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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

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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.

4 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?

5 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

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.

7 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).

8 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."

9 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

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 gasworks 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, ashwood, 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 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. 15

In 1820, the Conseil de salubrité du département 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 16

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 limewater, 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 través 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.

29 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

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 32
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

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 agri-food 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 41
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

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.

While in 2006 Gaz de France announced “We are 42
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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