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Antoine Fontaine

► To cite this version:

Antoine Fontaine. Heating France with nuclear power: Alternative heat politics and competing nuclear regimes during the 1970s. *Journal of Historical Geography*, 2021, 73, pp.1-10. 10.1016/j.jhg.2021.05.002 . hal-03244060

HAL Id: hal-03244060

<https://hal.science/hal-03244060>

Submitted on 1 Dec 2022

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Heating France with nuclear power: alternative heat politics and competing nuclear regimes during the 1970s

Abstract:

Nuclear power is largely analysed as a contested energy production technology with a focus on the factors for the success or failure of the development of nuclear programmes but little questioning of the usages associated with this energy production. By concentrating specifically on the question of usage, this article sheds light on an original timeline of the development of nuclear power in France in the 1970s. It highlights the existence of an intense debate on the means of using the energy that would be produced by this industry and on the models of technical, political, economic and spatial organisation of the energy system that would result. Based on an analytical work of several historical archival funds, this paper brings into light how three sociotechnical regimes were in competition to organize the French energy system during the development of the national nuclear programme. From an historical geography perspective, this paper provides insights for a critical rethinking of the development of nuclear programmes as well as for the politics surrounding the phase-out of nuclear power.

Keywords: nuclear power, heat politics, sociotechnical regimes, energy usages, energy transition.

1 Introduction

France is currently the world's second-largest producer and consumer of nuclear energy, after the United States, with fifty-six reactors that generate 70% of the country's total electricity production¹. These nuclear plants were largely built throughout the 1970s, as the number of operational nuclear reactors in France that were dedicated to energy production increased from nine in 1970 to forty-six in 1985. This period was marked by protests from anti-nuclear movements, starting with a programme that the government put at the centre of its national economic and industrial policy². Analyses of this history highlights a convoluted development path, in the middle of which the institution of nuclear power has continuously managed to adapt to keep this technological choice accepted³. In these contributions, although nuclear power is understood as a contested energy production technology, there has been little questioning of the usages associated with this energy production. By concentrating specifically on the question of usage, this article sheds light on an original timeline of the development of nuclear power in France. This timeline, which puts less focus on the dynamics of opposition to and support for nuclear, highlights the existence of an intense debate on the means of using nuclear heat. Based on the French case, this article questions the challenges of reconfiguring energy systems associated with alternative uses of nuclear heat, which were discussed during this decade at the scale of different countries (Germany, Finland, Sweden) and within several international arenas such as Euratom and the International Atomic Energy Agency⁴.

In doing so, this research tackles the question of socio-energy transition trajectories from an historical geography perspective. Following analyses about the consequences of the choice of fossil

¹ Réseau de Transport d'Electricité (RTE). *Electrical performance 2019 – Summary 2019*, 2019.

² G. Hecht, *The radiance of France: nuclear power and national identity after World War II. Inside technology*, Cambridge, 1998.

³ S. Topçu, *La France nucléaire: l'art de gouverner une technologie contestée*, Paris, 2013.

⁴ Revue Générale Nucléaire (joint work), Production et utilisation de la chaleur à basse et moyenne température d'origine nucléaire, *Revue Générale Nucléaire* 2 (1977) 82-83.

fuel technologies in the nineteenth century⁵, this paper questions the consequences of choices made in the 1970s around nuclear power. In this respect, this research is in line with several fields of study that question the conditions for expanding the nuclear energy industry in a variety of contexts around the world and the way in which this expansion influences the organisation of energy systems. Contributions to this area of research primarily take the form of the history of national nuclear policies. These works highlight that the success of nuclear programmes is based on a slow process, essential to which is considerable support from state institutions⁶. A second field of research suggests more specifically identifying the factors for the success or failure of development nuclear programmes. There are several factors in particular that appear to encourage this development: the centralisation of decision-making with regard to energy and organisation, significant commitment by the state to guide the country's economic policy, the influence of technocratic backgrounds in decision-making, communication linking technological progress and the revitalisation of the country and, lastly, less opposition from activists⁷. This analysis of the factors gives an outline to a preferred system for expanding nuclear power, without yet examining the existence of alternative paths. To this end, this paper offers a third analytical approach that goes on to question the existence of other expansion options. Through the analysis of debates relating to the construction of public energy policies in France in the 1970s, this paper underlines the existence of three strategies for producing and using energy from nuclear power plants and raises several questions: how these strategies suggested reconfiguring the national energy system? What geographic configurations have been considered? Is the expansion of nuclear power possible within non-centralised technical and political systems or in the context of less support from the state and technocratic corners?

To answer these questions, this article supports the notion that the strategies of producing and using nuclear energy maintained throughout the 1970s each constituted a “nuclear regime”. Through this notion, the discussion raised here is about how politics are conducted through technological means, what Hecht tackled as technopolitical regimes when studying the links between civil and military nuclear power in post World War II France⁸. More specifically, the nuclear regime is hereafter defined as all the forms of geographic, political and economic organisation that arise from a mean of producing, converting and using nuclear heat. By progressively examining the context in which three nuclear regimes appeared, were rejected or thrived, and by highlighting how the organisational logics they are based on cope, this article sheds light on the history of the French nuclear development and its impacts on the reconfiguration of the French energy system in the 1970s. Following on to a critical historiography of theories of technological determinism⁹, we point out that the routes for developing nuclear systems do not stem from one single technological choice, but from all of the political, geographic and economic choices that occur around them. In this sense, the article puts forward a discussion on the distinction made by Amory Lovins in his 1977 reference work, according to which the choices of energy sources and technologies commit societies to radically different transition paths. On one hand, the “hard energy path” would result from choosing fossil fuels and nuclear power and be

⁵ A. Malm, *Fossil capital: the rise of steam-power and the roots of global warming*, London, 2016.

⁶ P. Simonnot, *Les nucléocrates*, Grenoble, 1978; G.Hecht, *Ibid* ; S. Topçu, *Ibid* ; J.M. Jasper, *Nuclear Politics*, Princeton, 1990.

⁷ B. Sovacool, S.V. Valentine, The Socio-Political Economy of Nuclear Energy in China and India, *Energy* 35 (2010) 3803-13; S.V. Valentine, B. Sovacool, The Socio-Political Economy of Nuclear Power Development in Japan and South Korea. *Energy Policy* 38 (2010) 7971-79.

⁸ G. Hecht, *op.cit.*

⁹ L. Mumford, Authoritarian or democratic technics, *Technology and Culture* 5 (1964): 1-8; L. Winner, Do artifacts have politics, *Daedalus* (1980) 121–136.

based on an energy system that is built around a policy of supply, research into economies of scale, developing concentrated technical networks and centralised governance¹⁰. On the other hand, the “soft energy path” would stem from choosing renewable energies and be based on a policy of energy efficiency and decentralised governance¹¹. In view of the concept of the nuclear regime applied to the situation in France, this article emphasises that the development of nuclear power can follow hybrid paths that transcend the boundaries between the two categories, heuristically outlined by Lovins. To do this, the following sections present in succession: the methodological framework of the study and the data analysed, the French institutional context in the 1970s in which the question of uses of nuclear energy is debated and the emergence and logics of confrontation between three nuclear regimes. The two final sections summarise the lessons from our analysis of nuclear regimes and discuss the points contributed by the study to examine past, present and future energy transitions.

2 Methodology and data

The research presented in this paper is based on an analytical work of several historical archival funds that were carried out between 2016 and 2020. The work is largely based on the archives of three main parties that participated in a debate on the use of nuclear energy. The first is the public company Electricité de France (EDF), which is charged by the government with coordinating the construction sites for nuclear power plants and then ensuring their management. The second is a body connected to the Ministry of Industry and charged with the task of studying and advising policies related to energy consumption: the advisory committee on the use of energy (CCUE). Lastly, the third was a national agency attached to the Ministry of Industry charged with the task of studying and advising on questions of energy efficiency: the National Agency for Energy Savings (AEE). In addition, and to a lesser extent, the analysis is also based on the archives of several ministries and regional organisations that were involved in this debate. Our analysis of these archival funds is based on several types of first-hand sources: transcriptions of parliamentary debates, speeches, internal working notes, correspondence between these parties, study files and meeting minutes.

As a complement, this analysis is based on a series of semi-directed interviews led with parties involved in and witnesses to this history (directors of organisations, authors of reports, committee members) to ask them about the questions and interpretations raised by the archives. These interviews were partially carried out as part of the RECUPERTE research programme, which is focused on public policies of recovering and using heat. This programme partly focuses on the nuclear industry, which is a huge source of heat, within which the establishment of the recovery operation meets with significant economic, political and spatial obstacles today.

3 The uses of nuclear energy debated in the context of France in the 1970s

The debate on the methods of producing and consuming nuclear energy that interests us was part of the intense institutional and legislative events in the 1970s (see Figure 1). This began in the circumstances surrounding the first oil crisis. The sudden increase in the price of petrol between October 1973 and March 1974 posed significant risks for the energy and economic security in the country. The government thus saw the nuclear industry as the best way to control the growth in French energy imports. Although it had decided in the 1960s to start construction on eight nuclear reactors of 900 MW between 1970 and 1975, the scope of this programme was revised upwards several times. In March 1974, the prime minister finally adopted a plan for the 13 nuclear reactors of 900 MW in the

¹⁰A. Lovins, *Soft Energy Paths: Toward a Durable Peace*, New York, 1977, 26.

¹¹ Ibid, 39.

period of 1974-1975 alone based on the advice of national public company Electricité de France (hereinafter referred to as “EDF”)¹². This recalculation of the programme was based on the idea that economic growth is correlated with the growth in energy demand. However, the idea was already being criticised on an international level¹³. In addition, the acceleration of the nuclear programme should not only increase the country's energy security, but also support economic growth¹⁴. However, with regard to the scope of the nuclear programme, the country's industrial electricity demand was insufficient to use up the energy that would be produced. In line with the construction of nuclear power plants, EDF implemented a commercial policy that was intended to stimulate domestic electrical demand¹⁵, especially through the development of electric heating. Thus, at a time when other nuclear countries decided to reevaluate downwards their nuclear program, the French government and EDF initiated a massive nuclear program¹⁶.

At the same time as the acceleration in the nuclear programme, the French government implemented a second section to its new energy policy, dedicated to energy efficiency. This policy was built around the National Agency for Energy Savings (AEE), created in October 1974, with an initial emphasis on the topic of heating. The first measures adopted established in succession the foundations for thermal regulation of buildings and adjusting heating installations (decree 74-306), a maximum temperature level for heating buildings (decree 74-1025) and a punitive system in the event of non-compliance with these maximum heating temperatures (decree 75-733). This regulation, which aimed to set limits on the uses and lead to reduced consumption caused a shift in the nuclear programme, the success of which was based on a rapid increase in consumption of electric heating. This shift between the two sections of the national energy policy was criticised by the AEE and by several parliamentary commissions. These criticisms were heard by the government, leading to the process of adopting a national heat policy that started with the creation of a national expert commission on the use of heat in 1975, the adoption of a law on the use of heat from 1978 and the creation of a national heat agency in 1980. The alternative means of adding value to nuclear power plants that were studied throughout this process are exactly what we shall be considering in the following on nuclear regimes.

Figure 1: Institutional context of the national debate on the use of heat from nuclear power plants (by: author)

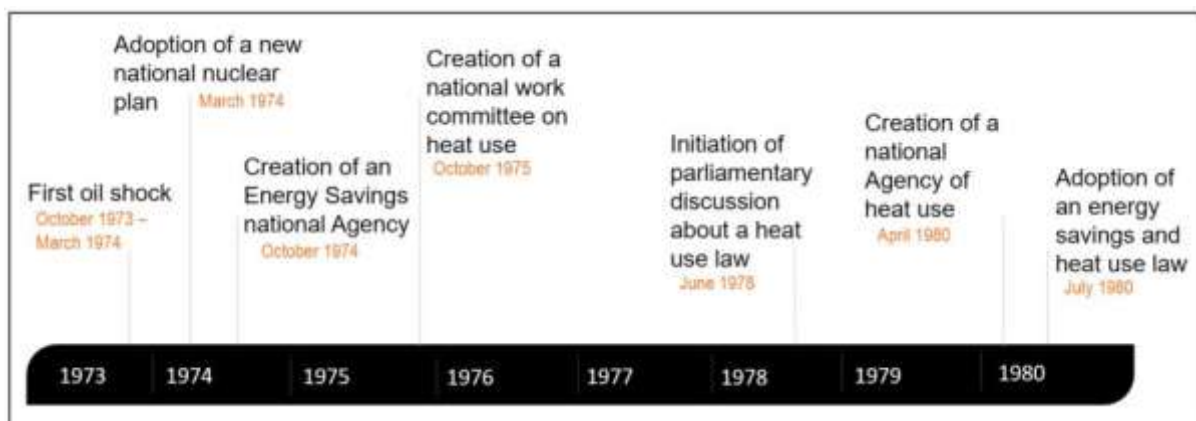
¹² M. Boiteux, *Haute tension*, Paris, 1993.

¹³ Ford Foundation and Energy Policy Project, *A Time to Choose*, 1974.

¹⁴ Interview with the vice-president and general reporter of the energy group of the 9th Plan General Committee.

¹⁵ Y. Bouvier, Économiser plus pour consommer plus: Les ambiguïtés de la communication d'EDF au temps des économies d'énergie, *Annales historiques de l'électricité* 10 (2012) 31.

¹⁶ J. Jasper, op.cit.



4 The rise of the French nuclear energy industry: three rival regimes

By analysing specifically the alternative means of recovering energy from nuclear power plants that are defended in this context, we highlight that the acceleration of the French nuclear programme and the construction of the power plants happened in the absence of a consensus on the methods of using the energy produced. The period was characterised in particular by the confrontation between three distinct nuclear regimes that appeared in parallel to each other and put forward very different technical, economic, geographic and political configurations to expand nuclear power.

4.1 The completely electric nuclear regime: policy of supply and centralised governance

The first nuclear regime emerged from the actions of national public company EDF with the support of the government. It was introduced in line with an energy centralisation policy implemented during the twentieth century starting with the law of 1919 known as the law of nationalization of hydroelectric energy. Since 1946, EDF has been responsible for the production, transport and distribution of electricity after nationalisation and the merging of 1,450 local electricity companies¹⁷. With the development of the nuclear industry, EDF's electricity provision goal was reinforced and made it possible to ensure the country's competitiveness on an international scale. The programme was built around a policy of supply, desire for an economy of scale and working towards a gradual reduction in energy production costs¹⁸.

As the manager of both the electricity production infrastructure and an expanding national electricity network, it was entirely logical for the company to offer a model of operating power plants that was aimed at only recovering electricity. In accordance with the principles of thermodynamics, the heat produced by nuclear reactions in the power plants is transformed with a yield of approximately 35% electricity. The rest of the energy is released as a vapour in the chimneys or lukewarm water of between 15°C and 35°C, depending on the season, which are difficult to harness to meet energy needs. The choice of completely electric recovery reinforces the importance of the electrical network at the heart of a national energy system. This network was, in particular, the vehicle for a national energy solidarity policy that stemmed from the tariff equalisation principle, which was

¹⁷ F.M. Poupeau, *L'électricité et les pouvoirs locaux en France (1880-1980): une autre histoire du service public*, Brussels, 2017.

¹⁸ A. Grubler, The Costs of the French Nuclear Scale-up: A Case of Negative Learning by Doing, *Energy Policy* 38 (2010) 5174-88.

adopted gradually from the start of the 1970s¹⁹. Thanks to the huge influx of electricity onto this network, the state made a commitment that all French households would pay the same price for their electricity, without taking into consideration where they were in the country and the distance that separated them from electricity production sites.

However, this kind of all-electric nuclear policy focused on supply encountered several difficulties. Nuclear electricity production works as a fundamental principle, meaning that it is constant all day and all night. However, the national demand for energy was unbalanced according to the time of day: significant in the morning and evening, lower in the middle of the day and very low at night. To adapt to this problem, EDF sped up its commercial policy that was started in 1968²⁰ and based on the development of electric heating and carrying over some electric consumption to night using preferential tariffs. The commercial policy of “integrated electric heating” encouraged the joint development of electric heating and improvements in heat efficiency for buildings. New housing was the primary target of this commercial policy. EDF promoted the idea that if insulation in these buildings was adapted to electric heating, this would be a credible alternative in terms of yield in view of other heating solutions (gas, wood, heating oil, heating networks).

By using the national electric grid, the energy produced by the nuclear power plants could be easily directed to its consumers across the entire country, with very low losses in the line during transport. For these reasons, the power plants did not need to be built close to large areas of consumption. However, the location of power plants depended on the likelihood of drops in temperature, seismic risks, challenges in security and radiation protection and the ease of construction²¹. Beyond matters of power plant siting, nuclear safety issues were at the centre of a nascent institutionalisation during the 1970s under the aegis of the Ministry of Industry and the French Atomic Energy Commission (hereinafter referred to as CEA). The goal was then to regulate without hindering the implementation of the national program through overly restrictive measures²².

The choice of fully electric recovery of the energy produced by nuclear power plants was the foundation of a first nuclear regime (see Table 1). This was characterised by a technical operating mode for power plants, specific geographic planning for their establishment and a system for transforming economic and social logics of energy consumption. Lastly, it tried to reinforce the centralised nature of governance in the French energy system. Nevertheless, this nuclear system provoked several criticisms, not only from anti-nuclear corners, but also from some defenders of nuclear power who believed that its development could be structured around other sequences. The first of these criticisms was related to the low energy output underlying this regime. Two thirds of the energy generated by nuclear power plants is lost. When considering that a portion of the electricity produced was used *in fine* for heating, some critics highlighted that the total output for this regime should be revised downwards by several percent by taking into account the losses of energy during transport²³. This regime is referred to as “energy waste”. The situation in the aftermath of the oil crisis pushed the government to adopt several measures restricting the development of electric heating by prohibiting

¹⁹ F.M. Poupeau, La fabrique d’une solidarité nationale: État et élus ruraux dans l’adoption d’une péréquation des tarifs de l’électricité en France, *Revue française de science politique* 57 (2007) 599.

²⁰ EDF archives – Box 823510 – memo from the sales department of 30 June 1970: It was starting in 1968 that the commercial department at EDF put into operation the first reference installations for total electric heating in housing as part of a display operation before launching its national supply in 1970.

²¹ Ministry for Industry and Research, « Rapport d’Ornano », 1974.

²² C. Foasso, Histoire de la sûreté de l’énergie nucléaire civile en France (1945-2000), unpublished PhD thesis, Université Lumière Lyon 2, 2003: 344.

²³ Institut Economique et Juridique de l’Energie (joint work), *Alternatives au nucléaire*, Grenoble, 1975.

advertising²⁴ and imposing a tax on the specifics that equip their housing with an electric heating solution (decree of 22 October 1977). The third criticism formed in opposition to this nuclear regime was based on the environmental impacts of technical operation of these power plants. With a fully electric recovery for production, the power plants emitted substantial amounts of heat waste. The temperature of this waste was limited by a national decree (no. 63-1228 of 11 December 1963) that restricted the actions taken by power plant managers²⁵ and could not cause the warming of natural areas or disturb them²⁶ (Lebreton, 1975).

The expression of these criticisms, also seen in activist areas, research and parliamentary institutions, accompanied the offer of an alternative means of nuclear development.

Table 1: The fully electric nuclear regime

	Technical method of energy production	Spatial organisation	Method of energy consumption	Criticisms of the regime
Fully electric regime	Nuclear heat is converted into electricity with a 33% yield. The rest of the energy is released as a vapour in the chimneys or lukewarm water (between 15°C and 35°C, depending on the season)	The power plants were located along rivers and oceans that made it possible to cool them and far from large urban centres as a precaution.	Electric heating had to be developed quickly to absorb the energy produced. Consuming electricity at night was encouraged to balance out curves in consumption.	(1) Energy output in this system is low (2) This system assumes a significant growth in energy demand that appears incompatible with the policy of energy savings (3) Heat waste from power plants warms rivers and damages natural environments

4.2 Nuclear regime of cogeneration: developing heat networks and energy savings

When adopting a law on recovering and reusing waste in July 1975, the National Assembly proposed facilitating recovery of heat waste from nuclear power plants. A first text adopted stipulated that the temperature of this waste be set depending on the uses that could be implemented for industry, heating buildings or the agricultural sectors²⁷. This proposal challenged the operation of nuclear power plants that was aimed at solely electric recovery and defended a logic of cogeneration. A cogeneration nuclear power plant produces both electricity and heat that can be recovered at a high temperature (between 80°C and 180°C). This operation led to a reduction in electricity production, but the heat recovered could meet a wide range of energy requirements. The general energy output from the power plant can go from 35% in the completely electric outline to 70% in the cogeneration outline²⁸. This proposal for reorganising the technical operation of nuclear power plants had a number of impacts. First, a cogeneration power plant emits less heat waste and therefore has less impact on the environment. Adopting a cogeneration policy then calls into question the spatial establishment of

²⁴ EDF archives – Box 891178 – Letter from the Minister of Industrial Development to the president of EDF of 25 December 1973 refusing to agree to an exemption to the prohibition on advertising electric heating.

²⁵ Louis Fagon, *Le Rhône nucléaire des années 1950 aux années 1990* (ongoing work)

²⁶ P. Lebreton, Electro-nucléaire et environnement dans la vallée du Rhône, *Revue de Géographie de Lyon* 50 (1975) 19-34.

²⁷ Archives for the Ministry for Industry – Box 1988 0199 39 – Report no. 394 by MP Weisenhorn, written on behalf of the production committee, submitted 15 June 1978, title 4bis.

²⁸ B. Bourgeois, *La récupération de la chaleur dans les centrales thermo-électriques - apports et limites de la notion de coût social en économie de l'énergie*, unpublished PhD thesis, Université de Grenoble, 1978.

nuclear power plants. It became interesting to limit the distance between power plants and large urban areas in order to reduce the cost of heat networks to be built and to more easily obtain economic conditions that are suitable to recovering heat. Lastly, the improvement in the general output of nuclear power plants due to this change in operating mode made it possible to generate the same quantity of energy while reducing the number of reactors that needed to be built. In light of these challenges, the cogeneration principle supported by this legislative proposal created a second nuclear regime (see Table 2). This regime did not appear to be compatible with the fully electric nuclear regime as the direct recovery of heat reduced the prospects for developing electric heating and thus the absorption of electric nuclear production. This incompatibility is revealed when questioning the two framework principles for the fully electric system: the importance of the number of nuclear reactors to build and the policy of geographic location of these reactors far from cities.

Table 2: The nuclear regime of cogeneration

	Technical method of energy production	Spatial organisation	Method of energy consumption	Criticisms of the regime
Cogeneration regime	Nuclear energy is recovered both in the form of electricity and as heat, which is collected at between 80°C and 180°C from the reactors. The electrical output is reduced, but the total electrical output can reach 70%. Heat waste is gradually reduced.	The power plants should not be located too far from urban centres to make it possible to recover heat in acceptable economic conditions using heat networks	Two types of energy networks developed in parallel: a national electrical network and local or regional heat networks. Recovering heat from nuclear power plants reduces the diffusion of electric heating and the demand for electricity in densely populated regions.	(1) Developing and maintaining two energy networks at the same time is an expensive choice (2) The power of existing power plants means finding centres with very high levels of consumption to justify the recovery of heat (3) The supply of heat from power plants is uncertain. It can be interrupted when power plants are stopped for maintenance.

This legislative proposal was dismissed by the government, which still financed several studies on the utility of direct heat recovery from nuclear power plants. These studies were jointly led by the Ministry of Industry through the advisory committee on the use of energy, by the Ministry of the Environment through the agency for energy savings and by the national committee for heat recovery²⁹. This group looked to draw lessons from ongoing operations in Northern Europe and Russia. In particular, the city of Stockholm has been supplied with heat since 1963 from the Agesta nuclear reactor, which is more than 100 kilometres away³⁰. On the other hand, this group is concerned with the specific case of Bugey to the east of Lyon, where a first reactor was put into operation in 1972 and where four other reactors were built. Based on the promising technical studies carried out by the CEA³¹, a first report made in June 1975 proposed supplying 40 hectares of greenhouses for agricultural,

²⁹ Archives of the Ministry for Industry and Research – Box 1989 0572 5 – Report from meeting n°235 of the advisory committee on the use of energy.

³⁰ Ibid.

³¹ G. Merle, Utilisation des rejets d'eaux tièdes des centrales thermiques en aquaculture, *Hydroécologie Appliquée* 1 (1991) 1-26.

horticultural or piscicultural uses and to supply a network to build that could heat the equivalent of 70,000 homes. This proposal meant only a minimum number of technical modifications to the power plant starting from the recovery of only lukewarm water and recovering their heat thanks to heat pumps. This solution was nevertheless in difficult competition with the use of heat networks powered by gas³². Following on from these conclusions, a second part of the study was launched to contemplate a more significant modification to the operation of the power plant in accordance with the cogeneration principle so as to recover high-temperature heat³³. The conclusions of the second report made in February 1977 were more encouraging. The grouping of the study demonstrated the technical and economic feasibility of testing a heat of 176°C in reactors 4 and 5 at the Bugey power plant to supply part of the Lyon urban area, as well as several towns on the outskirts of the network, from a network that is 100 km away as the crow flies³⁴. The extent of the outlet to the heat network appears to be sufficient, according to the technical and economic hypotheses given in this study, to make profitable the initial investments and compete with gas. EDF accepted selling heat produced by Bugey at the price of electricity that has not been produced, but refused to commit to continue with the supply in heat as the power plants had to be stopped for several days of the year in order to carry out maintenance operations. Before considering launching an operation from Bugey, the group ordered a legal study to clear two potential obstacles. If such an investment was undertaken, local elected representatives had to make it mandatory to connect the network to new housing. An adequate legal framework also had to be established to guarantee the durability of this operation over time³⁵.

The study conducted on Bugey highlighted the technical and economic use for nuclear cogeneration. The size of the heat networks to be developed depends on the identified demand for heat around the power plants. The greater the heat demand, the greater the length of the networks can be³⁶. The national commission on the use of heat, which gave its final report in February 1977, called on the government to commission a study on the scope of every region where reactors were being built or planned. This suggestion resulted notably in the creation of a first regional energy agency in Rhône-Alpes in 1977, which was commissioned to facilitate cooperation between actors and lead to nuclear heat recovery operations, including that in Bugey³⁷. This call for continuing studies was accompanied by a recommendation to not make choices that cannot be reversed, particularly through the uncontrolled development of electric heat³⁸. This recommendation strengthened the critical parliamentary positions regarding the fully electric regime and functioned as a basis for a call to develop the heat networks and the electric networks jointly³⁹.

³² Archives of the Ministry for Industry and Research – Box 1989 0572 6 – Study 106-GA presented 9 June 1975 to the advisory committee on the use of energy.

³³ Archives of the Ministry for Industry and Research – Box 1989 0572 6 – Report from the meeting of the advisory committee on the use of energy on 13 June 1975.

³⁴ Archives of the directorate for habitat and construction – Box 1994 0715 4 – Bugey report from the SERETE research unit for AEE dated 23 February 1977.

³⁵ Archives of the Ministry for Industry and Research – Box 1989 0572 6 – Report from meeting n°256 of the advisory committee on the use of energy on 2 March 1977.

³⁶ AFME archives – Box 1987 0072 57 – Leroy report, p. 20.

³⁷ Fontaine, Antoine. « Du nucléaire au renouvelable ». In *Face à la puissance: une histoire des énergies alternatives à l'âge industriel*, 341-52. Paris: La Découverte, 2020.

³⁸ AFME archives – Box 1987 0072 57 – Leroy report, p. 29.

³⁹ Archives for the Ministry for Industry – Box 1988 0199 39 – Report no. 394 by MP Weisenhorn, written on behalf of the production committee, submitted 15 June 1978.

In this context, EDF gave its support to all of the studies carried out on the alternative means of recovering heat at the government's request⁴⁰ but organised a strategy for defending the fully electric regime. The promotion of cogeneration projects represented a considerable risk for companies in the event that these projects created competition to its commercial policy. The only recovery system for low-temperature heat waste could, on the other hand, slightly improve the output of power plants without challenging their operating system. To do this, since 1975 the company has financed an experimental station for recovering lukewarm water for agriculture and horticulture at the Saint-Laurent-des-Eaux nuclear site in collaboration with the French National Research Institute for Agriculture (INRA) and the Centre Technique Interprofessionnel des Fruits et Légumes (CTIFL)⁴¹. Outside this type of prospect, the company's commitment is much more measured. As in Bugey, it refused to sign a contract for supplying heat that committed to a continuous supply⁴². Potential consumers of this heat should therefore finance the construction of the heat network, but also invest in a maximum-power boiler room for the network to free EDF from all responsibility for a potential interruption in supply⁴³. This double investment was intended to dissuade a number of potential consumers.

The challenge to the fully electric nuclear regime that appeared between 1973 and 1977, without this actually being translated into legislation, was expressed again in 1978 during debates on a draft bill on energy savings and heat use. At this time, several proposals were put forward in order to make cogeneration the standard for developing nuclear power plants by setting the public price for heat from nuclear power plants and by submitting for exemption the construction of a power plant that generates only electricity⁴⁴. To make this change in the nuclear system a reality, the supporters of cogeneration suggested changing the mission of EDF so that it was no longer based on the maximisation of electrical output at its installations, but instead their general energy output⁴⁵. In the circumstances that followed the Three Mile Island accident in 1979, the parliamentarians also requested the creation of a parliamentary office to evaluate the technical and scientific choices so that they could express opinions on the choices made by the government, especially on issues concerning nuclear power, from which they felt excluded⁴⁶.

Nevertheless, the reassessment of the nuclear programme structure raised by the cogeneration regime was the subject of several criticisms. These criticisms came from both the government and conservative and communist groups in parliamentary chambers. For the former, this was a matter of defending a nuclear policy that ensured France's standing on an international scale⁴⁷, for the others, this was a matter of defending a national industrial champion and a programme that generated employment and appeared to guarantee economic growth. However, a form of compromise was put

⁴⁰ EDF archives – Department for operating a nuclear plant – Box 897697 – Letter from the Minister of Industry to the EDF managing director requesting that their full support be given to studies on using heat, dated 22 February 1977

⁴¹ EDF. Eaux tièdes, mode d'emploi. Pour quelques degrés de plus. Pamphlet from presentation EG 5063/A., 1990.

⁴² EDF archives – Department for operating a nuclear plant – Box 897697 – Letter from Marcel Boiteux to all EDF departments of 28 July 1975.

⁴³ EDF archives – Department for operating a nuclear plant – Box 897697 – Working note from the general department for preparing a decree to be applied on recovering industrial heat waste, dated 13 July 1976

⁴⁴ Archives for the Ministry for Industry – Box 1988 0199 39 – Report no. 394 by MP Weisenhorn, written on behalf of the production committee, submitted 15 June 1978, p. 111.

⁴⁵ Ibid, p.113.

⁴⁶ Ibid, p.100.

⁴⁷ Hecht, 1998, op. cit.

forward when adopting the July 1980 law on energy savings and heat. The development of electric heat was considered a priority in less populated areas, while direct recovery of nuclear heat was announced as a priority for more populated areas⁴⁸. Adopting the July 1980 law in particular created favourable circumstances for the development of heat networks through a measure that made it possible for local elected representatives to make it mandatory for these networks to be connected to the zones that they define. At the same time, EDF collaborated with several partners to study a third technical option for recovering nuclear heat that would provide a compromise between the fully electric system and the cogeneration regimes that would be more favourable.

4.3 Mixed nuclear regime: a compromise between the fully electric and the cogeneration regimes

EDF appeared to be especially critical of the idea to apply the cogeneration principle to nuclear power plants that are operational and those that are being built. The installation of back-pressure turbines to release high-temperature heat made it possible to fully heat towns of 250,000 residents. However, EDF was uncertain of whether there was such a market in France⁴⁹. To this end, the public company provided its support for an alternative technical proposal to supply heat networks from a nuclear power plant. Over the course of the 1970s, the CEA's TechnicAtome company developed a prototype of a low-power nuclear reactor that was dedicated solely to producing heat to heat an average-sized town and to desalinising sea water⁵⁰. By means of this prototype, the CEA tried to regain the place it had in the French civil nuclear program before being ousted to the detriment of EDF at the end of what is known as the "war of the sectors"⁵¹. The prototype of the Thermos reactor had a power of 100 MWth, which made it possible to produce hot water of 120°C. Its small size (40 m x 40 m) facilitated its installation close to a city centre, limited the distance to be built from the network and made it possible to provide heat by replacing the existing solutions of heavy fuel oil or coal at a very competitive price. Furthermore, this reactor prototype functioned in a closed circuit with a heating network that eliminated heat waste. In doing so, the system's energy output was close to 100%, as all of the energy was injected into the heat network. The CEA identified about 20 French towns that had characteristics that were favourable to developing a heat network supplied by a Thermos reactor⁵². Although these small reactors appeared to be safer than the large reactors under construction, they were not considered free of any safety problems⁵³, which gave rise to some criticism. Developing this solution was nevertheless supported by both the defenders of the cogeneration regime and those for the fully electric regime. For the former, it made it possible to speed up the replacement of hydrocarbons, while improving the energy output for a part of the nuclear industry. For the latter, this option limited the potential development of electric heating locally, but did not challenge the operation of electric nuclear power plants established far from cities. The Thermos prototype nuclear reactor thus provided a third nuclear regime – the mixed nuclear regime (see Table 3).

Table 3: The mixed nuclear regime

⁴⁸ AFME archives – Box 2015 0184 56 – Transcription of exchanges during the final table of the conference of 11 December 1980.

⁴⁹ Ministry of Industry archives – Box 1988 0199 39 – EDF hearing at the National Assembly within the scope of the law for energy savings and use of heat on 10 May 1978

⁵⁰ B. Lerouge, La pile piscine Thermos, *Revue Générale Nucléaire* 2 (1977) 103-8.

⁵¹ G. Hecht, op.cit.

⁵² EDF archives – Box 916240 – Confidential note from the CEA management of 13 March 1981

⁵³ C. Foasso, Op.cit, 194.

	Technical method of energy production	Spatial organisation	Method of energy consumption	Criticisms of the regime
Mixed regime	Two types of power plants are developed. The first recovers its production in the form of electricity only with output of 35%. Less powerful power plants are dedicated to only producing heat for urban heat networks with output of close to 100%.	Process heat reactors are built close to urban centres to create short heat circuits. The location of electric reactors is not questioned	More densely populated urban areas are heated using nuclear heat networks. Less densely populated areas are more suited to developing electric heating	(1) Urban nuclear power plants compete with existing urban heating infrastructure (coal, wood energy, gas) (2) Urban populations criticise the construction of nuclear power plants close to cities (3) Developing these reactors in cities raises safety issues

The technical and economic feasibility of Thermos process heat reactors in France was, however, yet to be proven. As the CEA was keen to have a showcase demonstrating the utility of this prototype as soon as possible, in 1977 it attempted to conduct an initial project to heat the Saclay science campus close to Paris. This was quickly dismissed for economic reasons, as the demand for heat was not significant enough to consume what was produced by the reactor. The CEA became interested in the city of Grenoble, which had a number of benefits; the city had a heat network that was the most highly developed after that of Paris and there was already a local custom of using nuclear power as several nuclear reactors had been built for scientific purposes at the Grenoble Centre for Nuclear Energy (*Centre à l'Energie Nucléaire de Grenoble*) from 1958⁵⁴. Lastly, the city, which hosted the Winter Olympics in 1968, was an international showcase for the CEA to convey the use of its prototype. The project of installing a Thermos reactor in Grenoble was presented to local elected officials by the CEA and the Ministry for the Environment in December 1979. On this occasion, a working group was put together to conduct a local study and confirm interest in this option. This team brought together local actors who were involved in managing the heat network. In parallel with this, a local information committee that united residents' associations, environmental groups, trade unions and political parties was established to ensure transparency in the process⁵⁵. The local study attempted to centre the decision on the Thermos project on it being a technical and economic question. It was, above all, a matter of knowing whether the nuclear solution would be able to provide local consumers with low-cost energy, compared to the solutions already in place. The local and national press echoed a local debate that was largely economic⁵⁶. A local survey indicated that the residents of Grenoble had reservations about the idea of building a small nuclear reactor not far from the city centre, but were not fully opposed to it⁵⁷. Tensions surrounding the project raised more impacts than the installation of the reactor would have on the organisation of the heat network. These were then managed by a municipal heating company that consumed a large quantity of the coal extracted from nearby mines and had several coal boiler rooms that were recently renovated thanks to AEE subsidies. The decision to adopt the process heat reactor was thus determined by the extension of the network and the

⁵⁴ Y. Ballu, *De Mélusine à Minatoc: 1956-2006, 50 ans d'histoire du CENG devenu CEA Grenoble*, Veurey, 2006.

⁵⁵ A. Dalmaso, *Le projet Thermos (1975-1981) ou l'échec de l'atome au coin du feu*, Tours, 2008.

⁵⁶ Libération 22 septembre 1980, Le Monde 29 septembre 1980.

⁵⁷ A. Dalmaso, op. cit.

stopping of infrastructures that ran on coal⁵⁸. Beyond this context of competition, the technical and economic study comparing the different energy options for the Grenoble network, starting in 1980, quickly brought to light numerous technical and economic obstacles for the Thermos project. The temperature of the heat generated by the reactor (120°C) was not high enough compared to the operation of the Grenoble network (160°C). Therefore, a heavy oil boiler room was installed to boost the temperature of the water before injecting it into the municipal heating network⁵⁹. This option represented an additional cost and reduced interest in the nuclear reactor, which was initially intended to reduce consumption of carbon energy. The quantity of heat generated by the reactor then turned out to be too much for the only available network, as this was before it was extended to other towns in the urban area to form a sufficient outlet⁶⁰. The accumulation of limitations finally revealed that the existing coal option was still less expensive. Based on this economic argument, in the end the project was rejected by local officials who were concerned about the cost of building a nuclear reactor close to the city for the electorate.

The failure of the project in Grenoble was a heavy blow to the supporters of the Thermos prototype. Furthermore, outside this local lack of success, the socialist President François Mitterrand, newly elected in 1981, renewed the State's support to the French coal industry⁶¹. This reasserted competition shut down many prospects for developing the Thermos prototype and marked the failure of this search for compromise using the mixed nuclear regime.

4.4 Normalisation of the fully electric nuclear regime in the context of the 1980s

Increases in energy prices after the succession of two oil crises in the 1970s heightened interest in expanding the output of nuclear power plants by directly recovering heat – by cogeneration, by building solely process heat reactors or by reusing heat waste close to power plants – in order to reduce the cost of energy for consumers. However, the favourable circumstances for these alternative projects ended with the rapid reduction in petrol prices during the first half of the 1980s and particularly during the oil glut. Projects on directly recovering nuclear heat were once again in competition with gas, the price of which was decreasing and which was easier to utilise. The more ambitious cogeneration projects, especially at Bugey, were abandoned. Only a few projects for reusing lukewarm water from nuclear power plants for agricultural, horticultural or piscicultural purposes succeeded thanks to economic support from the regional governments (see Figure 2). The quantities of energy recovered as part of these projects were nevertheless insufficient compared to the projects that were imagined throughout the 1970s. One particular case could be seen as an exception. At the Tricastin nuclear plant, in the Rhône Valley, a project on heat recovery in a factory of the European Gaseous Diffusion Uranium Enrichment Consortium was successful at the end of the 1970s. The factory generated heat of 85°C that could easily meet the requirements of multiple factories and the site's operation also made it possible to guarantee continuous supply. In 1979, the case, monitored locally by the Rhônalpénergie regional energy agency and nationally by AEE, succeeded⁶² with the gradual

⁵⁸ AFME archives – Box 2015 0184 56 – Report from a meeting of the board of directors for the Promocal association on 22 May 1980.

⁵⁹ EDF archives – Box 916240 – Report on the meeting of the working group in Grenoble on 15 October 1980.

⁶⁰ Ibid

⁶¹ L. Warloutet, *Les Charbonnages de France et la reconversion au temps de l'ultime relance charbonnière (1981-1984)*, in S. Aprile, M. de Oliveira, B. Touchelay and K.M. Hoin (Eds), *Les Houillères entre l'État, le marché et la société*, 2015, 189-200.

⁶² AFME archives – Box 2015 0184 56 – Report from a meeting at the Ministry of Industry on 30 November 1979.

connection of 50 hectares of greenhouse and a heating network to the neighbouring town of Pierrelatte⁶³. However, the success of this project could not mask the general failure of the nuclear heat recovery policy with regard to the scope of the debates and the studies conducted over the course of the 1970s.

From an institutional point of view, there was soon a loss of interest in the question of using heat. The national project for recovering heat created in 1980 was dissolved on the creation of the French National Agency for Controlling Energy (AFME), which integrated the National Agency for Energy Savings (AEE) and the Commission for Solar Energy in particular⁶⁴. Within the AFME, interest in nuclear heat was eclipsed by studies into geothermal energy and wood fuel⁶⁵. With this loss of interest from an institutional perspective, opposition to the fully electric nuclear regime quickly fell away and left the field open for the rapid development of electric heating. The energy group of the Plan General Committee, several members of which defended the cogeneration solution in the 1970s, also advised the government to adopt a strategy of integrating electricity into the national energy mix as strongly as possible in the 1980s, through support for electric heating⁶⁶. Electric heating, which concerned less than 2% of new housing in 1970 and 19% in 1975, exceeded 45% in 1978⁶⁷. The 1980s were dedicated to the success of electric heating. This solution, which initially concerned more individual homes (70% in 1982), increasingly involved collective housing (45% in 1990)⁶⁸. The policy compromise suggested in 1980 that aimed to prioritise the direct recovery of heat through urban heating networks in densely populated areas and electric heating in less dense areas was not maintained. The rise of the fully electric nuclear regime led to a significant development in electric heating in urban centres and irreversible changes in the organisation of the overall French energy system that moved away from alternative nuclear regimes.

Figure 2: Map of the progress of heat waste recovery in nuclear power plants in France in 1990 (adapted from EDF 1990⁶⁹)

⁶³ P. Dubesset, Une retombée agricole du nucléaire rhodanien: les serres chauffées, *Revue de géographie de Lyon* 62 (1987) 193–217.

⁶⁴ T. Leray, B. de La Roncière, *30 ans de maîtrise de l'énergie*, Arcueil, 2002.

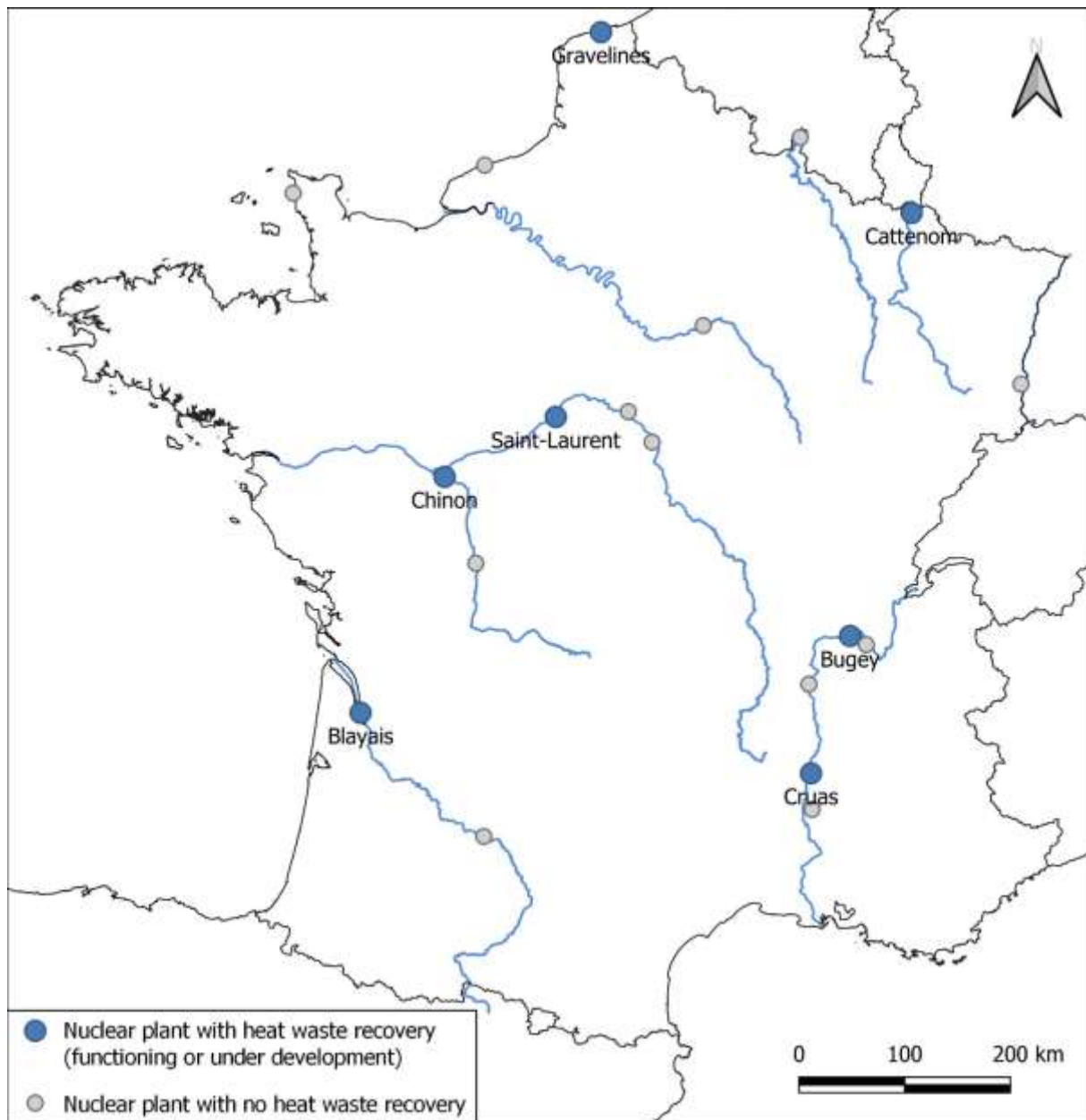
⁶⁵ Interview with the above-mentioned former director of AFME.

⁶⁶ Plan General Committee (Ed), *Rapport du Groupe long terme sur l'énergie. Préparation du 9ème plan*. Paris, 1983, 136.

⁶⁷ EDF archives – Box B0000436113 – Electric heating in housing, 1979 results.

⁶⁸ EDF archives – Box B0000436113 – Electric heating in housing, 1990 results.

⁶⁹ EDF. *Eaux tièdes, mode d'emploi. Pour quelques degrés de plus*. Pamphlet from presentation EG 5063/A., 1990.



5 Behind the nuclear choice: an energy system organised around heat policies

This study allowed us to highlight that after the success of French nuclear policy in the 1970s, the construction of power plants began in the absence of a consensus on the modalities of using nuclear energy. By analysing the context of the rise in the French nuclear programme, this article demonstrates the ratios of power between three nuclear regimes that are structured around a technical principle of nuclear heat recovery that leads to energy consumption methods and the geographic organisation of the national energy system. These ratios of power underline that the organisation of the French energy system throughout the 1970s stemmed less from the choice of nuclear technology than from the adoption of a heat policy that defined the conditions for developing the nuclear industry (see Table 4).

Table 4: Heat policy, nuclear regimes, and construction of an energy system

	Governance model	Political challenges
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Fully electric regime	<ul style="list-style-type: none"> (1) Governance centralised around the government and EDF (2) The production of energy is physically separated from the consumer (3) Local actors do not have the power to make decisions on nuclear power 	<ul style="list-style-type: none"> (1) The development of an electric network and the tariff equalisation establish a national energy solidarity (2) The very energy-intensive development of electric heating is based on the political choice of nuclear over-equipment. However, this makes it impossible to reverse the choice of a national nuclear plant.
Cogeneration regime	<ul style="list-style-type: none"> (1) Governance of a centralised electric system (2) Some regional structures grow to facilitate the development of cogeneration operations (3) Heat consumption is spatially reconnected to the production sites around power plants (4) Local actors are associated with the development of heat networks to meet their energy needs 	<ul style="list-style-type: none"> (1) The development of an electric network and the tariff equalisation establish a national energy solidarity (2) Regions close to a nuclear power plant benefit from low-cost heat and an advantage over other regions (3) The development of cogeneration limits that of electric heat and calls into question the strategy of nuclear over-equipment. The energy savings policy is at odds with the energy supply offer
Mixed regime	<ul style="list-style-type: none"> (1) Governance of a centralised electric system (2) The surge in national actors (EDF, CEA) that are responsible for heat production for cities requires a reassessment of the local managers of heat networks and local energy strategies that are already established. (3) Heat consumption is spatially reconnected to the production sites around power plants 	<ul style="list-style-type: none"> (1) The development of an electric network and the tariff equalisation establish a national energy solidarity (2) A compromise is established to prioritise the development of direct recovery of nuclear heat in densely populated areas and also electric heating.

The fully electric nuclear regime is based on solely electric recovery of heat generated by nuclear power plants. The rapid development of electric heating and the extension of the national electric network guarantee an outlet for absorbing this electricity, which is essential to the French choice of a massive nuclear program. The development of electric heating makes it impossible to reverse the choice of operating mode for these power plants. This operation leads to a centralised governance of the national energy system coordinated by the government and EDF, in which the production of energy is physically disconnected from the energy consumption. Through the tariff equalisation, this system establishes a type of national energy solidarity. On the other hand, the decision-making power of local actors is greatly reduced in this context.

The cogeneration nuclear regime is based on the combined recovery of electricity and heat from nuclear power plants. The development of heat networks around nuclear power plants for direct recovery of heat limits the development of electric heat. The incompatible nature of the policies of supply and energy efficiency encourages a revision downwards of the scope of the national nuclear programme. The governance of the electric system is not re-evaluated, however, another form of governance is put in place for heat. Some regional structures grow to facilitate the development of cogeneration operations in association with local actors. The electric network remains a medium of national energy solidarity, but the nuclear heat networks create regional clusters that receive low-cost heat. With these networks, heat consumption is reconnected in terms of space to the production sites.

Lastly, the mixed nuclear system is based on the coexistence of two types of nuclear power plants: the electric power plants, the operation of which is not reassessed, and the small-scale process heat

reactors that are close to cities. As a compromise, this nuclear system guarantees distinct and well-defined outlets for the production of two types of nuclear reactors. In the areas of process heat power plants, heat consumption is reconnected in terms of space to the production sites. Nevertheless, the management of urban heat production by national actors is a source of conflict in that it could call into question the role of the local managers of heat networks and local energy strategies that are already established.

6 Discussion

This article initially proposed analysing the path of development taken by the French nuclear programme throughout the 1970s by focusing specifically on the question of uses associated with nuclear energy. Based on this position, the objective of the research was to question the way in which the adoption of nuclear power contributed to the reorganisation of the energy system. This last section proposes highlighting two contributions to the paper and the research perspectives that they open up.

The development of nuclear power can follow several sociotechnical routes. The success of the French nuclear programme from the 1970s was based on a number of common factors shared by other nuclear programmes around the world⁷⁰: huge government support, the centralisation of decision-making around energy and construction challenges, its integration into national industrial and economic policy. This success has followed the “hard energy path” described by Lovins⁷¹: a supply policy, searching for economies of scale, the choice of energy waste, dense development of technical networks and centralised governance. However, our research highlights that several non-standardised development routes have been explored that are much more open to the challenges of energy efficiency and based partly on non-centralised networks and open to local and regional forms of governance. These alternatives characterise a certain flexibility in the types of organisation that can be built up around nuclear technological choice, although this creates considerable limitations. However, the French case remains unique. This contribution must be understood in a comparative approach looking at other national circumstances in order to study whether there are several competing nuclear regimes, if several political and spatial configurations for expanding nuclear power have been explored and how the electric and centralised regime prevailed.

Inherited energy regimes set the tone for future energy transitions. The energy transition that started in France in the 1970s has evolved in line with the urgent need to reduce the importance of imported fossil fuels, while supporting the growth of energy consumption. However, the three competing approaches to developing nuclear power did not suggest implementing transitions in the same way. Although the fully electric regime stimulated growth in the demand for energy, the other two systems suggested more emphasis on a policy of demand and energy efficiency. Today, the legacy of the fully electric nuclear regime largely restricts the construction of a new energy transition. The substantial development of electric heating creates a path dependence with regard to electric solutions, including the energy generated from renewable sources, while the development and increasing greenness of heating networks today appear to offer a solution that is both more efficient and more simple. An approach to energy transitions to follow in light of the idea of energy regimes should therefore allow us to more easily adopt a critical look at the constraints and opportunities in the processes at hand. The growing attention paid by geographers to challenges associated with the adoption of new sources of and new technologies for energy also highlights that several regimes for

⁷⁰ B. Sovacool, S.V. Valentine, op.cit; S.V. Valentine, B. Sovacool, op.cit.

⁷¹ A. Lovins, op.cit.

renewable energies are currently in competition in terms of alternative political, economic and geographic approaches to restructuring the energy systems.