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Debating the sustainability of solar energy: Examining resource construction processes for local photovoltaic projects in France.

The growing attention to sustainable transitions suggests that the development of renewable energies is a central pillar of the transition towards low-carbon societies. However, even though the boundary between renewability and sustainability may be considered minimal, renewable does not mean sustainable. This paper adopts a geography of resource perspective to investigate the sustainability of renewable energies as the result of a contextualized construction process at the scale of local energy projects. The first part of the paper examines how sustainability is addressed in the literature and postulates that a relational focus on resource construction processes offers new analytical perspectives for understanding the importance of context in the construction of renewable energy sustainability. Sustainability is specifically described as a political quality distributed among human and non-human actors within a milieu. Drawing from this theoretical construction, an analysis of two case studies of local photovoltaic projects in the French Rhône-Alpes region (southeast France) highlights how an energy resource might be endowed with very different modes of existence (Simondon), among which some appear to be sustainable and others do not. The final part of the paper discusses how a relational framework offers new perspectives to define and move toward more sustainable renewable energy systems.

Keywords:

Sustainability, renewables, context, resource, photovoltaic, relational approach.

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Introduction

The current development of renewable energies constitutes a central pillar of the transition towards low-carbon societies. The shift from fossil fuels and their diminishing reserve stocks to abundant and diffuse renewable energy sources opens up a wide range of opportunities to shape more sustainable modes of energy production and consumption. In this context, the boundary between renewability and sustainability might appear to be minimal [1]. However, several recent academic contributions have noted that renewable does not mean sustainable. The mere development of renewable energies is not sufficient for decreasing greenhouse gas emissions [2]. The development of most new renewable energy technologies may yield new or renewed environmental threats [3] related, for example, to the extraction of potentially scarce raw materials necessary for photovoltaic cells and wind turbines [4],[5],[6]. Furthermore, in the context of some specific energy projects, the valorisation of diffuse energy sources raises new issues related to social and spatial injustices in the form of land, resource and income grabbing [7],[8]. These criticisms call for a more systematic questioning of how the sustainability of renewable energies should be defined and might be achieved.

This paper offers a contribution to this academic and policy debate from a geographical perspective with a focus on the construction of renewable energy resources. We argue that the sustainability of renewable energies is at stake when local energy projects are structured. Following seminal contributions about the social, spatial and political construction of the renewability of some resources [9], we assume that the sustainability of renewable energies also results from a contextualized construction process. The examination of this assumption provides elements to answer three main questions: (1) what does it mean for renewable energies to be sustainable? (2) When, where and how is the sustainability of a local renewable energy production project at stake? (3) Beyond the quantitative goals, how can renewable energy public policies induce more sustainable development? We address these questions through the analysis of two local photovoltaic projects in southeast France in the context of the late 2000s and early 2010s: a ground solar farm and a community-based solar project on roofs.

To elaborate on and test our assumption, the first part of the paper examines the sustainability of renewable energies as it is currently discussed in the academic literature and underlines a need to explore the overlap of different studies (§1). Then, the paper proceeds with an analytical proposition to tackle sustainability as a political quality of a resource which may – or may not – emerge during the structuring of local projects (§2). This proposition is tested through the analysis of two case studies (§3). The final part addresses several discussion topics regarding what the contribution of our analysis might be for both academic and policy-related debates, and further research perspectives are given.

1 Addressing the contextual construction of renewable energy sustainability

Within both academic and institutional literature, sustainability is a multifaceted concept. Since its initial definition by the World Commission on Environment and Development, sustainability has been associated with the notion of development to describe a pathway that would meet “the needs of the present without compromising the ability of future generations

to meet their own needs” [[10], pg.43]. From 1987 on, sustainable development has broadly been understood as a development type that encompasses ecological, economic and sociopolitical aspects. Beyond this vague definition, sustainability involves the collective discovery of preferred development pathways [11] in the context of climate change and global crises. We underline hereafter four research approaches related to renewable energy sustainability and then highlight a research gap this paper fills.

1.1 Sustainable transitions emerge from the trajectories of sociotechnical innovations

Within the past decade, the achievement of sustainability has been increasingly addressed through the multidisciplinary and fast-growing academic research field of “sustainability transitions”, with focuses on multilevel transition trajectories [12], [13], [14], technological innovation systems [15], [16] and transition management [17]. These analyses focused on techniques and the corresponding innovation trajectories, and they provided an important contribution for the sociotechnical understanding of the development of renewable energies. Notably, these studies helped refine widely accepted analytical frameworks in terms of the multiple barriers of renewable energies during their development [18] for what has been described as a carbon lock-in [19], [20]. For instance, the multilevel perspective underlines that the construction of new sociotechnical regimes and modification of existing ones is contextual and fuelled by dynamics at the niche level, where radical innovations are developed at the microlevel, as well as slow-changing structural factors at the landscape macrolevel [13]. The speed of transition processes drastically varies in different parts of energy systems and at different scales [21]. However, the development of sustainability through the development of technological innovations is often approached from medium- to long-term perspectives. The role of fast-emerging local renewable energy projects in developing innovations and contributing to the development of sustainability in the very short term appears to be –at least partially– beyond the scope of this studies. Furthermore, the MLP’s “niche” does not necessarily match “the local” scale, and critics have addressed this approach as a rather naive geographical approach to sustainable transitions [22], [23]. Such critiques point towards the need for increased dialogue between the sociotechnical approaches of sustainable transitions, and some literature specifically dedicated to understanding the importance of the local scale in the construction of sustainability.

1.2 The importance of the local and community scales

An important body of scientific literature discusses the role of the “local” in multiple dimensions in the construction of sustainability. The role of grassroots innovations in the construction of a sustainable transition [24] has been increasingly scrutinized with a focus on community initiatives building the community capacity for more sustainable energy practices [25]. Increased local participation in renewable energy production projects has a positive impact on the development of renewables. For example, the emergence of locally driven renewable energy initiatives is perceived as a potential way to overcome some sociotechnical hurdles and leads to reduced local opposition [26], [27]. Local collective energy initiatives allow for the involvement of new actors in the development of renewable energies through the emergence of local debates and the distribution of benefits [28], [29], [30]. Furthermore, some local community-based energy projects tend to use local energy infrastructures and resources as common utilities and redefine local social sustainability pathways [31], [32]. Together, these contributions underline that the spatial context of the development of

renewable energies, and the local dimension, especially, is paramount for the construction of sustainability [33]. Locally inherited sociospatial configurations have important potential for fuelling the construction of a sustainable energy transition [34], [35]. However, the recognition of the importance of the community and local scales should not mask the role of the institutional and political context of energy policies in defining sustainability and enabling sustainable projects to emerge.

1.3 Sustainability is framed by institutional context and political processes

While recognizing the important and growing role of local actors in the development of renewable energies and the construction of a more sustainable energy future, a third body of literature underlines that sustainability construction is influenced by politics and political processes [36] within varied arenas from institutional to local debates about concrete projects. Beyond its vague initial definition, sustainability does not refer to a fixed set of norms [37]; it is not defined nor framed the same way in national strategies, and dedicated policies may not focus on the same aspects, be they environmental, governmental, economic, or social aspects [38]. Along institutional debates about the definition of what sustainability should be, experiments involving new multilevel models of energy governance adapted to the development of renewable energies remain highly uncertain and face political and contingent barriers [39]. The upper political levels pose severe constraints for the implementation of local sustainable initiatives and new governance structures [40]. For instance, the development of local initiatives and new local energy governance patterns in the European context is highly influenced by mutations in state interventions and the design of neoliberal energy policies [41] organized around market regulation [42]. This literature underlines that the contextual construction of the sustainability of given technologies, resources or specific local projects must be considered part of multilevel political process.

1.4 Resource geographies and the importance of materiality

With a focus on sociotechnical transitions and the importance of the local, institutional and political contexts, a fourth research field has proposed ways to reflect on the contextual construction of the sustainability of renewables. In the wake of post-structuralist intellectual currents, the development of relational approaches to space and geography as a science of action [43], [44], has fuelled a new geography of resources. Following Zimmerman's precursory work that called for a deconstruction of the essentialising of resources – "resources are not, they become" [45] – the dual aspect of resources was addressed; specifically, resources are simultaneously physical entities and social categories [[46], pg.1219]. Resources become at the whim of material assemblages and sociotechnical devices that endow things with qualities and regulate the construction of social relations [47], [48]. This trend in thought has fuelled works that illuminate the gap between the natural characteristics of a source or an object and the political qualities of this source or object once turned into a commodity or a resource [49], [50]. Such contributions created a research gap for the further political interpretation of resource construction processes. Within a relational approach, a resource cannot be reduced to a politically neutral result of a construction process. Thus, a resource cannot be seized apart from its governance system [9], [51] or apart from all the materialities –and the power relations they convey– required during the production process [32]. This new geography of resources addresses the construction of a resource's political qualities as an open and uncertain process.

We noted in this first section that several bodies of literature address the sustainability of renewable energies as a contextual and political problem with a focus on the specific dimensions of renewable energy development, including spatial, material and technical dimensions. The next part of this paper discusses a theoretical framework to address the contextual nature of the construction of renewable energy sustainability in the light of these three dimensions by treating sustainability as a political quality of a resource.

2 Sustainability as a political quality of a resource: a relational framework

The second part of this paper provides a theoretical framework to further understand the contextual and political construction of renewable energy sustainability as a multidimensional process encompassing spatial, material, and technical dimensions. As mentioned above, recent contributions to the geography of resources tend to treat resources as assemblages of human and non-human actors. Resource construction is thus acknowledged to be a relational process in which political qualities emerge. To examine sustainability as a political quality of a resource, we review how the existing literature discusses the relational development of resources and the emergence of political qualities from three dimensions: spatial (§2.1), material (§2.2), technical (§2.3) dimensions. Then, we note that Gilbert Simondon's relational philosophy might be a heuristic approach for understanding the contextual and political becoming of resources in these three dimensions taken together as a milieu (§2.4).

2.1 Siting processes and the spatial framing of resource development

Spatiality is an important dimension of the contextual and political construction of renewable energy sustainability. First, the construction of a resource occurs through the construction of an extraction or capture site. The transition from fossil fuels to renewable energy sources entails adopting a different perspective on the siting process. Unlike some fossil fuels that are already concentrated in space – and for which the siting process is largely constrained by physical deposits – the diffuse nature of some renewable energy sources leads to extremely open siting processes [52], [53]. Following Crosby's idea that diffuse energy sources need to be concentrated to produce tangible resources [54], the construction of a site according to the ways human and non-human actors are convoked appears to be a concentration process [32]. The same remark applies in the case of some unconventional fossil fuels [55]. These contributions have led to the reinterpretation of Andrew Barry's analytical proposition [56]: the construction of a 'site' understood as the concrete location where a project takes place is also the construction of a 'sight' understood as a specific relational organization around a source that produces political qualities. In a complementary analytical proposition, Labussière et al proposed to study the construction of the "*spaces of energy resources*" to understand "*how space is configured to channel and control turbulent materialities (e.g., wind, solar and so on)*" [[57], pg.245].

These analyses of the spatial dimension of resource construction processes systematically refer to the capacity of actors to agree upon a collective organization and to convoke several overlapping sociotechnical systems of different ages that respond to distinct planning logics (e.g., the electric grid, road network, and land uses), the compatibility of which may not have been tested. Thus, the sustainability of renewable energies might first seem to result from the capacity of actors to invent planning practices that ensure the compatibility of all the sociotechnical systems and materialities summoned during the siting process. In light of this consideration, the spatial dimension of the resource construction process is inseparable from the material dimension.

2.2 Resource qualities are materially constructed

If space constitutes an important aspect of the making of resources, the relational role of materiality must also be considered an essential dimension of the contextual making of resources [46,48] in light of ANT's distributed action theories [58], [59], [60], with recent examples dedicated to renewable energies [57], [61]. Existing studies about the material making of resources provide insightful analyses about the link between a source – endowed with essential qualities – and a resource – with qualities that are contextual. For instance, Timothy Mitchell's attempt to "*follow the carbon itself*" [[62], pg.6] to explain the construction of collective political action capacities shows how material configurations endowed energy resources with very different political qualities. In the context of Great Britain's industrial revolution, coal's material configurations –a solid matter extracted by many workers with simple tools in concentrated areas and transported by train following a centralized grid organization- allowed coal workers to gain political power by diminishing coal's fluidity [[62], pg.26]. Conversely, oil extraction requires far fewer workers [[62], pg.36], and its circulation as a liquid through pipelines and/or tankers allow oil firms to hamper the capacity of carbon workers, block carbon circulation and gain political power. In this contribution, Mitchell shows a direct link between the physical nature of a source (liquid or solid) and its political quality, i.e., the fluidity of carbon and thus the capacity of workers to control its flows, but emphasize the role of material configurations in the construction of these political qualities. In the same way, Gabrielle Hecht's analysis of uranium circulation from African mines towards western nuclear powers [63] illustrates the importance of the material dimension in the emergence of the political qualities of energy resources. Hecht specifically notes that uranium is endowed with drastically different qualities around the world: it is extracted in open mines in Africa and handled as a fairly benign matter by unprotected workers; it is then shipped to Europe and the United States. Only then is it framed as a dangerous matter to be handled with extreme caution. The study proposes to distinguish between radioactivity as a physical attribute of uranium and nuclearity as a politically modular quality: "*nuclearity is not so much an essential property of things as it is a property distributed among things*" [[63], pg.14]. Although the technical and political properties of a resource may stem from the same physical attributes, the construction of the political qualities of a resource is drastically different from one context to another [[63], pg.15].

These contributions suggest that resources and their political qualities are continuously reconfigured by their permanently evolving material context. As such, the emergence of the political qualities of resources appears to be an always-uncertain, outcome-driven process. In other words, political qualities always emerge from the mutual reconfiguration and redefinition of entities and actors. Thus, within our analysis of the emergence of sustainability as a political quality of energy resources, sustainability is less an essential quality of things than it is a quality distributed among mutually reconfiguring human and non-human actors.

2.3 Technics play a key role in the construction of political configurations

The third dimension of the contextual construction of renewable energy resource sustainability we discuss already appeared in filigree in the two previous sections. Among the abovementioned non-human actors, technological artefacts and networks often play a key role in the relational making of resources. Several academic debates have already questioned the link between technics and the circulation of political qualities. In a seminal paper, Mumford suggested endowing technics with political attributes according to the work and

social systems they tend to induce [64]. He qualified craftsmanship technics as democratic technics in the way they are mastered locally to enable the maintenance of local and autonomous means of production. Such democratic technics are opposed to authoritarian technics, in which network functioning frequently escapes local governance. Such technics impose new rhythms and modes of production that reduce local autonomous expressions, as craftsmen can no longer locally assure their maintenance [[64], pg.2]. Thus, Mumford defends the idea that the deployment of new technologies introduces new norms that induce new power balances within societies [65]. Following these ideas, Winner suggested sorting technics according to what he considers their flexibility. His studies suggested that even if technical artefacts themselves are not endowed with intentions, they might carry intentions [[66], pg.124]. According to their attributes of flexibility, some technics leave room for different forms of political organizations, and others impose one specific form [67]. From this, we assume that renewable energy technologies play a role in the construction of power relations, carry their own rationalities and are prone to influence the logic of organization, some leaning towards sustainable organizations and others towards unsustainable patterns. If the deployment of renewable energy technologies seems to create opportunities for more democratic and sustainable forms of development with increased energy access [68], some critics underline that such a deployment may occur at the expense of democracy [7, 8].

Within our relational framework's proposition, these debates about the importance of technics in the contextual construction of renewable energy resource sustainability echo ANT's distributed action theory. If political qualities emerge with the construction of heterogeneous relations within a given context [69], [70], technics, as well as other material and spatial features, constitute crucial dimensions of emergence. Thus, if sustainability is to emerge out of the construction of heterogeneous relations among many human and non-human actors in a specific context, our analysis of sustainability relies on a deep understanding of the role of this context. We hereafter propose to address the matter of context broadly as a ubiquitous milieu that channels the construction of a resource and the emergence of its qualities.

2.4 Energy resources are contextually endowed with different 'modes of existence'

Until now, we assumed that sustainability might be considered as a context-based political quality of energy resources. With information from an initial state-of-the-art model, we discussed the relational emergence of political qualities along several dimensions (spatial, material, and technical). To operationalize our analysis of sustainability as an uncertain political quality of resources, we propose to expand our understanding of the importance of context in the political becoming of resources with a reference to the singular concept of "associated milieu", as proposed by Simondon [71]. The associated milieu encapsulates a sum of intertwined spatial, material and technical dimensions through which heterogeneous relations are formed. Contrary to other notions of the milieu as a common and shared environment, he refers to the milieu as the specific environment of one individual (human or non-human), through which this individual comes into existence and is engaged in relational trajectories. According to the nature of and modifications of their associated milieu, entities might be endowed with what Simondon terms different "*modes of existence*" [71]¹ to designate the different relational becomings these entities are open to. We suggest tackling

¹ This concept of modes of existence is related to the different becomings one entity is open to and is thus distinct from Latour's understanding of the "modes of existence," which are not initially centered on one object but on distinct ontologies [72].

what we grasped as the context with the concept of associated milieu. Space, materiality and technics constitute the intertwined dimensions of associated milieus within which renewable energy resources are engaged in relational becoming trajectories resulting in modes of existence with various levels of sustainability. Specifically, the associated milieu of a resource encompasses the networks of human and non-human actors attached to a local energy project with a diversity of interests.

Table 1 illustrates this proposition. When a local energy project is initiated, the way an energy source is constituted into a resource depends on the formation of the associated milieu. According to how the associated milieu is formed, the resource might be endowed with different modes of existence. If the project is conflictual and does not succeed, the resource does not come into existence. If the project is implemented, the sustainability of the resource’s mode of existence depends on the capacities of project leaders to take into account the interests of the variety of human and non-human actors concerned with the project.

Thus, with this theoretical proposition, we assume that the sustainability of renewable energy resources results from a multiplicity of negotiations during the construction of heterogeneous relations between human and non-human actors at the scale of a specific project (illustrated in Table 1 by the blue arrows). The process of resource construction is not binary – either sustainable or unsustainable – and sustainability is not an essential quality. It is rather a quality distributed among things as well as a quality of a milieu. Furthermore, sustainability is the result of an always-open process; it is never guaranteed, and it is always under negotiation in light of the diversity of actor interests.

We test this theoretical proposition in the next section, which describes two local solar energy projects in the French energy policy context of the late 2000s and early 2010s.

Table 1: From the source to the resource: multiple modes of existence of the resource at stake

| Source | Associated milieu | Mode of existence of the resource |
|------------------------|--|--|
| Pre-individual reality | Intertwined spatial, material and technical dimensions | Resource does not come into existence |
| | | Resource is contextually endowed with an important level of sustainability |
| | | Resource is contextually endowed with a limited level of sustainability |

3 Local photovoltaic projects and sustainability in France: an empirical inquiry

Beyond our initial statement that renewable does not mean sustainable, we emphasize the importance of context in analysing sustainability. Within a relational approach, we suggest that sustainability be treated as an uncertain and always under negotiation political quality of energy resources at the scale of local projects. In the upcoming section, we test this

theoretical proposition through two case studies of a very specific energy resource: solar energy. The diffuse and abundant aspect of the source (solar rays) suggests that the resource constructed through its capture might be inexhaustible and its construction unproblematic. However, the materialities associated with the construction of the resource are exhaustible, and the way they are summoned might create controversies and hamper the construction process. These materialities include the land parcels and roofs that might host the solar technologies, as well as the technologies and networks through which the produced energy circulates.

The two case studies addressed in this paper are concerned with photovoltaic projects and present similar contextual aspects. Both projects emerged out of a moment of uncertainty about the evolution of French photovoltaic policies during the late 2000s and early 2010s (§3.1); they occurred in low-mountain villages, and both project areas benefited from similar sun exposure. The first case study takes place in the Natural Regional Park of Vercors within the Rhône-Alpes region and addresses a large ground-based photovoltaic farm project driven by a group of municipal elected officials that failed when the associated milieu collapsed (§3.2). The second case study takes place in the same region in a neighbouring natural regional park: the Bauges Massif Park. This case study addresses a collective and cooperative photovoltaic project driven by inhabitants and elected officials; the project targeted public and private roofs, and the associated milieu resisted multiple hardships (§3.3). Given their contextual similarities, our investigation questions how, where and when the sustainability of renewable energy resources is at stake at the scale of local energy projects. From this perspective, we examine how milieus emerged and how they induced specific modes of existence for the solar energy resource. Lessons from these case studies are then discussed in the final section.

Between 2012 and 2018, we examined the process of resource construction in the two case studies based on a qualitative methodology. During the first phase of inquiry, we performed 30 semi-structured interviews with project managers (elected officials and local and regional technicians), experts who worked on the projects (electric grid experts, landscape architects, and legal energy experts), participants in the projects (local investors and cooperative participants) and project opponents (inhabitants and environmental protection associations). We also observed six local meetings (public presentations of the projects)². This first phase allowed us to identify episodes in which the sustainability of renewable energies was at stake according to the actors. During the second phase, we analysed the interviewees' archives (meeting minutes, technical and legal papers, and expert reports) to obtain a detailed timeline of each project. In the third phase, we conducted five additional interviews to gather additional information and validate the timeline assumptions.

3.1 An energy policy context marked by important uncertainty

In the wake of the European agenda on renewable energy production, the French government implemented the first part of its first on-grid photovoltaic policy in the form of a feed-in tariff scheme in 2002. The scheme aimed to achieve quantitative goals but paid little attention to qualitative and local planning-related issues. During the first years of the scheme, the value of the feed-in tariff was acknowledged as too low and did not trigger much development in the sector. However, in 2006, the value of the tariff was doubled – and almost tripled for operations on roofs – which initiated a rapid and tremendous growth of the

² The observation of public meetings only concerned the second case study because when we started this study in 2012, the energy project examined in the first case study had already been cancelled.

number of photovoltaic operations and grid connection requests. At the same time, the government started to set up tender processes to induce the development of specific forms of photovoltaic projects (large industrial photovoltaic roofs and ground-based solar farms).

From 2006 to 2010, in the context of the extremely high profitability of investments in photovoltaic operations, the feed-in tariff scheme constantly overflowed as a result of numerous unforeseen developments in the market [73], [74]. Consequently, the value of the tariff and the conditions for its attribution were regularly adjusted. Adjustments partly took the form of the multiplication and complexification of the feed-in tariff categories according to the surfaces of panels, integration modalities, and building uses. However, the French government failed to control the evolution of the sector with these adjustments and decided to stop the attribution of the tariff for several months at the end of 2010. This crisis had harsh consequences for the development of the sector in terms of jobs (from 32,000 jobs in 2010 to 12,000 in 2012) [75]. In 2011, the government adopted a new mechanism to progressively lower the value of the feed-in tariff every three months according to annual quantitative development goals. However, the feed-in tariff scheme was still very complex, and the photovoltaic policy was regularly adjusted in what appeared to be a permanent trial-and-error experiment.

3.2 A ground-based photovoltaic farm project for which the associated milieu collapsed

Our first case study deals with a ground-based photovoltaic farm project undertaken between 2008 and 2010 in the Natural Park of Vercors; ultimately, the project failed. The project was initiated by a tender process initially published by the Ministry of Ecology, Energy, Sustainable Development and Land Planning (hereafter the Ministry of Ecology) and the Energy Regulatory Board in November 2008. The tender process aimed to induce the development of one ground-based solar farm ranging from 5 to 20 MWp in every French region for a national cumulative power total of 300 MWp [76]. Through this project, the Ministry of Ecology aimed to contribute to quantitatively achieving its renewable energy production goal based on European commitments and create sufficient demand to develop the French photovoltaic industry. Accordingly, the tender process enabled the selected projects to benefit from a subsidized tariff for important quantities of electricity that were not eligible for the feed-in tariff. The applications were evaluated according to three criteria of equal importance: the price per kWh they were to produce, an evaluation of the operation's environmental impacts, and the technical feasibility and implementation deadline [[76], pg.9]. Applicants were also asked to set up several measurement instruments and new technologies on the farm that were currently being tested by the National Institute for Solar Energy (NISE hereafter). For this reason, members of this institute were associated with the evaluation of the applications.

The ground-based photovoltaic farm project emerged in this context in a village (2600 inhabitants) situated on a plateau surrounded by agricultural fields and forests and next to one of the largest natural reserves in France. The project was driven by local elected officials who had connections with experts from the NISE and was seen as a great opportunity to generate new income for the municipality to fund other renewable energy projects and make the village an example for the energy transition. In developing their application for the national tender, the local elected officials started to explore the municipally owned lands with experts from the NISE in order to select a parcel for the photovoltaic farm. During their research, they were looking for a land parcel that could enable the production of cheap electricity for the application to be selected and for the municipality to generate important

income. The parcel mainly had to have good solar exposure, be near electric lines to reduce extra costs, and be close to the road network to facilitate construction and maintenance work. At this time, a local planning rule blocked the transformation of agricultural lands [77], and the only municipally owned lands remaining were forest parcels. After a one-day field visit organized by the municipal team with members of the NISE, a 20-hectare forest parcel was selected. At the direction of the mayor, the municipal team organized the first public meetings between July and October 2009 to inform all local actors about the project and seek their approval. Three arguments were presented: the forest being considered for cutting was of mediocre quality, the ground-based solar farm was not visible from the village, and the operation would generate important economic income for the municipality.

At this point, the project leaders had every reason to believe the way that they proposed to transform solar rays into an energy resource had an important level of sustainability. The project was endorsed by several solar energy experts because it was projected to generate important public income to be reinvested in new local renewable energy projects and did not degrade the environment in any protected local areas.

However, in the wake of these public meetings, several forms of opposition emerged; they criticized the parcel selection and declared the project unsustainable. First, a group of environmental protection organizations noted that the forest being considered for cutting was a major ecological corridor. Then, a group of inhabitants from the village and surrounding areas emphasized that the forest had many recreational uses and considerable value for the locals. They also advocated that even if the solar farm was not visible from the village, it would be visible from other villages for which the elected officials and inhabitants were not consulted during the development process. To make the parcel that was to be cut visible, they organized a large communication operation in November 2009. They attached large helium-filled balloons at the corners of the parcel and invited all local actors and media to the site. Following this operation, elected officials from the surrounding municipalities criticized both the absence of a participative process and the fact that the municipality where the project was run was capturing all the economic outcome and the other municipalities were the only ones facing the visual consequences. With a common voice, the opposition noted that there were enough already-anthropized spaces in the natural park (e.g., old open-air quarries, parking lots, and roofs) and that there was no justification for cutting 20 hectares of forest.

Finally, facing similar controversial situations in other regions, the French Secretary of State in charge of ecology declared in December 2009 that the development of photovoltaics should not be pursued at the expense of forests [[78], pg.27]. In addition, during the first months of 2010, the Ministry of Ecology finally cancelled the tender process due to the many local controversies and upon realizing that to produce cheap electricity, most candidates were using Chinese solar panels, which did not stimulate the French photovoltaic industry.

When the local elected officials made their project public, new actors got involved and tried to reinvigorate the project with perspectives that had been ignored to that point. In its initial form, the project was only structured around materialities that had an impact on economic profitability; notably, the electric grid and the electricity injection regulation were taken into account, but the landscape and associated local practices were ignored. The project's profitability was reached at the expense of both the local environment and the land practices. The associated milieu of the resource progressively collapsed when the project leaders failed to take criticisms into account and to negotiate the compatibility of the solar farm's project with newly convoked materialities. As a result, the project was cancelled, and

the resource did not come into existence. During this process, the solar energy resource was framed as a collective capitalistic investment (see Table 2), i.e., the colonization and transformation of new spaces that were not previously dedicated to energy production. This project would have allowed the production of electricity from a renewable source at a very competitive price but was contested by many actors due to its environmental consequences and the lack of space for local participation and income redistribution. Locally, the mode of existence of the resource would have been extremely conflictual and therefore would have had a limited level of sustainability.

Table 2: Summary of case n°1

| Source | Associated milieu | Mode of existence of the resource |
|------------------------|--|--|
| Pre-individual reality | <ul style="list-style-type: none"> - Ground-based photovoltaic farm project - High-profitability perspective if sited next to existing power lines and on a municipally owned parcel - Criticized for not taking into account landscape issues and existing land practices - Lack of space for local participation | <ul style="list-style-type: none"> - Resource framed as a collective capitalistic investment - Conflictual resource construction process - Resource did not come into existence |

3.3 A cooperative roof photovoltaic project for which the associated milieu resisted multiple hardships

The second case study addresses a collective and cooperative rooftop photovoltaic project initially driven by a regional NGO between 2010 and 2014. During the late 2010s, the vast majority of French photovoltaic projects were individual and private. People were investing in their own roofs, even if those roofs did not have optimal solar energy features (no shadows, southern exposure, and low slope). People with no capital to invest in suitable roofs or people without property were *de facto* excluded from photovoltaic projects. Moreover, the instruments of public policy that supported the photovoltaic development were mainly funded through a tax on electricity consumption. Thus, the less well-off households unable to invest in photovoltaic were paying their electricity at a higher price to finance the profitability of the investments of better-off households. The social injustice behind this photovoltaic development dynamic raised questions about its sustainability. In this context, the regional NGO developed a programme with both European and regional funds to experiment with alternative and more participative modes of local photovoltaic development. These alternative ways for local actors to collectively invest in roofs and generate shared incomes were thought to be more sustainable. The programme specifically addressed the development of small-sized photovoltaic operations (from 50 to 250 kWp) on public and private roofs at the scale of a village, and the programme was driven and funded by local actors (inhabitants, local companies, and municipalities). Among the eight pilot operations initiated in 2010, this paper focuses on the first successful operation that took place in the Natural Regional Park of the Bauges Massif.

The project was initially developed within the area of an intermunicipal entity that included six villages and was 101 km² in area and located in a low-mountain region. The area had approximately 4000 inhabitants. The project was led by a committee composed of engineers from the NGO and local mayors. The goal of this committee was to select a site to

develop a collective solar operation that would go beyond the production of shared profits. In particular, the committee considered that the photovoltaic project might be an opportunity to address landscape and architecture issues. The committee charged a local architect to organize participatory landscape workshops to collectively explore what a good solar roof for the project might be. During the summer of 2011, the architect led the participants to consider roofs not only in terms of what their solar energy production might be (orientation, slope, architecture, and short- and long-distance shadows) but also in terms of landscape and architectural integration. For example, most local roofs were covered with grey-blue slate, and some in poor condition (rusting iron sheets) might have been visually improved with the installation of solar panels. However, this participatory approach failed to provide enough information to select roofs and guide the siting process. In October 2011, the local committee suggested using a previous study – delivered by an engineering office in the context of a previous programme on solar energy – to select a site. The report counted all the roofs in the area and produced a table listing their surfaces, technical information, estimated solar energy capacities for production and estimated photovoltaic profitabilities. The report allowed the committee to select a site that would guarantee the collective project to be profitable but led them to set aside its initial landscape and architectural goals. With this decision, the site selection process became more conflictual than expected. Many inhabitants and elected officials involved in the project did not understand the site choice and decided to quit the process. Following the controversial selection of a site, the siting process was increasingly reduced to considering roofs as economic assets. Roof owners were contacted by a group of inhabitants and local elected officials to determine if they were willing to rent their roofs to the future energy cooperative. Once the owners agreed, technical studies were ordered to detail the costs of the necessary work (e.g., for the adaptation of the structure and renovation) and to precisely estimate the profitability of each roof. Furthermore, the electric grid operator provided a report on the technical feasibility and costs of connecting the considered roofs. In half the village, the electric grid needed to be reinforced to be able to absorb the electricity produced by the collective project. In light of the costs associated with such reinforcement, the expected profitability of roofs in half the village was drastically reduced. In a context where roofs were reduced to their economic attributes and the cooperative project was limited to the construction of collective economic profitability, the owners of the most profitable roofs did not understand why they had to pay for the collective costs and lose some of their expected profits. In addition, the report from the electric grid operator shed light on one management issue regarding the electric grid, which increased local tensions around the collective project. When individual projects were connected to the grid, investors only had to cover reasonable connection costs as long as the grid had enough capacity to absorb the electricity produced. However, the first person whose project required the reinforcement of the grid had to cover the entire reinforcement cost alone. Such a regulation induced a first-come, first-serve conflictual logic that would drastically limit the development of photovoltaics once the local electric grid was saturated. At this point, the project leaders failed to control the effects of this logic in the context of grid management. As a result, in October 2012, the owners of the most profitable roofs informed the project leaders that they were leaving the collective and running individual operations on their own roofs.

This project was initially launched as a participatory experimental process focused on an alternative way of developing photovoltaic operations. Framed as more than just a collective economic investment, the project represented an opportunity to shape a local pathway for

the sustainable development of solar energy. The resource making process was initially open to the participation of all local actors (inhabitants, municipalities, NGOs, and companies) and was seen as an opportunity for progress on several local issues (e.g., the landscape and architecture). However, the resource's associated milieu was progressively weakened when the project faced several hardships (lack of participation and an unfavourable policy context). The project was reorganized according to only the corresponding economic factors. This turnaround induced local tensions, and the project lost many supporters. Finally, several individual private projects initiated by this publicly funded program were achieved, but they drastically limited the potential to develop more local projects with regard to the capacity of the local electric grid. Due to the ways the leaders reorganized the project when facing hardships, the resource was finally endowed with an individual and controversial mode of existence (see Table 3) – the opposite of what the project was initially trying to achieve.

Table 3: Summary of the first phase of case n°2

| Source | Associated milieu | Mode of existence of the resource |
|------------------------|---|--|
| Pre-individual reality | <ul style="list-style-type: none"> - Cooperative roof photovoltaic project with important initial local participation - Project initially addressed landscape and architectural aspects of photovoltaic development - The electric grid management logic made individual projects easier and more profitable | <ul style="list-style-type: none"> - Resource framed as a private and individual capitalistic investment - Its mode of existence generated local conflicts |

However, these decisions by some roof owners did not mark the end of the collective project. The already-funded technical and financial studies were still relevant, and the cooperative project only needed a few roofs to succeed. The committee decided to call for additional project leaders among the local activist networks. The committee also insisted on the importance of selecting a majority of public roofs to reduce the risks of owners withdrawing from the group for economic reasons. This decision was enabled by the removal of the feed-in-tariff distinction between public and private roofs by the French government in January 2013, which finally endowed public roofs with the same profitability. In this way, the committee tried to strengthen the associated milieu of the project. With the contributions of some former members and the newcomers, the new roof selection process successfully obtained a mix of roofs with high profitabilities and others that presented architectural renovation opportunities distributed in two different villages. This choice allowed the project to collectively address the constraints of the electric grid without creating new tensions. A local cooperative was created that brought together inhabitants, local companies and municipalities. The cooperative funded a group of seven roofs in two neighbouring municipalities that produced cumulative power of 57 kWp during the Fall of 2014 and connected them to the grid. Based on what has been locally perceived as an initial success, the cooperative has since developed two new projects based on the same model by investing the initial profits and using the investments of new members: an operation involving three public roofs of 26 kWp connected to the grid during the summer of 2017 and an operation involving seven roofs of 120 kWp to be connected in 2019.

In the second phase of the project, the resource was finally framed as a vector of cooperative land planning, and its mode of existence generated a local consensus and appeared to be more sustainable (see Table 4). This local consensus even led to the development of several additional collective projects.

Table 4: Summary of the second phase of case n°2

| Source | Associated milieu | Mode of existence of the resource |
|------------------------|--|--|
| Pre-individual reality | <ul style="list-style-type: none"> - Cooperative roof photovoltaic project with important initial local participation - Majority of public roofs selected to reduce the risk of roof owners withdrawing for economic reasons <ul style="list-style-type: none"> - Architectural and landscape aspects readdressed - The selected roofs are spatially dispersed to reduce tensions about the electric grid | <ul style="list-style-type: none"> - Resource framed as a vector of cooperative land planning - Its mode of existence generated a local consensus. |

4 Conclusion and discussion

What does it mean for renewable energies to be sustainable? When, where and how is the sustainability of a local renewable energy production project at stake? Beyond the quantitative goals, how can renewable energy public policies induce more sustainable development? Starting with these three questions, this paper explored the rather complex link between renewability and sustainability of energy resources. The first section highlighted that the sustainability of renewable energies is discussed within four distinct research currents respectively focused on: sustainable transitions and sociotechnical innovations, the local and community scale, political processes and institutional contexts, resource geographies and the importance of materiality. We underlined that these four literature bodies tackle the sustainability of renewable energies as a contextual and political issue and point towards several problematic dimensions to address the matter of context: the spatial, the material and the technical. With a focus on resource construction processes, the second section of this paper built on relational thinking [71] to develop a theoretical framework to question the matter of context in the light of these three dimensions taken together. Within this theoretical framework, we suggested to address sustainability as a political quality of renewable energy resources which may – or may not – emerge at the scale of local energy projects. This suggestion was tested through the analysis of two case studies of local solar energy projects in the French energy policy context of the late 2000s and early 2010s. The final section of this paper underlines three distinct contributions which provide a first set of answers to our initial questions and point to some further research directions.

The first point of discussion raised by this paper relates to *the importance of context in the definition and construction of sustainability*. Following precursory works that called for the deconstruction of the essentialization of resources [46], [49], [50], our case studies indicate that solar energy resource sustainability does not come from a source, such as solar rays that would be hypothetically endowed with a political virtue, technology, or the best intentions of local energy project managers. Energy resource sustainability depends on multiple negotiations between human and non-human actors who progressively participate in a local project and tend to modify its nature. Sustainability is not an essential quality of a resource; it

is a quality distributed among human and non-human actors [58], [59] organized around an energy source to turn it into a resource [32]. This relational approach expands research perspectives to consider sustainability as a political quality of a milieu. Thus, the political process of preferred development pathways of collective discovery [11] should be carefully treated as a process of milieu management based on collectives composed of human and non-human actors.

This paper also provides a theoretical contribution to *reflect further on issues of power within the energy transition* by considering the relational becoming of resources in terms of their modes of existence [71]. We suggested that the many forms of assemblages that human and non-human actors might take during the development of local energy projects can lead to distinct modes of existence for resources. These modes of existence depend on how project leaders consider constantly evolving contextual issues. As a result, the different ways in which renewable energy sources are turned into resources [57] do not shape the same energy transition trajectories: some are more concerned with overall economic perspectives (case n°1), and others are concerned with local participation and outcome redistribution (case n°2). This observation provides a new understanding of what sustainability is. Since the relational becoming of resources is an open process, new actors and new problems might arise; thus, sustainability is associated with an always-open result that is constantly under negotiation. The analysis of the abovementioned case studies illustrates that sustainability is less a result than a process. The most desirable sustainability emerges when compatibilities among the materialities and agencies are negotiated and the interests of actors are convergent. In light of the many negotiations and adaptations to contextual issues (local controversies and policy evolution) the project collectives must constantly bypass, sustainability cannot be captured as a relational quality emerging from linear processes. This emergence is at stake during the course of circular planning processes marked by constant back-and-forth negotiations and by the capacity of local actors to hold together what constitutes their milieus. These findings suggest the need to perform long-term case studies to capture how local planning practices evolve for unsustainable renewable energy projects to become sustainable, as well as how such practices might evolve in the opposite direction. Further contributions should explore how this relational way of addressing issues of power within renewable energy resource construction processes may contribute to the spatial justice and energy justice literature.

The third and final point of discussion is related to *the problem of sustainability within renewable energy policies*. Because sustainability does not have a clear definition and is rather a collective process of the invention of desirable futures [11], determining if some renewable energy policies are more sustainable than others is not easy. In the light of our case studies, some conclusions might be drawn from the French photovoltaic policies. In the wake of a liberal European agenda, the French development of renewable energies has mostly been framed by quantitative goals and the techno-economic devices used to reach these goals. As shown in the case studies in this paper, French photovoltaic policy between 2009 and 2017 appeared to have framed the economic dimension of the development of the sector but to have ignored most of the questions regarding the local forms of this development. This top-down approach enabled the development of the sector but did not guaranteed its sustainability. Following the arguments raised in this paper, we suggest that a more sustainable renewable energy policy is one that gives more space for action and for the bottom-up initiatives to develop local sustainability transition pathways. The sustainability of renewable energies rests on the development of participative and consensual land planning

practices at the local scale and must be open to the specificities of individual territories. Sustainability is not only relational, it is relative; what is considered a sustainable practice in one place may not be considered sustainable in another. Thus, our analysis should be extended to other institutional contexts, other countries and other energy technologies. Context matters in the construction of a global sustainable energy transition and more attention must be paid to the not-so-simple link between renewability and sustainability at the microscale of specific projects.

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