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The territorialisation of industry in times of transition. Ecosystems, infrastructures and hubs in the green hydrogen sector.

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Abstract

Current evolutions of the relationships between industry and the state associate explicit objectives of industrial transformations for ecological reasons, a growing interest in sovereignty-driven interventions in industry, and the linkage of industrial development to social concerns. This paper examines these evolutions by analyzing the territorial inscription of industry, its practical manifestation and its consequences. We speak of styles of territorialisation of industry to characterize the articulation of three components: the construction of an industrial sector, the design and use of policy instruments, and the material consequences of spatial interventions. Using the example of the nascent green hydrogen sector in France, we contrast three styles of territorialisation, which we label "ecosystems", "planned infrastructures", and "hubs". Each of them encompasses visions of the relationships between public and private actors, faces tensions and frictions, and has inevitable exclusion effects. We contend that the study of styles of territorialization is a productive analytical entry point for understanding the politics of transition.

Keywords

scalability, innovation, hydrogen, territory, industry

1. Introduction

In 2018, the French government launched the *Territoires d'industrie* initiative ("Industry territories"), which funded projects led by manufacturers and local authorities and sought to revive industry in neglected areas. Three years later, an interim report (Territoires d'industrie, 2021) stressed that many projects were paving the way to the re-industrialization of hundreds

of territories across the country, thanks to billions of euros of public and private investments. The report insisted on the fact that territories had *carte blanche* to design projects adapted to their needs. *Territoires d'industrie* was presented as an explicit answer to the yellow vest crisis that attempted to provide resources to marginalized territories (La tribune, 2019). As such, it added social concerns to cluster-based industrial policies that had previously just been incentives for local public and private actors to cooperate rather than strategies based on dedicated technological options (Cohen, 2007; Nathan & Overman, 2013). The report introduced another significant difference with industrial policies that had limited state intervention to the promotion of local partnerships between public and private actors. *Territoires d'industrie* was said to target "a new dimension" in the post-covid era, since a national program called *France Relance* would provide additional funding for industrial sectors related to energy transition, of which green hydrogen was one of the key examples. Making "territories of industries" would also be about relegitimizing direct state intervention to develop large-scale industrial projects. Analytically, the *Territoires d'industries* report is an illustration of the complex relationships between industry and the French state, whose *dirigisme* tradition has changed over time without ever disappearing (Ansaloni and Smith, 2018). It also illustrates current evolutions often described with the vocabulary of transition, which associate explicit objectives of industrial transformations for ecological reasons, a growing interest in sovereignty-driven interventions in industry, and the linkage of industrial development to social concerns. As the *Territoires d'industrie* initiative suggests, this changing context seems to be affecting the territorial inscription of industry. As other papers in this special issue show, this situation is an invitation for scholarly analyses to re-examine the ways in which states, local authorities and business actors participate in defining public problems and introducing policy instruments, or, in other terms, engage in "political work" (Smith, 2019).

In this paper, we take up this invitation by analysing the territorialisation of industry at a time of ecological transition. Specifically, we use the example of the nascent green hydrogen sector in France to contrast three styles of territorialisation of industry, which we label "ecosystems", "planned infrastructures", and "hubs". We argue that studying the territorialisation of an industry adds a fruitful dimension to analysis of its government (Smith and Jullien, 2014). In so doing, it offers a stimulating entry point for understanding the redefinitions of policy-industry relationships that are accompanying this era of transition.

Our use of the term "territorialisation" is inspired by two analytical traditions. First, research in political geography has examined the many material, legal and economic processes whereby

territories are constituted, or, in other words, processes of territorialisation (Elden, 2013; Vandergeest and Peluso, 1995). This body of scholarship invites us not to take "territories" for granted but to focus instead on initiatives that have both spatial effects and social consequences such as the control of land and its populations by technical and legal devices, and which ultimately "establish authority" (Rasmussen and Lund, 2018: 389). Importantly, several studies have shown that private organizations can engage in processes of territorialisation alongside, or possibly against, state actors (Corson, 2011; Lund and Rachman, 2016; Raeymaekers, 2014). In the cases we focus on in this paper, these processes can comprise the construction of infrastructures for energy production or distribution, as well as the partnerships with local public bodies in which business actors engage.

A second analytical tradition on which we build stems from Science and Technology Studies (STS) and particularly studies in STS that examine the combined ontological and normative consequences of technological projects. Sheila Jasanoff has shown that technological projects associate effective realizations and visions of future developments, and that this association is central for the perpetuation, and possibly the displacement, of power (Jasanoff and Kim, 2015). This approach offers analytical resources for studying industrial developments in domains such as IT or energy transitions, where technological programs have material consequences that physically transform territories and human beings, whilst also being vehicles for state-making ambitions (Bowman, 2015; Laurent et al., 2021). In a domain like ecological transition where material interventions on local sites (for instance to build solar panels, wind turbines or hydrogen charging stations) are associated with ambitious promises of economic and social transformation at local and global scales, this perspective directs our attention to the fact that territorialisation associates spatial interventions and future perspectives. Whether or not these future perspectives eventually come to life, they play important roles in defining certain priorities at the expense of others, for instance by imagining the future extension of infrastructures or envisioning the replication of new technologies on a massive scale. As such, they are resources for the political work of public and private actors.

These two analytical traditions help us to understand the territorialisation of industry as the process whereby industrial development is associated with territorial transformation. This process engages the role of the state (and the nature of its industrial policy), includes or excludes local concerns and distributes various political roles to business actors, whether they participate in territorialisation or resist it. Thus, territorialisation offers an entry point for exploring the transformation of industry and territorial formation, and the political work that public and

private actors engage in order to articulate the two dimensions. Ultimately, this paper will show that the territorialisation of industry can adopt different styles, characterized by contrasting visions of territorial formation, policy actions and private interventions. We speak of "styles of territorialisation" to characterize diverse imagined geographies, that is, diverse ways of envisioning spatial evolutions and possibly implementing them. Using the case of hydrogen in France, we argue that the analysis of styles of territorialisation offers a productive entry point for studying the politics of industrial development in times of transition. Beyond the specificities of this case, we show that exploring styles of territorialisation enable the analyst to describe how the general objective of "transition" translates into various associations between public and private interventions. Some are deliberately agnostic about technological options while others envision clearly defined technological choices (e.g. hydrogen cars or hydrogen as an energy carrier). Some work with fragmented territories and others result in nation-wide infrastructural work. In some cases, policy-makers have explicit territorial ambitions. In others, transforming territories is not the main objective but an inevitable implication of policy and industrial choices. In all cases, we show that analysis of styles of territorialisation offers a productive entry point for studying how state interventions, private initiatives and territorial formation go hand in hand, as well as identifying the geographical and social consequences of this process.

In the following, we start by presenting the methodological approach we have adopted to study the territorialisation of industry in times of transition and, specifically, our empirical case of green hydrogen in France. We then discuss three styles of territorialisation which, drawing upon the main objectives of the actors promoting them, we label as: "ecosystems", "planned infrastructure", and "hubs". We show that each of these three approaches problematizes territories in ways that envision different hydrogen sectors and policy mechanisms, and that each of the three implies different exclusion mechanisms and, consequently, different sources of fragility. We conclude by discussing the implications of these three styles of territorialisation in terms of tension and exclusion, for the case of green hydrogen and beyond.

2. Studying the territorialisation of green hydrogen in times of transition: materials and methods

Hydrogen is particularly interesting for our reflection not only because it is currently subject to "technological hype" (Bakker, Budde, 2012) as a promising solution to ecological transition (Lepercq, 2019), but because growing interest in this technology is connected to material

properties that have territorial consequences. First, the promoters of hydrogen describe it as an interesting energy carrier that could provide practical means for electricity storage, thereby solving the intermittency issues that plague many renewable energies. Second, hydrogen can be used in vehicles instead of electric batteries. Due to the ability to store hydrogen in compressed tanks onboard vehicles, it enables transportation over long distances without the need for time-consuming charging. Third, hydrogen has been used for decades in heavy industry, for instance for ammonia production or metallurgy processes, during which time it has been produced by carbon intensive chemical reactions involving hydrocarbons (mainly methane). Replacing this so-called "brown" hydrogen with "green" hydrogen, produced through a process called electrolysis that uses electricity and only emits water vapor, or through the reformation of bio-gas, could provide a feasible way to decarbonize industrial activities (Lemarchand, 2022). These three characteristics suggest that an "industry of green hydrogen" contributing to ecological transition might involve diverse private actors, from mobility ones to those of energy production and heavy industry. These characteristics also imply that developing green hydrogen requires infrastructures of production and distribution, which are bound to materially transform the physical sites where they will be introduced. In turn, this supposes at least some level of coordination with local public bodies, potentially inviting them to become active participants in the development of the industry. This means that researching the green hydrogen industry means addressing questions about how to intervene on and with territories, and how to transform them. Thus, we have chosen to study the territorialisation of the hydrogen industry by following development projects and exploring the ways in which they problematize their infrastructural needs and relationships with local actors.

In the following, we do so by focusing on the case of France - an interesting example for the study of policy-industry relations because of the pervasiveness of the *dirigisme* model and its contemporary transformations (Ansaloni and Smith, 2018). Before 2014, there were no government initiatives dedicated to hydrogen, and industrial activities on the topic were limited to exploratory research conducted in large companies. Since then, hydrogen has gained momentum in France as in other countries, and has become the topic of several national and local initiatives, some of which we have observed and analysed in real time. Throughout these initiatives, we will see that French actors often contrast the situation in France with that of other countries, particularly Germany. While we do not attempt to systematically compare the French case with those of other countries, the comparison regularly made by the actors we study has helped us characterize how they understand the territorialisation of hydrogen. More generally,

our interest is less about the specificities of the French case than the variety of territorialisation it contains which, we argue, is analytically useful to understand the territorialisation of industry beyond the specificities of our empirical examples. Accordingly, we conducted our analysis in sites where the territorial question has been explicitly discussed in conjunction with that of the future hydrogen sector. We base our study of this style of territorialisation on 26 interviews with public officials and private actors undertaken in 2020-2021 as well as the relevant public documentation and the specialized press. We also attended 6 professional events where stakeholders were discussing ways to scale up hydrogen technologies.

In the following developments, we adopt a chronological narrative that reflects recent changes in the hydrogen industry in France over the 2014-2022 period. We show how actors in France have formulated different styles of territorialisation in response to controversies over the ways in which a green hydrogen industry can and should emerge. These styles of territorialisation combine three related elements. First, they depend on, and contribute to shape, the identities of industrial actors and their interests. Second, they are based on policy instruments meant to promote industrial development. Third, each of them is associated with an imagined geography, that is, a way of envisioning spatial evolutions and possibly implementing them. Thus, our analysis of styles of territorialisation connects the economic, political and spatial dimensions of the relationships between industry and territory.

We identified these styles of territorialisation by paying particular attention to the change of and within hydrogen projects in France, the debates that have accompanied them and in which policy-makers and industrial actors were involved. We focused particularly on disagreements among these actors, since they were signs of conflicting priorities and, in many cases, uncertainties about future developments. That there were disagreements in the cases we studied is not surprising and is, in many respects, a consequence of the flurry of policy initiatives related to hydrogen. In France as in other countries, these initiatives differ according to the domain they target (e.g. mobility or the decarbonation of heavy industry), the public bodies that lead them (European institutions, national or local governments) and their associated funding instruments. This means that who wins and who loses might well vary depending on policy choices (Upham et al., 2020) and that tensions might appear among public and private actors and/or across different levels of government (Trencher and van der Heijden, 2019).

3. Ecosystems. Fragmented experimental territories.

In 2014, industrial actors gathered in a professional organization called "AFHYPAC" (French Association for Hydrogen and Fuel Cells) launched initiatives on hydrogen mobility. In addition to a few large companies like ENGIE (energy) and Michelin (tyres), AFHYPAC brought together manufacturers of technologies related to the production of hydrogen-powered fuel cells or technologies for building refill stations or green hydrogen manufacturing (electrolysers). One of the two emblematic companies of this organization in 2014 was a start-up, Symbio, which manufactures first generation hydrogen fuel cells. The second emblematic company of the organization at the time was McPhy, which manufactures electrolysers. All the members of AFHYPAC knew each other well. Many of them were located in the same area in the Auvergne Rhône Alpes region in South-Eastern France. They all saw mobility as a central domain of application for hydrogen.

Yet mobility also raised a number of issues. If hydrogen is used to store energy for mobility, then infrastructures are required to produce it and ensure that vehicles can access refuelling stations. For AFHYPAC, the challenge was that no such infrastructures existed and that their absence added significant costs to any development of hydrogen for mobility. To respond to this challenge, these industrialists developed an approach based on “captive fleets”, composed of a limited number of hydrogen vehicles with predictable users and routes. In a project called Hyway that AFHYPAC members ran from 2014 to 2019, users were all professionals driving companies’ cars using predictable routes, which made it possible to introduce a limited number of electrolysers for hydrogen production and refuelling stations. What mattered for them was to secure commercial opportunities even before starting production, which was done through partnerships with local public bodies and local companies who could become users of hydrogen cars. AFHYPAC members benefited from financial support from the Auvergne Rhône Alpes region, ADEME (the French state’s agency in charge of applied research in energy) and the European Union's fund for territorial development (Tenerrdis, 2017).

For the companies involved and the public funders of the project, these captive fleets were explicitly experimental. In line with ADEME’s support for “demonstrators” (Marchal, Bodineau, 2022), all of them defined Hyway as an experiment, which would assess users’ behaviours and the cost effectiveness of hydrogen production. Meant to be an initial test before future developments, Hyway served as a resource for AFHYPAC members’ political work. They used it to demonstrate the possibility of developing hydrogen mobility technologies and engage in follow-up projects, often in partnership with local public bodies. Hyway was not even

completed when the Auvergne Rhône Alpes region decided in 2017 to spend 15 million euros on an initiative called Zero Emission Valley, which saw 20 hydrogen refuelling stations and 15 electrolysers built throughout the region. Zero Emission Valley also received 14.4 million euros from ADEME through a program called "Territorial ecosystems" (H2 mobile, 2023), and a 10.1 million European grant.

This new phase shows the strength of the ties among AFHYPAC members, and between them and local public bodies. It also illustrates the growing densification of infrastructures in the areas of the initial experiments, and the intensification of social and economic ties between public and private actors in the region. AFHYPAC did not however limit its interventions to Auvergne Rhône-Alpes. Instead, it used the example of the projects begun there to convince other local bodies to engage in similar projects. One example is the Dinamhyse project, explicitly inspired by the Auvergne-Rhône-Alpes experiments, and conducted in the Grand Est region in a way that resembled Hyway and Zero Emission Valley. In the Grand Est as in Auvergne Rhône-Alpes, partnerships associated public and private actors, received national financial support through a program designed to fund "territory-based innovative and promising investments" (French Government, 2018), and gradually extended the scope of hydrogen mobility to include buses, trucks and boats (Pôle véhicule du futur, 2019).

As they engaged in projects such as Zero Emission Valley or Dinamhyse, AFHYPAC's members started speaking of "ecosystems" to characterize their approach. The term echoed the name of ADEME's program that had funded many of AFHYPAC's initiatives – "territorial ecosystems". AFHYPAC's members spoke of ecosystems to designate what they had managed to do in Auvergne Rhône-Alpes, and hoped to replicate in places like the Grand Est and elsewhere (see fig. 1). The term "ecosystem" has become fashionable in innovation studies, prompting scholars of the field to engage in theoretical discussions which often conclude that the notion is profoundly ambivalent (Suominen, Seppanen and Dedehayir, 2019). The industry's actors we met never referred to this literature, but they shared with innovation scholars an insistence on collaboration between diverse actors, the need to support these heterogeneous partnerships with dedicated public funding, and the territorial inscription of industrial projects. This insistence is inscribed in a broader evolution of innovation policy in France. Innovation scholars have discussed how the French state withdrew from direct intervention in technological choices in the late 20th century, and gradually engaged in the promotion of innovation through collaborative initiatives at the local level (Mustar and Laredo, 2002). These initiatives comprise the "Competitiveness Clusters" (*Pôles de Compétitivité*)

managed by public and private actors and which have supported various projects, including AFHYPAC's.

We use the term "ecosystem" to label a style of territorialisation that associates three components. First, it involves industrial actors, either start-ups or large companies, that see hydrogen as an innovative and experimental domain. Here, the nascent hydrogen sector is about mobility, yet gathers together actors who are not companies with longstanding investments in the domain (such as car manufacturers or transportation providers). Second, this style of territorialisation is based on policy instruments that are more about innovation and territorial development than industry itself. These instruments do not target specific industrial sectors. Rather they take the form of calls for projects intended to incentivize local public bodies and private companies to cooperate in testing new technologies for transition. ADEME's demonstrator and Territorial Ecosystem programs and the Programme Investissements d'Avenir all bring together local development concerns around an objective of innovation development, while leaving open the choice of which territories and industries to favour. Third, ecosystems make local public bodies (cities and regions in our case) central actors, compete against each other to attract public funding and private interest, and, if successful, engage in experimental projects.

The style of territorialisation based on ecosystems is not just about anchoring industrial development at the "local" scale. AFHYPAC members explicitly envision the scalability of their projects, yet their version of scalability is not about replicating a given technology outside its experimental site. Since it is based on the gradual densification and intensification of material, social and economic ties, it is not about "up scaling" but is more about "deep scaling" (Laurent & Violle, 2024). Accordingly, the promoters of ecosystems foresee a future national territory of hydrogen mobility made up of multiple ecosystems, each specific to the needs of the places in which they are based[1] (see fig. 1).

[1] For instance, ecosystems could be made of taxi fleets, hydrogen buses or hydrogen garbage trucks.

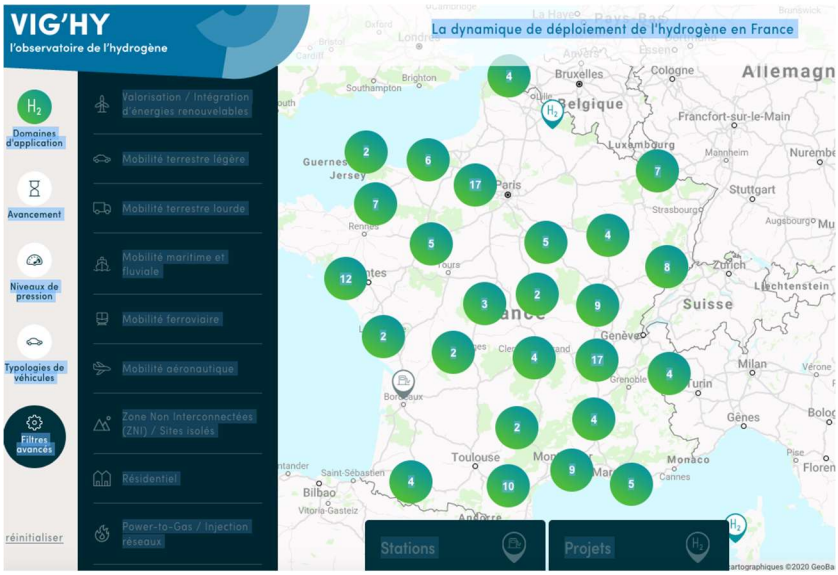

Fig. 1: A country gradually covered by hydrogen ecosystems (extract from AFHYPAC official website)

The map in fig.1 is telling. It displays a style of territorialisation that results both in the increased development of technological projects in certain sites (those of the ecosystems) and a fragmentation of the national space, possibly unified in the future if the ecosystems grow sufficiently.

This style of territorialisation produces territorial fragmentation related to a hydrogen sector primarily focused on local mobility and to policy instruments that organize competitions for public funding. This fragmentation has consequences for the future of hydrogen mobility: since infrastructures are tied to local needs, the possibility to circulate from one ecosystem to the next is not guaranteed. Perhaps more fundamentally, it associates the adaptation to local needs with the marginalization of the territories that are left out of hydrogen development projects. Fragmentation extends to the industrial actors as well. Since ecosystems respond to local needs, the private companies involved may differ from one ecosystem to the next, even if electrolyser manufacturers like Air Liquide or hydrogen fuel cell manufacturers seek to develop markets that span across various ecosystems. This makes it difficult to envision a strong coalition of industrial interests in favour of ecosystems. We will see that alternative propositions, by contrast, are associated with much less fragmented industrial and policy actors, and result in less fragmented territorial formation.

4. Planned infrastructures. A national territory covered by state-funded infrastructures.

AFHYPAC's members saw the ecosystem approach as a response to a situation in which the prohibitive costs of infrastructure forced them to find ways to ensure the economic balance of costs and profits in real-time. Many of them contrasted this choice with what a project manager at AFHYPAC described to us as "Germany's strategy", consisting in "setting up hydrogen stations throughout the country, while accepting that there will be no customers at the start"[2]. In interviews and public events, we regularly heard French actors describing the German federal government's choice to spend millions of euros in building hydrogen production and refueling stations throughout the entire national territory.

This description is at best an approximation of the German hydrogen policy and its evolutions[3]. For many of the French actors who formulated it, it serves as a shared argumentative resource. Thus, car manufacturers regularly referred to Germany to contest the relevance of ecosystems. A person in charge of public affairs at a major French car manufacturer told us that:

"In France, we talk about building local ecosystems, but this is very experimental and not coordinated. How do you expect us to start producing hydrogen cars on a massive scale without any certainty of support, and without any guarantee of being able to charge them in France?"

-10/201/2020 interview

For her, the problem with ecosystems was that they offered no credible pathway toward economies of scale, i.e. the massive production of standardized objects that make production costs diminish. For people like this interviewee, these standardized objects are cars. They require infrastructures to be used (roads and access to energy). Indeed, car companies have based their economic reasoning on the assumption that these infrastructures will be constructed and maintained by the state. Hence the dismay of French car manufacturers when they realized that no such state intervention was foreseen. For them, the development of ecosystems was bound to be "too small-scale", "local" and "experimental". These criticisms, which we repeatedly heard, were also derogatory, signaling an inability to engage in economies of scale. We saw in the previous section that the proponents of ecosystems are less in favor of "the local"

[2] Interview, 10/25/2020

[3] While the development of a hydrogen mobility policy was at the heart of German federal initiatives in the 2010s, things have changed since then. Since the 2020s, federal initiatives have mainly focused on decarbonising heavy industry, and not all German car manufacturers seek to develop hydrogen mobility (Dieler, 2023).

than engaged in a redefinition of what scalability is in a situation where no massive public investments are in sight. Yet the proponents of ecosystems are also well aware of the car companies' positions. Indeed, they see them as the consequence of the inability of the state to engage in industry development in ways that would explicitly choose among technological options and invest in infrastructures accordingly. A person in the Auvergne-Rhône-Alpes projects phrased this diagnosis as the absence of a "national industrial policy":

> *"Car manufacturers in France are not following because there is no national industrial policy. There is no impetus and no strong governmental support that sends out a signal to the car manufacturers..*
>
> -07/07/2020 Interview

This interviewee's comments echoed many other comments in the same vein that we heard during our fieldwork. This diagnosis stems from an implicit definition of what an industrial policy should be, namely a state-led intervention in favour of well-defined technical options and supported by the massive public investments needed to plan large-scale infrastructures. Accordingly, we label as "planned infrastructures" the style of territorialisation associated with this version of industrial policy. Here, the hydrogen industry originates from the transformation of an existing industrial sector, car manufacturing. State intervention relies on an ability to plan at the national scale the types of technology to develop and the location of hydrogen production sites and charging stations, as well as bearing the cost of these large-scale infrastructures. This style of territorialisation envisions a national territory known and acted upon by a central authority, and unified by infrastructures that make the circulation of standardized technical objects possible, thereby echoing past policy programs that have explicitly attempted to harmonize political and economic space through the construction of infrastructures (Misa and Schot, 2005).

The style of territorialisation based on planned infrastructure is a pervasive reference for French car manufacturers, and an explicit objective in some countries[4]. Yet it is also based on expectations and promises about the future rather than present results. Unlike ecosystems, this second style of territorialisation has not been implemented in France. It has served as a critical resource for actors contesting ecosystems and seeking to promote other articulations between

[4] In 2015, for example, the Japanese state started speaking of a "hydrogen society" and introduced massive funding for building production and recharging infrastructures across the country (Behling, Williams, Managi, 2015).

industry and territory. This style of territorialisation goes hand in hand with a type of political work that make private companies (car companies in our case) attempt to convince public bodies to engage in massive public investment in anticipation of future massive industrial production and use. The realization of such anticipations is problematic, because of the amount of public money involved and the potential tensions with other industrial policy choices. In France, senior officials in charge of hydrogen were critical of hydrogen mobility policy targeting private individuals: they considered that it would compete with the already existing policy initiatives on electric mobility and worried about the risk of high charging infrastructure costs (Pesme, 2021). Critical of the style of territorialisation based on planned infrastructures, these officials gradually developed an interest in another version of hydrogen policy, which re-imagined the relationships between industry and territory.

5. Hubs. Geographical nodes and national energy policy.

In the early 2020s, French government officials started to envision an alternative to both ecosystems and planned infrastructures in promoting hydrogen as an "industrial sector". An advisor at the Prime Minister's Office used these terms when she told us that she was critical of an "innovation policy" promoting ecosystems in order to explore various technical options:

> "We can no longer be in an innovation policy mode. We can no longer finance demonstrators and see which technology will win. (…) The objective of our new plan is to think about economies of scales, massification of hydrogen volumes and industrialisation."
>
> -10/30/2020 interview

Yet the "economy of scales" she mentioned differed from the one that car manufacturers hoped for. She had in mind a different industrial sector and state interventions that would not consist of large-scale infrastructure planning. At the time, Bruno Le Maire, the French minister of economy had just announced a plan to "create a new industrial sector: the hydrogen industry" (Le Maire, 2020). Revealingly, this "sector" was not mobility, and not a pre-existing industry (such as car manufacturing). It was to be a new one based on the production of green hydrogen through electrolysis, one which Le Maire wished to "upscale to an industrial level". Contrary to the ecosystem approach, it would not be about experiments and innovation. Accordingly, in September 2020 the French government launched a massive investment plan for hydrogen. Part of the post-covid recovery program called *France Relance* and mentioned in the *Territoires*

d'industrie report with which we opened this paper, this plan earmarked 7 billion euros for the development of the hydrogen sector (Banque des territoires, 2020). This considerable amount of money was not for spurring the development of ecosystems or planning infrastructures. Its purpose was the decarbonation of the hydrogen used, or to be used, in heavy industries. To do so, the post-covid hydrogen plan granted public funding to companies using hydrogen on the condition that it was produced by electrolysis and that the volumes used were higher than 20MW of hydrogen per electrolyser (Winbids, 2022). The introduction of this threshold was a condition for this plan to be about "industrialization" and not about "innovation" anymore, and to guarantee a nationally produced supply of hydrogen.

When drafting the plan, policy makers again made Germany a point of comparison. The French plan was described in the press as:

> *… a response to the announcement of a German decarbonisation plan in June 2020, which proposed to spend €7 billion over ten years to build the infrastructure to produce and/or transport 5 gigawatts of hydrogen from renewable energy sources to decarbonise its industry* (Les Échos, 2020).

Yet this French "response" was remarkably different from the German approach. Germany's plan envisioned the construction of transnational pipelines to import green hydrogen produced using energy from solar panel fields in Southern Europe or Morocco. The aim of the French plan, by contrast, was to produce green hydrogen using nationally produced electricity to power large-scale electrolysers. This initiative made the French state an active player in industrial policy – and one that explicitly uses an argument related to sovereignty, control and national development. It did so by implementing a supply strategy, whereby what matters is to massively (and nationally) produce green hydrogen and organize an industrial sector accordingly. This approach functions within a technical apparatus in which the electricity that powers the electrolysers is both green and relatively cheap. It relies on the French energy mix essentially composed of nuclear energy, and can only produce "green" hydrogen so long as nuclear energy is also considered "green" – a qualification that is regularly debated, as recent tensions between France and Germany show[5] (Le Monde, 2023).

[5] Under European law, green hydrogen is meant to be produced from renewable energies. Hydrogen produced from nuclear energy is known as "purple hydrogen". France's representatives to the European Commission are pushing for nuclear power to be considered as a renewable energy. In the RED III directive adopted by the European Parliament in September 2023, nuclear power is treated as a "low carbon" energy source, enabling it to benefit from European subsidies similar to those for renewable energies (Cleary Gottlieb, 2023)

Since green electricity could be produced in France (as long as nuclear was green), the plan did not envision large-scale hydrogen pipelines connecting the country to solar panel fields in Spain or Morocco. Rather, and as an official at the Prime Minister's office explained in an article in the specialized press, France "chose to massively deploy electrolysers, connected to the electricity grid, and therefore as close as possible to the places of use" in order to "minimise the costs of transporting and distributing hydrogen". Massive volumes of hydrogen would be produced and used in dedicated sites that officials in charge of the plan soon called "hubs" (Bui, 2022). An example of such hubs is the "Grande région hydrogène" in Lorraine, where the sites of former coal power plants are repurposed as hydrogen production sites by electrolysis, for use in nearby steel factories (Birat, 2022).

We borrow the term "hub" to label a third style of territorialisation, one that is the product of government initiatives aimed at redirecting hydrogen policy from mobility to heavy industry. Here, the hydrogen sector is not made up of innovative actors developing fuel cells for mobility (as in the ecosystem approach) or the outcome of the transformation of existing industrial sectors (such as the automotive industry as in the planned infrastructure approach). Instead, the hydrogen sector is the result of the transformation of much larger companies, comprising both producers and users of hydrogen, and which decarbonize existing industrial processes thanks to green hydrogen. This understanding of the hydrogen sector echoed changes amongst the industrial actors involved in AFHYPAC and originally involved in the development of ecosystems. This organisation welcomed the French plan as heralding a "new era", which it accompanied by changing its name to "France Hydrogène" following considerable growth within its ranks (H2 mobile, 2020). Rather than being an association of innovative producers of hydrogen fuel cells, the organisation would now speak for a hydrogen sector that also comprised large-scale companies that use hydrogen within industrial processes. This evolution made mobility a domain of hydrogen application amongst others, one which could be supported by the French plan if its projects reached the threshold of hydrogen volume. In this context, the members of France Hydrogène continued to be involved in the development of ecosystems while seeking to benefit from new sources of public funding.

The second characteristic of the style of territorialisation based on hubs is an industrial policy based on active state interventions promoting hydrogen production and use. When presenting the new hydrogen plan, the minister of economy Bruno Le Maire contrasted it with what he called the "Chinese solar panel strategy". He alluded to an episode well known in French industrial policy circles, which had seen Chinese companies win French calls for tenders for

solar panels. Yet, Le Maire now said, “it is not the vocation of the French taxpayer to finance Chinese industry”. Lessons had been drawn and policy choices made: the French state would actively commit to the development of a national hydrogen sector. For Le Maire:

> *the responsibility of the Minister of Economy and Finance is first of all to support French industry, French workers and French jobs.*

“Supporting French industry” may imply various forms of state involvement. In this context, it referred to the commitment of the French state to support a hydrogen hub approach that would benefit the national industry because it used French energy and involved industrial sites in France. This evolution echoes broader transformations at the European level, where the need for the active involvement of public bodies in the development of transition technologies has been a central component of the recent “Green Deal”, later complemented by a post-Covid recovery package called Next Generation EU.

The third characteristic of the hub-based style of territorialisation relates to the kind of territory it imagines. It relies on a national energy policy associating nuclear power and a principle called *péréquation tarifaire* (tariff equalization). This implies that the geographical location of electricity consumers does not affect electricity costs, a principle that has been a central tenet in France since the nationalisation of Electricité de France shortly after World War 2 (Yon, 2014). Thus, the imagined geography of hubs is national (as it is linked to a national energy policy-making electricity prices the same across the country) while also introducing geographically differentiated infrastructures. Hubs suppose that hydrogen industry is developed in localized sites, where the massive production and use of hydrogen are located. These hubs are set to be connected by pipelines circulating nationally-produced green hydrogen across the country (see figure 2).

Figure 8 : Étendue du réseau de canalisations de transport de l'hydrogène nécessaire pour raccorder les grands pôles industriels et d'énergie – Source : EU H2 backbone (EHB : European Hydrogen backbone).

Figure 2: a network of hubs connected by pipeline (extract from Bui, 2022).

This last element is a source of fragility. Proponents of the post-covid hydrogen plan see the identification of the hubs' locations and its associated consequences to be a major issue. The person in charge of the strategic committee for hydrogen told us on interview that she had heard critics of the hydrogen plan stress that if "charging stations are mainly around ports or steel factories" (which are indeed part of the objectives of setting up hubs) then the use of hydrogen would not extend beyond heavy industry. Hubs are located according to the needs of heavy industry and not others – such as those of a transportation system allowing hydrogen vehicles to cross the country and requiring well positioned charging stations. And as with the planned infrastructures for mobility, the pipelines envisaged to connect them require large amounts of public funding. In 2023, no such pipelines were constructed, and there was little sign that they would ever be.

Conclusion

Starting from a contemporary concern for the territorial inscription of industry in an era of ecological transition, this paper has used the example of hydrogen in France to characterize three styles of territorializing the industry (see figure 3). These styles of territorialisation did not emerge in neat succession, rather they have coexisted with one another. Critics of the fragmentation of ecosystems, or of the fragility of the as yet non-realized planned

infrastructures, show that this coexistence produces additional sources of frictions, and leaves open the question of which hydrogen policy (if any) will eventually stabilize.

	Ecosystems	**Planned infrastructures**	**Hubs**
Industrial sector	Innovative companies in the mobility domain	Cars manufacturers and their suppliers	Heavy industries and their suppliers
Policy	Cluster policy, innovation policy	Infrastructure policy	State support for heavy industry (including nuclear)
Industrial territories	Fragmented in localized ecosystems supposed to become more dense	Unified at the national scale by transportation infrastructure	Fragmented in hubs, unified by electricity prices
Tensions	Coordination and connection across ecosystems	Infrastructure financing, deciding on location	Going beyond heavy industry and involving other domains (mobility)
The excluded	Places outside ecosystems	Local specificities ignored by central planning	Mobility needs left aside by the focus on heavy industry

Figure3: Three styles of territorialisation of industry

Each style faces practical and economic issues, and evolving governmental priorities may account for the evolution of their respective importance. At any case, contrasting these styles opens up a space for critical analysis. Specifically, it directs analytical attention to the sources of tension and fragility associated with issues of coordination among ecosystems, massive investment for planned infrastructure, and the limitation of hubs to heavy industry. This comparative approach also invites us to pay attention to the exclusion effects that each style of territorialisation inevitably produces. The fragmented territories of ecosystems leaves aside the localities who are not members of any of them. The competition amongst territories upon which it relies necessarily results in further asymmetries. The centralized territory associated with planned infrastructures supposes that central decisions are made, possibly ignoring the specific needs of local cities or regions –this is precisely why local territories regularly insist on developing an ecosystem that matches their specific needs. The national territory unified by

energy policy and structured by hubs relies on a supposedly "green" nuclear electricity and prioritizes certain uses (heavy industry), possibly at the expense of others (e.g. mobility).

While the example of hydrogen has enabled us to identify these three styles of territorialisation, we argue that the approach we propose is relevant beyond this case. Speaking of styles of territorialisation has allowed us to connect sociotechnical configurations with explicit spatial ambitions or implicit geographical implications. The examples we studied have shown that linking industry and territory is part of the engagement of public and private actors in transition projects, and an (explicit or implicit) component of their visions of industry and policy. This dynamic can be identified elsewhere, and the analysis of styles of territorialisation can shed light on the politics of industrial development in times of transition beyond hydrogen. For example, the tension between ecosystems and planned infrastructure is just as visible in the case of self-driving cars. While car companies might see real-life tests conducted in cities as the first steps before massive replication begins elsewhere, many cities resist their becoming laboratories which generate external benefits and, instead, seek to integrate such tests into the gradual densification of their own transportation systems (Haugland and Skjølsvold, 2020). More generally, debates over renewable energies often display tensions between bottom-up and top-down approaches (Evrard and Pasquier, 2018). These approaches are characterized by different understandings of state interventions and private projects and result in different imagined geographies, which echo the differences between ecosystems and hubs.

Ultimately, studying the territorialisation of industry adds an analytical layer to the analysis of industry/policy relationships by studying the territories that are anticipated (and in some cases materially constructed) when industrial sectors emerge or evolve, and who is involved in the corresponding processes, as well as who and what is left out. Starting the analysis, as we did in this paper, not from the examination of ready-made industrial sectors or industrial policies but of processes of territorialisation provided us with an entry point with which to explore how the general objective of "transition" is implemented in practice and with what consequences. The fragmented territory of ecosystems illustrates a mode of policy action that refuses to choose which technology to develop and where, and prefers to leave such arbitration to competition amongst territories and to the initiatives of innovative companies. The national territory unified by large-scale infrastructure imagined by car manufacturers supposes massive state investments for private actors to benefit from technology development. The promotion of hubs is a manifestation of a policy making energy production and supply a matter of sovereign state action, within which heavy industry needs to take a part. Our exploration of the three different

styles of territorialization linked to hydrogen-based industrial projects suggests that investigating other imagined and partly realized territories of industry offers a well-lit analytical path to follow when seeking to understand the politics of state interventions and private initiatives in times of transition.

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