroleum prices became apparent at the World Energy Congress in Detroit in 1974 and the Congress in Istanbul three years later. The foundation of the Conservation Commission in 1975, the sub-commission that would over the following decades become an important part of the WEC's activities, was a direct reaction to the renewed interest in research on energy economics following the oil crisis. Even though the commission was initially encouraged by the OECD, and the Western nuclear industry had a firm foothold in the commission, it diversified over the years and included members from Eastern Europe and OPEC countries as well. The reports were intended to put forth a global perspective on energy security, going beyond both the International Energy Agency's and the OPEC's statistical work.[16]

An Archaeology of Knowledge on Energy

The WEC's history ranges across almost an entire century. Over this period of time, knowledge on energy changed profoundly with the organizations, professions and methods involved in its making. Thus, the material published by the WEC enables a history or sociology of knowledge, an archaeology of knowledge, or historical epistemology.[17] Such an investigation can take on many forms. It can focus on the practices of standardization, the conflicts and negotiations, or resources, technologies and markets shaping and being shaped by knowledge.[18] From its very beginning, the WEC cherished international understanding among engineers and technicians. While it never acted as a standardizing body, it sought to influence the standard setting procedures of other international 16

14 Tim Büthe, "Engineering Uncontestedness? The Origins and Institutional Development of the International Electrotechnical Commission (IEC)", *Business and Politics*, vol. 12, n°3, 2010. Vincent Lagendijk, *Electrifying Europe: The Power of Europe in the Construction of Electricity Networks* (Amsterdam: Aksant Academic Publishers Transaction Publishers, 2009). Thijs Van de Graaf and Dries Lesage, "The International Energy Agency after 35 Years: Reform Needs and Institutional Adaptability", *The Review of International Organizations*, vol. 4, n°3, 2009. Richard Scott and International Energy Agency, *The History of the International Energy Agency, 1974-1994: IEA, the First 20 Years* (Paris: OECD/IEA, OECD Publications and Information Centre, 1994). Giuliano Garavini, *The Rise and Fall of OPEC in the Twentieth Century* (Oxford: Oxford University Press, 2019).

15 Wright, Shin and Trentmann, *From World Power Conference to World Energy Council*, 9 (cf. note 2).

16 See for the main reports of the Conservation Commission World Energy Conference (ed.), *World Energy: Looking Ahead to 2020* (Guildford: IPC Science and Technology Press, 1978). Jean-Romain Frisch, *Energy 2000-2020: World Prospects and Regional Stresses: Report* (London: Graham & Trotman, 1983). Jean-Romain Frisch and World Energy Conference, *World Energy Horizons, 2000-2020* (Paris: Editions TECHNIP, 1989).

17 Michel Foucault, *Archaeology of Knowledge* (London: Routledge, 2010). Michel Foucault, *The Order of Things. An Archaeology of the Human Sciences* (London: Routledge, 2002). Hans-Jörg Rheinberger, *On Historicizing Epistemology: An Essay* (Stanford, CA: Stanford University Press, 2010). Thomas A. Stapleford, "Historical Epistemology and the History of Economics: *Views Through the Lens of Practice*", *Research in the History of Economic Thought & Methodology*, vol. 35A, 2017.

18 Daniela Russ, "Working Nature: A Historical Epistemology of the Energy Economy" (Ph.D diss., University of Bielefeld, 2019).

bodies, such as the International Organization for Standardization (ISO, formerly ISA), the International Electrotechnical Commission, or the UNIPEDE. Moreover, it required a certain degree of standardization of terms and units for internal understanding. One of the longest discussions centered around the concept of 'resources' as it was used in the *Statistical Yearbook* and later the *Survey of Energy Resources*. An archaeology of knowledge of the resource concept would shift attention to its form –the rules according to which something appears as a resource– and relation to the industries, professions and groups using it. Such an approach could reveal both processes of standardization (of methods, instruments, and units) and changes in the organizational, technological, and professional 'landscape' of knowledge on energy (from a more geological to a more economic determination of resources). Covering together almost one hundred years of statistical information and methodological knowledge, an analysis of the *Statistical Yearbook* and the *Survey of Energy Resources,* as well as the respective discussions in the IEC, could inform such an undertaking.

The Interaction of Documents and Discourses

17 In recent decades, the WEC shifted towards more frequent and more policy-oriented publications. Rather than 'publications' on a topic, they should be understood as more performative documents, as they explicitly seek to 'set an agenda', to make a contribution to a debate and inform policy choices, or to provide 'actors' in the field with a map to guide their decisions. As such, these documents do not just display knowledge whose making can be studied, but they intervene in the so-called field of energy in a regular manner. They claim to 'represent' a state of the field, while at the same time being shaped by the WEC's position in the network of international and national organizations providing information on resources and energy policy. The *Energy Trilemma Index* and the *Energy Issues Monitor* are the most apparent examples of this new publication strategy, which started with a major organizational restructuring in the 1990s. These publications lend themselves to a fourth approach –one that combines their broader function in a discourse with their making through processes of standardization and negotiation.

CONCLUSION

The WEC makes for a unique archive for energy history for three reasons. Firstly, it covers a period of almost one hundred years with various forms of publications. Secondly, the documents mirror the most significant debates affecting many different industries, such as international standardization, public or private ownership, or the conflict between market and planning approaches in energy policy. Thirdly, in contrast to many other archives in the history of energy, it brings together many different industries and allows to study their changing relations over the time. In other words, the WEC's publications document the emergence of an interconnected field of energy. However, in order for historical research to make use of this material, the role of the WEC in the international field of energy politics, as well as the internal making of the documents have to be studied in greater detail. Thus, this paper is not only a call to explore the history of energy, but also the World Energy Council, through the analysis of its manifold publications. 18

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REVIEWS

ISSN 2649-3055

JEH RHE

Journal of Energy History
Revue d'histoire de l'énergie

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POST DATE
23/09/2020

ISSUE NUMBER
JEHRHE #4

SECTION
Reviews

KEYWORDS
Transition, Innovation, Mobility, Renewable

DOI
in progress

TO CITE THIS ARTICLE
Anaël Marrec, "L'Europe en transitions, Énergie, mobilité, communication, XIXe – XXe siècles (Yves Bouvier & Léonard Laborie (eds.), 2016)", *Journal of Energy History/Revue d'Histoire de l'Énergie* [Online], n°4, published 23 September 2020 URL: energyhistory.eu/en/node/227.

L'Europe en transitions, Énergie, mobilité, communication, XIXe – XXe siècles (Yves Bouvier & Léonard Laborie (eds.), 2016)

Bibliographic reference

Yves Bouvier & Léonard Laborie (eds.), *L'Europe en transitions, Énergie, mobilité, communication, XIXe – XXe siècles* (Paris : Nouveau monde éditions, 2016)

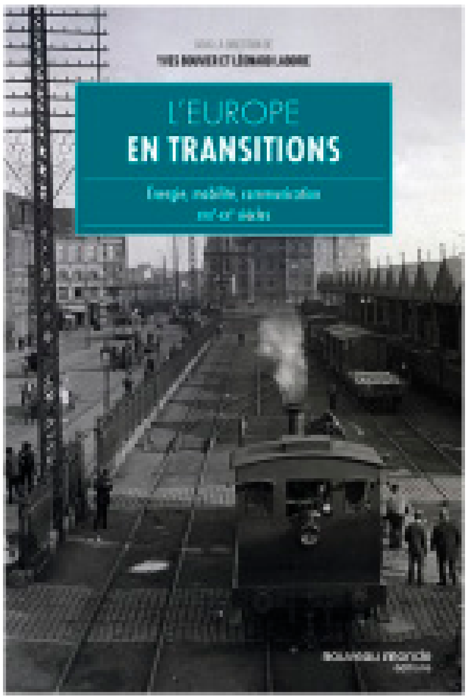
Abstract

Exploring the notion of an energy transition by way of specific energy calls for reconsidering the history of each energy individually, with gas being no exception over the long term. Three sequences have been observed since the early 19th C., which can be represented by three colors: black gas (or manufactured gas), blue gas (or natural gas), and green gas (or biogas). Each one demonstrates the instability of techniques, internal evolutions, and their integration within economic and social contexts, which were themselves in transition. Is it most appropriate to speak of a transition, a turning point, or a change?

Plan of the article

→ Long-term technical changes in various fields
→ Transition as a historical concept
→ Genealogy of technological change's and territorial resources' thought and management

ISSN 2649-3055



1 This book deals with the material transitions in the fields of energy (wood, coal, oil, renewable energies, electricity), mobility (maritime transport, ports, motorways) and communication (digital networks) in Europe since the 19th century. It is the result of the work carried out under the French "Writing a New History of Europe" programme, which aims to trace the history of this economic, political and material space through the prism of technology. The objective of its authors is to shed light on European innovation policies in response to the economic and environmental challenges posed by these three sectors to the European institutions.

LONG-TERM TECHNICAL CHANGES IN VARIOUS FIELDS

2 The book is very rich in all the themes addressed and opens up interesting avenues for historiographical reflection.

3 Reynald Abad studies how administrators, businessmen, engineers and scientists constructed and perceived a "wood crisis" in 18th century France, as well as ways of responding to it. The establishment of administrative expertise and the publication of economic discourses feed into the construction of a global thinking on the structural balance between uses and resources of heat at the national level as well as the perception of a "wood crisis". Public authorities put in place binding and then incentive measures to guide wood production and consumption towards a new balance.

Charles-François Mathis in turn examines future projections on national energy balances, but he changes century and field of study. He analyses the ways out of coal dependency in England in scientific discourses and novels of anticipation between 1865 and 1914. He distinguishes two main types of discourse which, despite their antagonism, advocate a better use of resources and the use of new sources of energy: the first, which is in the majority, expresses a technophile liberalism, while the second reflects a form of anti-modernism. 4

Bruno Marnot analyses the transition from "traditional" port systems to "industrial" port systems from 1850 to 1900 in the world. He mobilizes the notion of technological system to study the factors and characteristics of these changes. The global economy of the 19th century is an essential factor for transformations in these interfaces between seas and continents. The constant changes during this period meet the requirements of an increase in freight capacity, fluidity, economies of scale, and lead to the spread of ports in the form of artificial structures, the generalisation of motorised engines and the standardisation of equipment. 5

Alain Beltran examines the substitution of electric lighting for gas lighting in Europe at the end of the 19th century. Beltran considers this change as an archetype of energy transition, which is embedded in the second industrial revolution. The author highlights the slowness of this change, the logic of competition and complementarity, the differences that exist according to the territories and their political organizations, and resources. This technical change is associated with new values associated with the moving ideal of modernity. 6

Géraldine Barron studies the replacement of sails by steam engines in the 19th century in the 7 naval equipment of industrialising nations, particularly in France and the United Kingdom. The case study highlights the progressive and contrasting nature of this change, which is described as a "maritime transition". However profound it may have been, since it saw the affirmation of hegemonic steam navigation in the military and merchant navies, it lasted a century and experienced periods of open possibilities, as evidenced by the terminological uncertainties and the many technical "hybridizations". The author highlights the complexity of the process and its international nature.

8 Matthieu Flonneau analyses the "motorway transition" in France in the 20th century. He focuses on the inter-war period when the motorway moved from an uncertain and marginal position to a dominant position in speeches and public policies. The author thus intends to nuance the reading of a history of the motorway where "technocrats" and companies have imposed a new road regime based on the motorway. On the contrary, he underlines the non-linear and progressive nature of the process, which is characterized by hesitations, where additions of technical regimes are observed more than substitutions.

9 Yves Bouvier traces the "trajectory of renewable energies in the Community institutions resulting from the Treaties of Paris and Rome" from 1955 to 2008. While renewable energies were relegated to non-European areas and studied as part of dynamic but fragmented research, they were taken into account in European research policy in the 1970s, which declined in the following decade. The establishment of a European market and the liberalisation of all economic sectors, as well as the rise of environmental issues, put renewable energies at the heart of a Europe's energy union at the end of the 1990s.

10 Valérie Schaffer and Benjamin G. Thierry study the transformations of digital networks in Europe from the 1960s to the 1990s. During this "European transition of digital networks", a set of closed, centralised digital networks intended for a professional audience is being replaced by the web, an open network resulting from the convergence between IT and telecommunications, intended for the general public. The authors highlight the complexity of the transition, ecumenism, cohabitation and the progressive integration of different technical solutions during this transitional phase.

Pascal Griset uses a systemic approach to describe "informational transitions", i.e. the "process of creating and renewing information and communication technologies" (p. 314). He gives a place back to the figure of the innovator that historical practices have set aside since the 1970s, in order to bestow upon European citizens the power to take, as individuals, a place in the history of these technologies, and to enable Europe to regain technical and economic leadership. 11

TRANSITION AS A HISTORICAL CONCEPT

In terms of theoretical contributions, the questions about the notion of transition in history can be first considered. The authors of the introduction stress the scarcity of historiographical works treating this notion. Little questioned as such, it was addressed in some books that dealt with energy transitions in history and was not applied to mobility and communication techniques[1]. Thus, the authors of the book find in it 12

1 The notion of energy transition had been the subject of some historical work. The authors cite the articles published in the *Journal of environmental innovation & societal transitions* on the subject as well as, for the French sphere, the book *La transition énergétique, un concept historique?* edited by Pierre Lamard and Nicolas Stoskopf (2018). See also: Astrid Kander, Paolo Malanima and Paul Warde, "Energy transitions in Europe, 1600-2000", *Papers in innovation studies* (Lund: Lund University, CIRCLE, 2008). Vaclav Smil, Energy transitions, history, requirements prospects (Santa-Barbara: Praeger, 2010). Roger Fouquet, "The slow search for solutions: Lessons from historical energy transitions by sector and service", *Energy Policy*, vol. 38, n° 11, 2010, 6586-6596. Yves Bouvier, "Les transitions énergétiques dans l'histoire, entre succession des techniques et sédimentation des enjeux", in Yves Bouvier (dir.), *Les défis énergétiques du XXIe siècle. Transition, concurrence et efficacité du point de vue des sciences humaines* (Brussels, P.I.E. Peter Lang, 2012), 23-36. Since then, historical work on the energy transition has increased. For example: International symposium on transitions in the history of energy in Milan (Dec.

a relevant conceptual framework to the study of technological change over time while protecting themselves from a teleological and linear conception of the history of techniques[2]. In this way, they intend to enrich a conceptual apparatus that has become classic in the history of technology, and in particular the notions of revolution and innovation. This work is therefore an extension of a history of technology that places Schumpeterian innovation at the heart of its analysis, considering it as a determining factor in the history of technology in industrialized countries since the 19th century.[3].

13 Through this notion, the authors highlight the superposition of periods, during which different factors operate in a complex way. Various techniques coexist, whether competing, complementary or simply juxtaposed. Some uses are prolonged and modified while others appear, "hybridizations" emerge and persist, and this without there being a clear break between the adoption of one and the abandonment of the other. Several contributions demonstrate this well: in the shipbuilding sector, the steam engine was introduced very gradually and in a contrasting way depending on the sectors of activity concerned, from the military navy to fishing (G. Barron); in lighting techniques, electricity became dominant after a long period of competition at the turn of the 20th century (A. Beltran); digital networks emerge as multiple heterogeneous and closed networks that integrated very gradually into an open network of networks until the hegemony of the web (V. Schaffer and B. G. Thierry).

Bouvier pays particular attention to defining the notion of transition in order to refine the historical analysis of technological change. He gives it several degrees of precision: in the narrowest sense, transition implies not only a substitution of energy sources (in this case, renewable) for others (here, fossil fuels), but also long-term projections and policies that voluntarily guide energy shifts, and finally, "profound changes in energy consumption patterns". From this point of view, there has been no "energy transition" in the field of renewable energies, even since the 1980s. If such an energy transition has taken place, it is the one that resulted from the French nuclear programme and led to the substitution of the atom for fossil fuels in the years 1970-1980[4]. However, a looser energy transition has been observed since the 1980s: "a smooth change in production methods through the introduction of new technologies, certainly challenging monopolistic structures and the centralized production model, but without revolutionizing industrial players or disrupting technology for users" (p. 269). Finally, since the 1950s, the European institutions have promoted the energy transition in the broadest sense of reducing hydrocarbon consumption. 14

However, it is regrettable that the notion of transition did not demonstrate a more in-depth theoretical perspective. Following Bouvier's classification effort, we can distinguish two main ways of approaching the transition that make it possible to refine the historiographical significance of the various contributions. The transition is both a historiographic tool and object. 15

2017). Peter G. J. Pearson, "Past, present and prospective energy transitions: an invitation to historians", *Journal of energy history*, n°1, 04/12/2018. Charles-François Mathis and Geneviève Massard-Guilbaud (dir.), *Sous le soleil. Systèmes et transitions énergétiques du Moyen Âge à nos jours* (Paris : Éditions de la Sorbonne, 2019).

2 This risk was highlighted by Jean-Baptiste Fressoz in "Pour une histoire désorientée de l'énergie", *Entropia*, n°15, autumn 2013, 173-187.

3 Without mentioning a very rich literature on each of these subjects, it should be recalled that the classical long-term narratives of the history of technology have placed energy uses at the centre of the socio-technical transformations that have taken place in the contemporary period. See for example: Lewis Mumford, *Technics and civilization* (New York: Harcourt, Brace and Co.; London: George Routledge & Sons, 1934). Maurice Daumas, *Histoire générale des techniques* (Paris : Presses universitaires de France, 1962-1978). Bertrand Gille, *Histoire des techniques : technique et civilisation, technique et science* (Paris : Gallimard, 1978).

4 Bouvier thus takes up a proposal developed in the article "Les transitions énergétiques dans l'histoire, entre succession des techniques et sédimentation des enjeux", in Yves Bouvier (dir.), *Les défis énergétiques du XXIe siècle. Transition, concurrence et efficacité du point de vue des sciences humaine* (Brussels, P.I.E. Peter Lang, 2012), 23-36.

16 As a tool, it allows to study and model long-term technical changes, which is the case in the majority of contributions. We could then distinguish three types of transition:

1. the substitution on a global scale and in the long term of one technology or resource for another, or their adoption (Barron, Marnot, Beltran, Schafer & Thierry, Griset),
2. the substitution on a global scale and in the long term of one technology or resource for another, or their adoption, voluntarily oriented by actors (political and industrial), involving a vision of the future (Bouvier, for nuclear energy and for renewable energies since the 1990s),
3. a policy aiming to guide global change, whether or not it has been followed by effective change ("failed" transitions: Abad, Bouvier for renewable energies over the period 1970-1980).

17 As an object, the transition is analysed in three contributions, which question how actors thought about technical change at a global level to meet future objectives. They then look back in the past for what could be similar to a political thought and project similar to the current energy transition project. Three contributions fit into this category (Abad, Mathis, Bouvier)[5].

In its most open sense (type (1)), the transition would have merited a more in-depth reflection on its articulation with the classical conceptual tooling of the history of technology. If it is simply a change in technical practices over time, one may wonder what distinguishes it from innovation, since this notion is itself widely used without being defined other than as "the ability to produce and consume something new" (Bouvier & Laborie, p. 10). Similarly, if some authors oppose the revolution by its progressive (or even "soft") aspect[6], they envisage that a transition may involve revolutions and vice versa[7]. In this case, what is its real contribution to the historical analysis of technological change, which, after all, already considered the superposition of techniques, the need for long time, and the complexity of a set of parameters (technical, economic, political, social, cultural)? 18

The authors of the introduction consider their work as part of the search for tools to support European research and innovation policy. The ideological dimension of the "revolution" having been stressed and fostering caution in its use, one might have expected greater precautions with regard to the transition, whose political significance is also recognized. Such a step back ensures a reflexive approach and makes it possible not to naturalize categories and concepts. Thinking about technological change through Schumpeterian innovation, for example, guides the analysis in the context of the production/consumption or producer/user relationship. Can't we think of technological change, outside these categories? 19

GENEALOGY OF TECHNOLOGICAL CHANGE'S AND TERRITORIAL RESOURCES' THOUGHT AND MANAGEMENT

Beyond the notion of transition, the contributions of this book concern the construction and the performative dimension of global, economic 20

5 Abad describes as a transition his object, namely the "objective or subjective appreciation that contemporaries may have of the energetic balance of the kingdom". For Mathis, it is a question of looking for "ways to reduce the place of coal in Victorian and Edwardian societies through the development of new energy systems or the use of other sources" (p. 88-89). For Bouvier, the "energy transition" can be understood in a more or less loose sense and he identifies in this respect several types of energy transitions in the Community Europe since 1955. In the loosest sense, it is a limitation of the consumption of one energy source, which may result from lower consumption or substitution by another energy source. A more precise meaning also includes political will and measures in the direction of this limitation, which imply a global and future vision of energy on the part of these actors. An even more restricted meaning implies "profound changes" in energy consumption patterns, i.e., for the 1955-2008 period in Europe, a transformation of actors and energy uses. In this sense, there has been no energy transition to renewable energies since the 1950s.

6 Bouvier & Laborie, p. 18 ; Beltran, p. 169 ; p. 189. Barron, p. 134-135. Barron prefers the term "maritime transition" to that of "maritime revolution", commonly used by contemporaries of change who were experiencing a deep change (p. 130-135).

7 Bouvier & Laborie, p. 18.

and prospective thinking, which is applied in the three sectors studied, and especially energy.

21 Abad and Mathis show the construction, at the dawn of industrialization, of a global economic thinking based on new administrative and management practices. They show that the notion of energy balance and scarcity, as well as future projections, are precocious, as are the measures taken by public and private actors to guide change towards new balances. The moral aspect of these visions is also remarkable: the "good user" and the "bad user" of wood, the responsibility towards future generations, the values associated with the idea of civilisation, which Beltran also evokes about lighting at the turn of the 20th century. This is in line with the observation made by Bonneuil and Fressoz (2013): the environmental imbalances generated by the development of industrial civilization have been created with full knowledge of the facts and this awareness has not been sufficient to stop the process[8].

22 The history of renewable energies in the European institutions over the period 1955-2008 is a good example of the discursive, material, economic and political construction of Europe. It shows how, after the failure of a Community construction by a common energy policy, the market, and in particular the energy market, was the key factor to make Europe an integrated area. Despite the ambitions announced in the introduction, it should be noted that this article is the only one to question the construction of the European space based on its physical infrastructures.

Another striking feature highlighted by some contributions is the performativity of discourses on land use planning and the resource making of territory. Abad shows the constitution of wood as an energy resource, or more precisely as a raw material for the production of heat and power, based on administrative expertise and a new accounting way of managing resources on a kingdom scale. This resource construction is accompanied by public takeover and management. Flonneau shows how the rhetoric about the need for highways in France in the inter-war period preceded the hegemony of this type of infrastructure in the post-war "road regime". 23

Finally, the history of renewable energy in Europe since 1955 is instructive for understanding current energy policies. Bouvier shows that if renewable energies have taken a timidly increasing place in European energy balances since the 1990s, it took place within the framework of a liberalization of the energy market, where the actors of change remain the dominant actors of the energy sector. From this point of view, there is no major change in production and consumption patterns. This leads to a certain scepticism about the possibility of a sufficiently rapid change to address the major energy problems currently facing us (and, first and foremost, global warming)[9]. 24

8 Christophe Bonneuil and Jean-Baptiste Fressoz, *L'événement anthropocène. La terre, l'histoire et nous* (Paris: Le Seuil, 2013).

9 In another article on the energy transition, Bouvier shows an essential difference between the energy transition advocated by current policies, and the one led by the French government during the nuclear programme: it would be a transition "from the bottom" instead of a transition "from the top". Yves Bouvier, "L'horizon nucléaire en France, transition énergétique ou énergie de transition?".

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