

“That the sun might become the source of their wealth”: A Forgotten History of Alternative
Energy Technology in Nineteenth-Century France

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Abstract

This paper explores the construction and exhibition of the first solar-powered engine at the 1878 Exposition Universelle in Paris by Augustin-Bernard Mouchot (1825-1912). It traces the development of a discourse of resource management in light of a perceived coal shortage within France and across Europe in the closely interacting realms of science and politics. Engineers, geologists and political economists addressed and proposed solutions to the challenge of France's relative coal poverty (in comparison to England and Germany). Surveys of coal resources were tied to estimates of national power and prestige. Looking at Mouchot's invention helps to uncover the debates surrounding France's industrial competitiveness during the Third Republic. This paper also raises questions about the failure of the device to be implemented over the long term, focusing on the geography of patronage in the French scientific establishment as well as the relationship between metropolitan-governed French science and the utility of a device designed and tested in Algeria.

Strolling the park at Trocadéro on a sunny day during the 1878 Exposition Universelle in Paris, a visitor would encounter an enormous silver-plated cone. Next to this strange contraption, a roast beef rested, cooling down beside a rumbling steam engine that curiously lacked a combustion chamber. What was this strange sight? In this small corner of Trocadéro, noted one guest, coal had been completely banished!¹ Twenty-four square meters of reflective surface trapped the sun's rays and converted their heat into usable energy, performing an astonishing array of tasks. The device had captured the public's imagination, the interest of Académiciens at the French Academy of Science and the patronage of France's two successive political regimes from the construction of the first prototype in Tours in 1860 under the Second Empire over the course of nearly two decades preceding this scaled-up 1878 version.

Behind this device, the world's first solar-powered engine, was a provincial mathematics teacher from Tours, Augustin-Bernard Mouchot (1825-1912). His work, now forgotten, piqued the interest not only of the scientific establishment in Paris but also of the popular press long before its debut at the Exposition Universelle. By examining the trajectory of Mouchot's career, I argue that we can glimpse the uncertainty about the future of energy regimes plaguing Europeans in the latter half of the nineteenth century. Taking Mouchot's device seriously allows us to recover a discourse of resource management shared by the state, the French Academy of Science and the popular press in which the question of location is central. A careful reading of the discussion of the energy supply suggests important geographical dimensions to the extraction, trade and use of combustibles that fueled nineteenth-century industry. This specificity had implications for Mouchot's device, which achieved optimal performance outside of metropolitan France.

¹ Adopted from an account given by Henri de Parville, quoted in Mallat de Basillan, "Récepteur Solaire," *Encyclopédie des sciences, des lettres et des arts, 1877-1878*. 350-355. Paris, 1878. <http://gallica.bnf.fr/ark:/12148/bpt6k6375955g>.

In order to faithfully render this climate of uncertainty, we must treat the device as the historical record suggests it was treated by authorities within both the scientific establishment and the French government-- that is to say, it should be taken seriously and placed firmly within the realm of possibility and not mere novelty or utopian fantasy. Among the scant literature that does exist on Augustin Mouchot, François Jarrige has situated Mouchot's invention in the context of the "imaginaire solaire" of the Third Republic.² This, I will show, does a great disservice to a project that received formal encouragement, in the form of state sponsorship, attention and even the Legion of Honor for its originator. What Jarrige has referred to as the "solar myth" that "nourished the literary imagination" feeds into a teleological narrative of fossil fuel dependency that denies the promise of a solar-powered engine in the nineteenth century.

This paper attempts to reconstruct the viability of the project by recapturing ideas about natural resources within France. Exploding the claim that Mouchot's device was utopianism or fantasy generates further questions. If the device was, mechanically speaking, plausible, what accounts for its failure? To address this issue, we must turn our attention to geographical dimensions of the discourse of resource management within the French state. First, the social geography of patronage posed a high barrier to entry into the French scientific establishment. Mouchot had to grapple with his status as an outsider to the exclusive Académie des Sciences, which precluded his long-term involvement in French science. Second, we must look at the literal geography of the Third Republic—that is to say the position of France's empire and the relationship between colony and metropole. The fact that the device was best suited for use in France's quasi-colonial territory in Algeria proved to be a liability rather than an asset. In short, the passage of the solar receptor into obsolescence was not on account of its mechanical failure.

² François Jarrige. " 'Mettre le soleil en bouteille' les appareils de Mouchot et l'imaginaire solaire au début de la Troisième République." *Romantisme*. 150 (2010), 85-97.

Rather, the social conventions that governed entry to French science and the situation of Algeria as periphery led to its abandonment.

Solar heat as mechanical work

Mouchot's first experiments with the solar receptor date from 1860 in Alençon where he began his career as a mathematics teacher at the local *lycée*. Using modest materials—his first prototype employed a wooden crate with a blackened interior as the receptor—Mouchot began to apply the principles of solar heat. Such a machine was plausible in light of decades of discovery about the equation of heat and mechanical work.

In Mouchot's 1869 publication, *La chaleur solaire*, he describes the properties at work in his solar receptor and his early-stage experimentation. He credited recent developments that explored the role of heat in machines for opening the possibility of his invention.³ His extensive summary of recent developments in energy science speaks to his relative erudition. Mouchot's experiments arose in response to scientific questions of how much work could be extracted from a given source. Thomas Kuhn has explored this period of closely related discoveries on the exchange of heat and work in the middle of the nineteenth century, often referred to as “simultaneous discoveries,” in his classic work *The Essential Tension*. Kuhn writes of the public announcements of the hypothesis of energy conservation by several scattered European scientists, working more or less independently and without knowledge of the others, between 1842 and 1847.⁴ These discoveries heralding the interchangeable nature of heat and work and positioning them as a single force, energy, foreground Mouchot's discussion of his own research. In 1869, he could confidently write, “What is the sum of the heat and by consequence of work,”

³ Augustin Mouchot, *La chaleur solaire et ses applications industrielles* (Paris: Gauthier-Villars, 1869), 2.

⁴ Thomas Kuhn, “Energy Conservation as an Example of Simultaneous Discovery,” in *The Essential Tension: Selected Studies in Scientific Tradition and Change* (Chicago: University of Chicago Press, 1977), 67.

equating the two thanks to the path breaking work of men who were just barely his predecessors.⁵

Kuhn's essay is helpful in examining why Mouchot might have resolved to tackle such a problem. Kuhn writes that his pioneers of energy conservation did not have a unified understanding of "work" as a point of departure, but instead approached specific mechanical problems, which then led to their discoveries. Indeed, Kuhn writes, seven out of the nine pioneers of energy conservation were engineers working on engines, and avoiding excessive theorizing of natural philosophers.⁶ Putting the accent on this application-first approach is important to Mouchot's understanding of his own work.

Following an exhaustive summary of all the work done on solar heat from antiquity to the present, Mouchot writes,

If the historical detail into which we have just entered prove that physicists have been preoccupied for ages with means of putting solar heat to work, it is fair to say that the majority of their discoveries of this genre consisted of machines that were more clever than they were likely to be used.⁷

For Mouchot, utility was of the utmost importance. Throughout the text, it is clear that he is not claiming originality in theoretical principles; instead he is putting the principles set out over literally millennia to work.

L'aménagement de la richesse minérale

This is a story about coal as much as it is one about solar power. *La chaleur solaire* provides a genealogy of the principles that informed Mouchot's research, but it is also a tool of self-promotion. Mouchot self-consciously reproduces the language of a coal shortage, drawing

⁵ Mouchot, *La chaleur solaire*, 11.

⁶ Kuhn, "Energy Conservation," 90.

⁷ "Si les détails historiques dans lesquels nous venons d'entrer prouvent que les physiciens se sont préoccupés longtemps des moyens de faire travailler la chaleur solaire, il est juste de reconnaître que la plupart des leurs découvertes en ce genre consistaient en machines plus ingénieuses que susceptibles d'être utilisées." Mouchot, *La chaleur solaire*, 175.

attention to the promise of the solar energy as a “free resource” in a way that was meant to draw the attention of officials.⁸

In the two decades spanning 1860 to 1880, the conversation about resource management was a conversation about coal extraction and trade. The expansion of rail networks during the decade of 1850 greatly abetted the growth of the coal mining industry, particularly in its importance to the iron industry, in which it was necessary to bring coal to the site of iron ore employed in the coking process. But it also created a steady demand for coal to fuel the trains and coke to smelt the iron necessary for the ever-extending network of rails. As Rolf Peter Sieferle has noted, the idea of an “industrial revolution” refers to the transition from an agrarian system to new manufacturing processes on an unprecedented scale. Modern growth resulted from the harnessing of coal, which provided an almost infinite supply of energy in the short term to a growing population.⁹

Coal had been known to stand in as literal currency, replacing workers’ salaries in some areas.¹⁰ Its importance to both the everyday and national interests should not be underestimated. Mouchot’s presentation of his device exhibits the internalization and reproduction of this discourse of resource management. The convergence of recent developments in energy science, geology and geopolitical concerns pointed to limits to industrial growth, a claim that appeared to be refuted by several decades of unhindered economic progress. The text of Mouchot’s publication sheds light on contemporary anxieties about how France might meet its growing energy demands by focusing on experiments and application. While Mouchot’s intent to capitalize on the usefulness of the invention in the world’s warmer regions is clear throughout

⁸ “une ressource gratuite” Mouchot, *La chaleur solaire*, 2.

⁹ Rolf Peter Sieferle, *The Subterranean Forest: Energy Systems and the Industrial Systems*, translated by Michael P. Osman (Cambridge: White Horse, 2001), 33.

¹⁰ Specifically in the 1830s in the Loire basin. Ernest Lamé-Fleury, “La propriété souterraine en France-02,” *Revue des deux mondes*, t. 12, 1857, http://fr.wikisource.org/wiki/La_Propri%C3%A9t%C3%A9_souterraine_en_France/02, 196.

the text, it would be wrongheaded to neglect his European context. At the time of the publication of *La chaleur solaire* in 1869, Mouchot had not yet traveled to Algeria to conduct experiments. In fact, all of his trials had been carried out in Tours, using data he collected there, or drawing on the observations of others generally taken from Paris.¹¹ And, while we know that the colonial applications of the device became its largest merit, it was continuously emphasized for its utility at home in France.¹² One part of his immediate context then, was a growing awareness of the finite nature of coal supplies upon which the past century's industrial growth was predicated.

The existence and exploitation of coal resources was intimately tied to estimates of national power. Mouchot came of age at a time when popularizers of science introduced geology and all of its implications to a larger public, while officials were occupied with increasing France's industrial competitiveness.

The French state had an active interest in coal mining and intervened accordingly. The project of "l'aménagement rationnel" was at the heart of the discourse of resource management. This meant finding a balance between the private mining corporations who managed the mines, and national interest in stabilizing the price at a level conducive to industrial output. The state had the authority to grant and deny concessions and monitored safety and conditions by sending inspectors trained at the Ecole des Mines out annually. The interventions of the state were amplified in 1854, when four decrees regulating concessions were instituted. In the name of "l'aménagement rationnel de la richesse minérale," these decrees dismantled the Compagnie des

¹¹ Mouchot, *La chaleur solaire*, 47.

¹² 1876 report of *Revue des sociétés savantes* discusses the utility of the machine to meet daily household needs within France. *Revue des sociétés savantes*. T.10. (Paris: Imprimerie Nationale, 1876), <http://gallica.bnf.fr/ark:/12148/bpt6k202608t/f88.image.r=mouchot.langEN>, 86.

mines de la Loire with the financial assistance of Crédit Mobilier to discourage its monopolizing practices and check its overexploitation.¹³

Sharpening awareness of finite resources enabled Mouchot to secure patronage first in the imperial workshop at Meudon under the Second Empire and then under the Third Republic. In *La chaleur solaire*, Mouchot, a specialist in neither geology nor political economy, confidently asserts that coal stocks will become exhausted. “Unlike our forests,” he writes, “the coal stocks are not replenished, and yet we have seen the wood supply become more rare. Is there any reason to imagine that the situation with coal, one in which the deposits are never refilled, can avoid dearth?” And yet, Mouchot continues, “the consumption of coal worldwide increases annually, while scientists scramble to calculate the expiration date of this period of bounty.” With this in mind, Mouchot aims to disabuse his readers of their false sense of security.¹⁴ By inserting his own work into the discourse of resource management, he made an appeal for state support.

From where does Mouchot derive this information about the exhaustion of coal? He is making nods to the current debates and existing work in the field of geology. The vague allusion to the calculations of the rate of coal exhaustion draws upon the work of Louis Simonin in France and William Stanley Jevons in Great Britain, both popularizers of the idea of coal shortage. Simonin, a graduate of the Ecole des Mines de Saint-Etienne, was a journalist who

¹³ Lamé-Fleury, “La propriété souterraine en France-02,” 194-197.

¹⁴ “Que les dépôts de houille et de pétrole lui fournissent longtemps encore leur énorme puissance calorifique, nous n’en doutons pas. Mais ces dépôts s’épuiseront sans aucun doute: le bois qui, lui, cependant, se renouvelle, n’est-il pas devenu plus rare qu’autrefois? Pourquoi n’en serait-il pas de même un jour d’une provision de combustible où l’on puise si largement sans jamais combler les vides qui s’y forment? Quand on pense à l’énorme consommation de houille qui se fait annuellement dans le monde, puisqu’en France, par exemple, il n’est pas de ligne importante de chemin de fer qui ne brûle plus de mille tonnes de charbon par jour, on ne peut s’empêcher de conclure qu’il est prudent et sage de ne pas s’endormir à cet égard dans une sécurité trompeuse. Ainsi, dans un avenir lointain sans doute, mais qu’on essaie déjà de calculer, l’industrie ne trouvera plus en Europe les ressources qui sont en partie la cause de son essor prodigieux.” Mouchot, *La chaleur solaire*, 214.

often wrote about mining in France and abroad.¹⁵ An 1865 article appearing in the widely circulating bi-monthly, *La revue des deux mondes* entitled, “De l’extraction croissante et de l’épuisement de la houille” made note of the permeation of wider culture by this previously specialized knowledge. In the article, Simonin cites the recently enlarged readership of the annual report of the Comité des houillères françaises, beyond the usual one of engineers and economists.¹⁶ The specter of a coal shortage, one previously confined to the ranks of technical specialists, had seeped into public life.

Mouchot’s warning echoed Simonin’s on many points. In particular, his invocation of the forest equilibrium, which man had still managed to exploit beyond repair, recalls the work of both Simonin and Jevons. In fact, it was the perceived wood shortage and the all-too-real elevation in wood prices that resulted which led to the introduction of coal. In 1769, the first ships from Newcastle arrived at Paris carrying coal.¹⁷ Slowly, Frenchmen stifled their protests against coal usage which had initially been met with public outcries of disgust when faced with its insalubrious effects on health and landscape. Coal had a history of use in a domestic setting in pockets of France where it was easily obtained near the surface. Yet the volume of coal use prior to the nineteenth century was negligible owing to the great and cheap availability of wood for the production of fuel and charcoal for the metallurgical and glass industries. Increasingly prohibitive wood prices and the new demands of industry paired with refined techniques for extraction led to the unequivocal embrace of coal.¹⁸ According to Simonin, industry found in

¹⁵ In the second edition of *La chaleur solaire*, published in 1879 with an additional chapter on the large receptor, Mouchot specifically credits Simonin for mentioning the device in the *Revue des Deux Mondes* and generating interest at home and abroad. Mouchot, *La Chaleur Solaire et ses applications industrielles* (Paris: Gauthier Villiers, 1879), 187.

¹⁶ Louis Simonin, “De l’extraction croissante et de l’épuisement de la houille.” *Revue des deux mondes*, 267.

¹⁷ Simonin, *La vie souterraine ou les mines et les mineurs* (Paris: Hachette, 1867), 1.

¹⁸ The transition to coal use dictated the priorities of late eighteenth-century science as well. In 1788, the Académie des Sciences proposed the subject of coal exploitation for its prize

coal its *pain quotidien*.¹⁹ Nourished and sustained by the fuel, consumption continued at a rapacious rate.

When Mouchot chides his readers for operating under a false sense of security (*une sécurité trompeuse*), he is referring both to the general sense of complacency among those who refuse a vision of a future without coal, but also more literally of a threat to the nation. A lack of coal menaced national security. The smooth functioning of the military apparatus was contingent upon access to coal. Simonin wrote, in 1865,

We know that coal intervenes in the defense of states and it has been for several years the driving agent of our military fleet. As a source of mechanical movement, the coal is also used in all of our factories, in a good portion of our merchant ships, and on all of our railroads.²⁰

Military operations without access to combustible fuel were unthinkable. The expediting power of the steamship and railroad, would, in the event of a coal shortage, render the French army impotent.

Furthermore, France's territorial integrity could be undermined in a time of crisis by her economic dependencies. France's inability to meet the coal demands of its growing population made borders porous by reliance on imports. Simonin reported in 1867, "Nevertheless, that which is lacking to balance production and consumption [of coal] is borrowed from England [...] France is, herself, in this regard, a tributary of Great Britain [...] Belgium, Great Britain and the Prussian Rhineland supplement our deficit [of coal]."²¹ Supplementing her consumption with the

in natural history. The contest was renewed in 1791, and then in 1793, and was not awarded until the third round. Lamé-Fleury, "La propriété souterraine en France-02," 193.

¹⁹ Simonin, *La vie souterraine*, 27.

²⁰ "On le sait, la houille intervient dans la défense des états et c'est depuis quelques années l'agent moteur de notre flotte militaire. Comme source de mouvement mécanique, la houille est de même employée dans toutes nos usines, sur une bonne portion de nos navires marchands, sur tous nos chemins de fer." Simonin, "De l'extraction croissante," 267.

²¹ "Toutefois ce qui manqué pour équilibrer la production et la consommation est emprunté à l'Angleterre [...] La France est elle-même, sous ce rapport, tributaire de la Grande-Bretagne [...] La Belgique, la Grande-Bretagne et les provinces Rhénanes supplément à notre déficit." Simonin, *La vie souterraine*, 289.

exports of three neighbors, but also rivals, could spell weakness in a time of crisis. Simonin reported that three-fifths of this additional coal was supplied by England, one-fifth by Prussia and one-fifth by Belgium. The Cobden-Chevalier Treaty of 1860, between France and England guaranteed that the pace of coal importation from England would continue unfettered. By laying bare France's unnerving dependencies, Simonin attracted the attention of the public and government officials alike. All this was to Mouchot's advantage, as he secured subventions from the government of Napoleon III, and later the Third Republic largely by cashing in on such fears.

This concern resonated with a wider audience and amplified the already present sentiment that France operated in the shadow of Britain. British innovations in technology during the eighteenth-century, nurtured by the free market and a spirit of tinkering, lent them an early and significant lead that dampened France's share of the market and curtailed its empire during the Seven Years' War and the Napoleonic period. The end of outright Franco-British hostilities ushered in an age of strained alliance characterized by economic rivalry.

The Geological Survey

Coal, wrote Roderick Murchison, director of the British Geological Survey, was "the meter of power of modern nations."²² The geological survey inaugurated an age in which mineral wealth provided an index of national power. Surveys were important discursive tools for understanding finite resources. In the seventeenth and eighteenth centuries, forest surveys enabled agents of the monarchy to assess the damages of deforestation and regulate woodcutting both in France and abroad.²³ The geological survey was the newest incarnation of this fear of shortage, revealing the finite nature of the coal supply. Yet the geological survey was a novelty

²²Murchison to Layard, 23 Feb. 1866, Layard Papers, BLAM 39118, ff.410-411, quoted in Robert A. Stafford, "Geological surveys, mineral discoveries, and British expansion, 1835-1871," *The Journal of Imperial and Commonwealth History*, 12:3 (Jul. 2008).

²³ Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens and the Origins of Environmentalism, 1600-1860* (Cambridge: Cambridge University Press, 1995), 180.

because it represented subterranean levels and reimagined the nation in terms of features that were not immediately observable to the average citizen. The effect of representing the familiar territory of the nation as unfamiliar and in terms of strictly mineral deposits produced a shudder of collective fear among coal dependent industrialists and political economists.

Murchison was among the first to recognize that the supply of coal was limited in his capacity as director of the Geological Survey. The first geological surveys completed in the mid-nineteenth century played an important role in establishing the extent of mineral deposits, and then in distilling and presenting this new knowledge visually. Perhaps unsurprisingly, the first national survey was carried out in Britain, where early industrial growth fueled by the transition to coal as fuel made the knowledge of mineral deposits economically valuable. The first national survey, in the form of the Ordnance Survey of Britain, was carried out in 1835 and “provided base maps for authoritative evaluation of the nation’s mineral wealth and guidance of its efficient exploitation.”²⁴ Six years later, two mining engineers drafted the first survey of France in six sheets. It was not until 1868, under the Second Empire that the Service de la carte géologique was created to match its British counterpart.²⁵

Valued for their predictive power, geological mapping also advanced a theory about the age and origins of the earth, creating a new sense of geological time. Deeper knowledge of coal deposits also allowed mining engineers to appraise the various types of mineral combustible. The variation in hardness, percentages of carbon content, and prevalence of various types of coal led to a hierarchy in which anthracite became prized over lignite, which burned with less efficiency and was incidentally the most common form within French borders.²⁶ The ability to discern and

²⁴ Stafford, “Geological surveys,” 4.

²⁵ David Oldroyd, *Thinking About the Earth: A History of Ideas in Geology* (Cambridge: Harvard University Press, 1996), 124.

²⁶ Simonin, *La vie souterraine*, 23.

locate coal of varying degrees of quality represented France's combustible impoverishment with acuity.

In 1866, Murchison testified in front of an audience of the Royal Geographical Society about the reality of an impending domestic shortage and the need to supplement British coal with colonial possessions.²⁷ British coal resources far outweighed their French counterparts, and concerns about the fate of the industrialized world drifted across the channel.

Developments in Britain in the decade following 1860 served to confirm preexisting concerns about the pace of industrialization as a result of the convergence of three factors. First, the conclusion of the Cobden-Chevalier treaty eroded French protectionism for years to come, inevitably increasing the consumption of British imported coal. Secondly, the conclusion of the geological survey in Britain and France allowed contemporaries to assess the full scope of coal reserves; and finally, the return of mineral statistics revealed the unsettling rate of consumption over recent years.²⁸

The intersection of geology and industry contributed to a sense of decline in France. Their faltering industrial power, especially in light of Germany's rapid rise, was intensified by the study of geology. The age of the geological survey delivered knowledge of the earth's finite resources to the European public, a public that had come to depend on coal for their daily needs. Indeed, in the journal *Annales des mines*, the issues spanning 1867 to 1872 include appendices of

²⁷Stafford, "Geological surveys," 21.

²⁸ William Stanley Jevons, *The Coal Question: An Inquiry Concerning the Progress of the Nation, and the Probably Exhaustion of our Coal-mines*, (London: Macmillan and Co., 1906 [1865]).5. Geological survey in France by Durfrénoy and Elie de Beaumont, mining engineers appeared a 1/500,000 scale in 1841; in 1868 the Service de la carte géologique détaillée et des topographies souterraines was created to create a national survey on the scale of 1/80,000 and replace the surveys previously carried about by departmental representatives. http://bib.mines-paristech.fr/Accueil/index.php/Patrimoine/cartotheque_patrimoniale/histo_carte_geol_France/

tables revealing mineral statistics focused on combustible materials of Britain and Prussia.²⁹ This data shows France outpacing other European countries in combustible imports, particularly with regard to its imports from England. In 1867, France imported 1,971,256 tons of coal—by far the most, considering the second largest quantity amounted to 637,152 tons sent to Hamburg. Unable to meet its own fuel needs, France’s industry depended on neighbors, and thus, peace.

Amputated coalfields and a “culture of defeat”³⁰

In France, the public was drawn into debates about coal after 1870 with new pangs of urgency. The diffuse sense of cultural decline seemed to be affirmed by defeat at the hands of the Prussians in 1871, and then by the bloody insurrection of the Commune. The inauspicious beginnings of the Third Republic did little to reassure the French people, and the loss of Alsace and parts of Lorraine according to the terms of the Treaty of Frankfurt translated into the loss of a key coal-producing region in the Lorraine basin. These French losses were made all the more distressing by German success at increasing the productivity of the mines.³¹ By fusing mining concessions (prohibited under French law) and attaching them to large German companies, output increased shortly after the takeover, much to French chagrin.

Chagrin and bitterness were deeply intertwined with the sentiment of revanchism that pervaded politics during the Third Republic. This amputation resounded with an earlier one, excavating long-buried feelings of affliction at the 1815 boundary between France and Germany. This settlement deprived France of the extensive and highly profitable coal pits at

²⁹ See Appendix, *Annales des mines*, (1869), 647-666 for Britain’s statistics from 1867. See Appendix, *Annales des mines*, (1869), 667-669 for Prussian statistics from 1867, *Annales des mines*, (1869:16), 632-634 for mineral production in the Zollverein in 1867.

³⁰ Wolfgang Schivelbusch, *The Culture of Defeat: On National Trauma, Mourning and Recovery*, translated by Jefferson Chase (New York: Picador, 2004).

³¹ George Lamb, *Coal mining in France, 1873-1895*, dissertation, University of Illinois at Urbana-Champaign, 1976.

Saarbrücken.³² Although neither Alsace nor Lorraine contained France's largest coal concessions, other valuable mineral deposits were located below the surface. The drawn-out negotiations of the Treaty of Frankfurt resulted in the French cession of a stretch of ten kilometers in the department of Moselle along the frontier with Luxembourg in order to retain the city of Belfort, a sliver of land that had been spared in the preliminary agreement. In a retrospective account of the government of National Defense, Jules Favre wrote that this land was ceded with full knowledge of the rich deposits of iron ore.³³ These mineral deposits proved especially useful to the Germans who had access to plentiful coal nearby in the Ruhr basin and accelerated German industrial output. Furthermore, the Germans stood to inherit French infrastructure, including the Canal des Houillères (completed under the auspices of the French government in 1866) connecting Saarbrücken pits with the Marne-Rhine canal (completed in 1854), and thus unencumbered transport between the coal of Saarbrücken to the iron ore lying in the formerly French departments.³⁴

At the conclusion of *La chaleur solaire*, Mouchot makes one of his most surprising statements. He writes,

Thus, at a time that remains without a doubt faraway, but one that we have already begun to calculate, industry will not find in Europe any more of the resources that are in part the cause of her prodigious growth. What will we do then? Will we take to the work of the wind, of currents of water, of human motors, of machines heated by charcoal; or will we be forced to go and collect from faraway the rays of the sun, to emigrate to the regions where we again invade. The annals of human history, far from showing this eventuality

³² Lamé-Fleury, "La propriété souterraine," 199.

³³ He cites the mineral deposits as the first reason for this demand, and the reduction of the French border with Luxembourg for defense purposes by one-third as secondary, although Bismarck presented this demand in light of the many German soldiers who had fallen in the area. Jules Favre, *Gouvernement de la Défense nationale*, pt. 3, (Paris: E. Plon, 1875), <http://gallica.bnf.fr/ark:/12148/bpt6k64398684>, 372.

³⁴ Coal was generally brought to the site of iron ore for the coking process. Lucien Gallois, "Alsace-Lorraine and Europe," *The Geographical Review*. 6 (Aug. 1918), <http://www.jstor.org/stable/207474?seq=1>, 114.

as doubtful, rather foresee this, because to teach us that the regions that have nourished large populations require rest, like the earth after a great harvest.³⁵ While undoubtedly this was engineered rhetorically as a provocation, it also reflects a fundamental truth of the coal problem. Perhaps Mouchot seriously envisioned the people of Paris emigrating and re-establishing industrial civilization in the Sahara. And, as he clearly indicates, as someone thinking on the scale of geological time, this should not be mocked, as the reverse migration had occurred. In fact, Charles Lyell's publication of *Principles of Geology* (1830-33) contributed to the growing popularity of the idea of the continuity of the planet. The idea that the earth was still engaged in the same types of long-term changes that occurred during prehistoric times lent certain credibility to this mass migration. Supported additionally by knowledge of the flora that contributed to coal formations, contemporary science pointed to the drastically different climate conditions in Europe thousands of years ago. In a series of essays on coal in *La revue des deux mondes* appearing through 1857 and 1858 by Ernest Lamé-Fleury, *polytechnicien* and graduate of the Ecole des Mines, writes of vegetation at the time of the coal formations that was "made fertile by a temperature that we estimate to be double that of today."³⁶ The confluence of paleobotany and geological work on the age of the earth demonstrated beyond a doubt to men of a scientific mind that 1) the conditions for creation of coal deposits no longer existed in Europe and 2) different zones experienced different climates over history, making the proposition of a southern migration of European over the *longue durée* plausible.

³⁵ "Ainsi, dans un avenir lointain sans doute, mais qu'on essaie déjà de calculer, l'industrie ne trouvera plus en Europe les ressources qui sont en partie la cause de son essor prodigieux. Que fera-t-elle alors ? S'en tiendra-t-elle au travail du vent, des cours d'eau, des moteurs animés, des machines chauffés au charbon de bois ; ou sera-t-elle forcée, pour aller recueillir au loin les rayons du soleil, d'émigrer dans les régions qu'il dispute encore à ses envahissements. Les annales du genre humain, loin de rendre cette dernière éventualité douteuse, sont plutôt de nature à la faire pressentir ; car elles semblent nous enseigner que les contrées qui ont nourri les grands peuples ont besoin, comme le sol après une abondante moisson, d'une période de repos" Mouchot, *La chaleur solaire*, 230.

³⁶ "Fécondée par une température qu'on estime au double de celle qu'il possède maintenant," Lamé-Fleury, "La propriété souterraine en France-02," 186.

The shortage of coal, for all of its nightmares, did not actually indicate a full out exhaustion. This is noted by Jevons and Simonin. Rather “exhaustion,” as clarified by Jevons, signified a time when the costs of extracting coal rose to a point that it was no longer feasible.³⁷ This realization only added to nationalistic fervor, and fear that the supply of coal within France’s own borders was insufficient because of the difficulty in mining it. In fact, later studies of the French coal industry have corroborated this point. France did not lack coal, as some may have feared, but rather its coal was difficult to extract. Innovations in mining technology had overcome these setbacks for the time being, but the growing demands of industry ensured that France would be playing consumption brinkmanship if alternatives were not sought out.

The social geography of patronage

Mouchot’s emphasis on practical application served to mark him as an outsider to French academic science. Doubtless, he was already an outsider to the establishment. His formation at the Université de Dijon in physics and mathematics placed him outside the orbit of the Paris-based grand écoles. Lacking the imprint of the Ecole Polytechnique, Mouchot’s incorporation into the Ministry of Public Instruction, which ultimately afforded him an audience with the Academy, is surprising.³⁸ Their interest speaks to the strength of his work.

Working within France, but uninitiated in the circle of the Académie des Sciences presented a real challenge to anyone who wished to participate in French science. In comparison

³⁷ Jevons, *The Coal Question*. xix.

³⁸ The two institutions were mutually beneficial. This relationship was formalized under the 1799 charter of the Ecole Polytechnique, which required three Academicians to serve on its governing body *ex officio*. This connection remained intact in spite of the various upheavals of the nineteenth century. The Academy was invested with the power of nomination to posts within the Ecole Polytechnique in 1830. See Maurice Crosland, *Science Under Control: The French Academy of Sciences 1795-1914* (Cambridge: Cambridge University Press, 1992), 236-241.

to the British system, in which Victorian physics thrived in part based on its accommodation of industrialists and engineers, French science was an impossibly closed system.³⁹

Mouchot's promising beginnings in the imperial workshops of the Second Empire proved to be a false start. After the French defeat in the Franco-Prussian war, Mouchot's prototype disappeared during the siege of Paris. But as much as Mouchot had lost in the violence, chaos and regime change, he gained by way of France's recovery. The interest of the newly formed Third Republic in science as a means of national revival would more than compensate for his earlier losses.

In 1875, he was granted an audience with the prestigious Académie to present the solar receptor, which succeeded in producing 140 liters of vapor to power a motor.⁴⁰ To have an audience was an accomplishment, but to achieve incorporation was an entirely different matter. The *Revue des sociétés savants*, a publication of the Ministry of Public Instruction, provides a record of the Ministry's meetings. Mouchot's work is signaled by the minister, Waddington, in his pronouncement on the awarding of funds. Waddington introduces the promising discovery as belonging to "a modest school teacher from Tours."⁴¹ The summary of Mouchot's work and its promise is reported as being met with lively approval. This line sets Mouchot apart from the litany of other scientists and their discoveries that preceded him, introduced only by their names.

Misreading empire

Well before Mouchot's expedition to Algeria, he described the promise of converting solar heat into work in the "torrid regions" of the globe. Mouchot's science was not merely one

³⁹ See Crosbie Smith's discussion of James Prescott Joule's career in Manchester. Smith, *The Science of Energy: A Cultural History of Energy Physics in Victorian Britain* (Chicago: University of Chicago Press, 1998), 53-76.

⁴⁰ Mouchot, *La chaleur solaire*, (1879), 9.

⁴¹ "Un modeste professeur du lycée de Tours." *Revue des sociétés savants*, t. 11. (Paris: Imprimerie Nationale, 1877), <http://gallica.bnf.fr/ark:/12148/bpt6k202298p/f50.image>, 48.

with applications confined to the borders of France; in fact its conditions for optimal results lie beyond the Hexagon. The solar receptor provides a particularly interesting glimpse into ideas about resource management for France and its colonial possessions.

On the one hand, the results of Mouchot's 1877 experiments in Algeria were promising. His application-first approach tested the utility of the receptor for tasks suited to the everyday needs of a military expedition. He traveled the country and systematically testing the caloric yield of his devices at various locations and altitudes.⁴² These included the distillation of water and alcohol, the baking of bread and cooking of meat, which were all tasks of great importance to the French military in light of the shortage of naturally occurring coal and tinder in Algeria. These minor uses were subordinate to the primary goal, which was to determine the utility of a large solar powered engine for agriculture, to power a motor for elevating water for irrigation purposes, and industry.

Yet the importance Mouchot attached to the application of the device in the colony, more specifically in Algeria, indicates a fundamental misreading of French Empire. By attaching himself to the imperial mission, he hoped to further himself, and his work. But the French situation in Algeria was characterized by a rhetoric that did not reflect the conditions there. This misunderstanding rendered Algeria a permanent disappointment and periphery where, instead of advancing Mouchot's goals, the device languished in the realm of the impractical.

It is now a scholarly imperative to question the old center- periphery paradigm and insist on a two-way exchange between metropole and colony. While taking this expanded view of the relationship between the two has yielded fruitful results and illuminated the colonial experience, from the perspective of land management in Algeria the rigidity of the classic center-periphery

⁴² " Séance du 20 Février 1878," *Revue des sociétés savantes* / publiée sous les auspices du Ministère de l'instruction publique et des cultes. Sciences mathématiques, physiques et naturelles (Paris: P Dupont , 1862-1883), 101. <http://gallica.bnf.fr/ark:/12148/bpt6k2022992/f134.image>.

model proves valid. This is in large part due to Algeria's special status within France's Empire that denied its local specificity, and the fantasies for restoration of the land there inscribed in the French national consciousness.

The image of Algeria propagated by French officials in the metropole was at odds with the situation on the ground. The gross *décalage* between the myth of agricultural bounty and the reality stunted the growth of settlements. The French conquest was consistently depicted in terms of their restorative role in Algeria, drawing on the common bonds of Antiquity that drew the two sides of the Mediterranean together. On the political-legal level, this fantasy of Mediterranean symmetry was enforced beginning in 1848 with Algeria's acquisition of special status as a French *département*. As an integral part of France, it was assumed that European style governance, and agriculture, could be imported in what amounted to a refusal to recognize difference. For all the rhetoric of symmetry, Algeria remained an underdeveloped, under settled periphery.

The idea of the French presence in North Africa as restorative enjoyed a long history in modern France, from its initial formulation during Napoleon's 1798 invasion of Egypt and through the conquest of Algeria under Charles X in 1830. In her study of French Algeria, Jennifer Sessions highlights the backward-looking agrarianism that characterized the French perspective of Algeria and dictated policy there. Since, as Sessions writes, the settler colonialism in place there "aims to occupy land rather exploit its inhabitants labor and to create new societies rather than control existing ones," Algeria was the perfect canvas for French technocrats to sketch an idealized, hyper-productive colony as extension of Europe.⁴³ This myth of agrarian bounty constructed from blind faith in earlier travel accounts and the writings of antiquity showed remarkable resilience in the face of experience. Instead of recognizing the drastically

⁴³ Sessions. *By Sword and Plow*, 323.

different circumstances, officials insisted on heavy-handed measures that treated Algeria as part of Europe.

It is worth noting that French colonialism was not so impervious to local conditions everywhere. With regard to natural resource management, earlier efforts at colonization showed a fine appreciation and willingness to learn from local conditions. For example, in Richard Grove's *Green Imperialism*, the author describes the traffic of knowledge about forest conservation back from the colony of Mauritius to France proper during the seventeenth century.⁴⁴ In particular, he focuses on the figure of Pierre Poivre, an Académicien and intendant on Mauritius, who was "able to elevate indigenous-non-European epistemologies on their merits alone and then adapt them for his own purposes."⁴⁵ The danger of the French myth of restoration was its implication that North Africa had degenerated. This made the consultation of indigenous people about exploitation of the land unthinkable as it devalued, or denied, their local knowledge. The Arabs, so the thinking went, were impossibly poor stewards of the land and had caused its decline. Thus, the French state had produced a discourse natural resource management expressly excluded local knowledge. The French *mission civilisatrice* enforced abroad aimed to recover the supposed agricultural wealth not only for French profit, but for the benefit of the backwards colonial people.⁴⁶ Only by insisting on historical evidence from the Greco-Roman period could the desert be made to flower. This was pure hubris and had the effect of devaluing the local context, reinforcing the association of colony with periphery.

Yet the rhetoric of agricultural bounty became amplified in the years immediately following 1871. The revival of scientific interest was pursued alongside renewed imperial thrust

⁴⁴ Grove, *Green Imperialism*, 168-263.

⁴⁵ Grove, *Green Imperialism*, 193.

⁴⁶ For a discussion of the *mission civilisatrice* in Africa, see Alice Conklin, *A Mission to Civilize: The Republican Idea of Empire in France and West Africa, 1895-1930* (Stanford: Stanford University Press, 2000), 11-38.

in Algeria. In his read on the aftermath of the Franco-Prussian War, Wolfgang Schivelbusch wrote that the French Third Republic rebounded by transmuting French nationalism from a military zeal to an expression of cultural superiority that played out in its imperial possessions.⁴⁷ In 1871, the French brutally suppressed the Kabylie uprising in Algeria. Seizing some eleven million acres for settlers to punish Muslim and tribal populations, officials launched a push to recruit settlers to redeem the land.⁴⁸

Persistent overestimation of Algeria's agricultural potential became fused with aspirations for industry there. In 1867, a mineral survey of the territory was conducted. The author of the report, which appeared in the *Annales des mines* of 1869, concluded, "Algeria includes a great number of mineral deposits that can offer diverse resources to industry."⁴⁹ In this memoir, intended to call attention to Algeria's riches, the lack of high quality coal is addressed almost immediately making the situation, in the words of one mining engineer, "disagreeable." Limited deposits of anthracite, of mediocre quality, and lignite (an inferior burner) were available, but these were difficult to access and would not be sufficient fuel for any real industry. The surveyors found deposits of salt, lead, copper, zinc and numerous construction materials, but the lack of coal inhibited any real industry.⁵⁰ The scarcity of both mineral and vegetable combustible in the colony drew it into a web of French dependency. Yet officials remained undeterred and elaborated plans for establishing industry in the colony. Indeed, Mouchot was

⁴⁷ Schivelbusch, *Cultures of Defeat*. Also see Jennifer E. Sessions. *By Sword and Plow: France and the Conquest of Algeria*, (Ithaca and London: Cornell University Press, 2011), 17.

⁴⁸ *Optants*, or former residents of Alsace and Lorraine settled in Algeria in large number during the 1870s. For more on the migrations of Alsatians and Lorrainers to Algeria, see Fabienne Fischer, *Alsaciens et Lorrains et Algérie, histoire d'une migration, 1830-1914* (Nice: Serre, 1999).

⁴⁹ "L'Algérie renferme un grand nombre de gîtes minéraux qui peuvent offrir à l'industrie ces ressources très variées." M. Ville, "Notice sur les gîtes minéraux et les matériaux de construction de l'Algérie." *Annales des mines* (1869), 133.

⁵⁰ M. Ville, "Notice sur les gîtes minéraux et les matériaux de construction de l'Algérie." *Annales des mines* (1869), 133-198.

accompanied on his 1878 expedition by a certain M. Gudin, a specialist in railroad planning, surveying in preparation for an unrealized Trans-Saharan Railway.⁵¹ The plans for the rail network further accentuated the demand for a source of power in Algeria and potential niche for Mouchot's invention.

While previously Mouchot entertained dreams of maximal efficiency outside of France, following his first bout of experiments there in 1877, the invention and its setting were inextricable. The warm reception of the public and glowing accolades that Mouchot received at the Exposition Universelle provided him with the occasion to print a revised edition of *La chaleur solaire et ses applications industrielles* with an account of his experiments in Algeria. In the revised version, appearing in 1879, the original text appeared largely unchanged save for the addition of a ninth chapter and an updated foreword and conclusion. Drawing examples for utility from the Sahara to Cochinchina, Mouchot's new field of application spans the French empire.⁵² These additions were inflected with fervent hopes for its adaptation in such torrid regions when compared with the first edition. Hitching his personal ambitions to the "civilizing mission" of the Third Republic moved the device permanently outside the sphere of the metropole and positioned it within the colonial periphery, where it was soon abandoned.

Science and industry on display

The exposition of Mouchot's invention at the 1878 Paris World's Fair suggests its importance to both a national and imperial registers. Nineteenth-century world's fairs were classically imperial affairs, and the one staged in Paris in 1878 had the special task of projecting an invigorated vision of the Third Republic. In the journal *L'Exposition Universelle Illustrée*, an organ for stirring up anticipation for the event, the career of General MacMahon is given front-

⁵¹ Mouchot, *La chaleur solaire* (1879), 201.

⁵² "C'est ainsi que, dans notre colonie de Cochinchine, à Saïgon par exemple, l'eau doit être soumise à l'ébullition pour devenir potable." *La chaleur solaire* (1879), 223.

page treatment. The article reports on his illustrious career, which not coincidentally found him as governor of Algeria, then president of the Republic. Macmahon

...wished to prove to all nations that the Republic is a government of peace and concord and its power is such that, under his aegis, France had reconquered on the battlefield of industry, the situation that she had held in 1867.⁵³

The publication itself announced that it was resuming the role of its predecessor and indeed the numbering begins at issue 61. Drawing a line of continuity between France's last successful production on the world stage and the present moment served to elide the calamitous intermittent years which featured a heavy blow to France's military, territorial integrity, international prestige as well as internal fracture and violence of the Commune. The Third Republic staged the Exposition Universelle to bury this recent past and obscure its own birth from defeat and discord.

The display of Mouchot's invention is indicative of an engagement with public interest in energy consumption. The device belonged to the register of spectacle—it was used for boiling water, making coffee, pasteurizing Algerian wine, producing electrical currents, in addition to the famed ice block. This battery of small applications undermined its greater potential. The fact that the large solar receptor was not completed until September of 1878, and the exposition ran from May to October is a testament to how its greater promise was overlooked. To attendees, the device had become a curiosity with little bearing on life in Europe.

Instead, the Exposition Universelle served to cement Mouchot's receptor in the colonial imaginary. Mouchot was exhibiting in the section of the Ministère de l'instruction publique, not, as one might expect, alongside other inventions in a section devoted to industrial technologies. Instead, he was alongside "des immenses cartes dressées par la Commission de topographie" of

⁵³ 1867 was the last time Paris had hosted a World's Fair. *L'Exposition Universelle de 1878 Illustrée*, no.61 (1 May 1876), Paris: Commission de l'Exposition, 2. <http://gallica.bnf.fr/ark:/12148/bpt6k5824648m>.

the French empire, affirming the association of the device with a colonial other.⁵⁴ The author of this passage further elaborates,

We often repeat that at the time of the Romans our colony of Algeria could independently fill the granaries of Italy... We must make every effort to have the natives adopt our system of agriculture. What is the best means of accomplishing this if not establishing a considerable number of farm-schools where the Arabs might come to do apprenticeships?
55

He offers a refrain of the restorative myth as misreading of Algeria's natural resources.

Unsurprisingly, Mouchot's invention is positioned in the same section, and the very same column, as policies for making Algeria more profitable in a way that totally misunderstood the land.

The solar-powered engine offers a promise of a bright future for occupants of the colonies. The author of an article in *L'Exposition Universelle Illustrée*, identified only as Adelin, wrote,

These results are indeed very curious and even more so instill in us the greatest hopes for the future that M. Mouchot's invention could provide in lands scorched by the unforgiving sun. The sun would thus become a source of their wealth...⁵⁶

It also provided a reassuring vision of the future, transforming the abundance of sunlight that was counted among the perils of life in Algeria, into a source of wealth. But most striking is the author's use of "their" (leur in the French). In talking about parched lands, he has distanced himself from the inhabitants. Already, the French had abandoned their association with the

⁵⁴ "Section Française," edited by Jules Brunfaut, *Expo Universelle de 1878 Illustrée: publication internationale autorisée par la Commission*. 149 (1878), <http://gallica.bnf.fr/ark:/12148/bpt6k5825433s/f3.image>, 757.

⁵⁵ "On a souvent répété qu'au temps des Romains notre colonie d'Algérie pouvait à elle seule approvisionner les greniers de l'Italie...il faudrait faire adopter aux indigènes une partie de notre système agricole. Comment y arriver, si ce n'est en créant un nombre considérable de fermes-écoles où l'Arabe viendrait faire son apprentissage?" "Section française," 757.

⁵⁶ "Ce sont là des résultats très-curieux et qui plus est, propres à nous faire concevoir les plus belles espérances pour l'avenir que l'invention de M. Mouchot peut donner aux pays desséchés par un soleil ardent. Le soleil deviendrait ainsi la source même de leur richesse..." Adelin, "La Chaleur Solaire: Son Emploi Industriel," *L'Exposition Universelle de 1878 Illustrée*, <http://gallica.bnf.fr/ark:/12148/bpt6k5825440x/f7.image>, 809.

project and placed it at both a geographical and a chronological distance—in short, it was perfectly suited to the colonial imagination.

Mouchot's device briefly became the centerpiece for a new colonial imaginary. Literally, as it turns out, in one depiction on the front cover of the magazine *La Science Populaire* from 1882 (see Appendix, Figure 1). The receptor sits amid several contraptions, similar to those that on display on the Champs de Mars at the Exposition Universelle. At the bottom of the page, a banner reading “The sun—cooking aid—distiller—printer—photographer—rotisserie---fire starter---electrician—mechanic—etc.---etc.” appears, heralding its versatility. Strikingly, two men, noticeably dark and lacking shirts, occupy the middle ground. One appears to be in the midst of tending to a machine (perhaps peeling potatoes before boiling them in a trough?) while the other sits, half-reclined upon the frame of the receptor, at rest. In the background, a small figure in a suit stands at the gate, surveying what lies in front of him. The self-assured title, “La Conquête du Soleil” suggests the double conquest at work in the image: of the sun in its role as prime mover of nature, harnessing the rays to suit the needs of colonists, and then of Algeria, subdued after the paroxysms of violence in the 1860s and 70s. This picture captures the pervading vision of colonial life in Algeria from the metropole, one ultimately at a distance from reality.

Conclusion

Mouchot and his device quietly faded from the press and from scientific establishments in the years following the Exposition Universelle. His partner in his later years, Abel Pifre, continued to exhibit the device at his home on Rue d'Assas in Paris. On a clear day, visitors

could pass by and watch the device perform an array of tasks.⁵⁷ The device had traveled from the realm of possibility to mere curiosity fixed within the French colonial imagination.

What seems to us as utopianism had once enjoyed a moment of serious consideration by effectively engaging with the discourse of natural resource management. Within the context of fears of a European coal shortage and a resurgence in colonial enthusiasm, Mouchot's solar receptor gained real traction in public opinion and financial support. Yet the factors governing French science and the status of Algeria both agriculturally and industrially as unproductive periphery were not conducive to sustained support for Mouchot and his device. Furthermore, the first French imports of petroleum had begun in 1861, and came to occupy a growing share of the market in the ensuing decades, dominating the market by the eve of World War I.⁵⁸ "Peak coal" became less worrisome with petroleum as a more efficient and cleaner-burning alternative.

Mouchot's device partakes in the wider phenomenon of the forgotten history of alternative energy sources. These projects have been largely neglected by historians. They are either been taken as unremarkable, and thus unworthy of study (such is the case of wind and watermills); or due to their failure to take hold (as in this early case of solar power) become a casualty of "inevitable" progress fed by fossil fuels. Returning to these stories and attempting to reconstruct the moments of possibility can help us to see beyond the blinders of fossil fuel dependency that govern the modern world and to recapture earlier ideas about natural resources.

⁵⁷ "Le soleil," *La Science Populaire*. Paris, no.131 (17 Aug 1882). <http://gallica.bnf.fr/ark:/12148/bpt6k54190713>.

⁵⁸ Daniel Murat, *L'intervention de l'Etat dans le secteur pétrolier en France* (Thèse de Droit, Université de Paris, 1968), 8-11.