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Les matérialités de la transition énergétique en montagne : pour une approche critique

(Dis)Connected. Energy Materialities of Isolated Sites in Mountain Areas

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(Dis)Connected. Energy Materialities of Isolated Sites in Mountain Areas

Marie Forget et Kilian Ayroles

Introduction

- 1 Although the term “energy transition” is widely considered to refer to a homogenous and unidirectional progression towards an uncertain future, numerous scholars have shown that it encompasses a wide variety of institutional, economic, social and geographical processes (Bridge *et al.*, 2013, Anderson & Wylie, 2009, Calvert, 2016). Indeed, the energy transition does not just involve replacing fossil and fissile sources of energy by so-called renewable energies; it also requires changes to technical systems, social organisation and practices, representations of the world and cultural models (Akrich *et al.*, 2006). These changes will necessarily lead to changes in energy materialities (Bakker & Bridge, 2008; Balmaceda *et al.*, 2019; Cederlöf, 2021; Bridge & Gailing, 2020) on both the global and territorial scales. Consequently, the energy transition is an opportunity to rethink the current sociotechnical system (Deshaies, 2014)
- 2 Because mountain territories are particularly sensitive to climate change, have access to only a limited range of energy resources and are often difficult to access, they have a special place in this transition. The development of hydropower (Varaschin *et al.*, 2012; Dalmaso, 2008), which led to the construction of national electricity grids (Varaschin *et al.*, 2009), placed mountain areas at the forefront of the deployment of electricity services. In more recent decades, whether or not mountain territories have played a central role in supplying energy has depended on the role(s) they are given within their country (peripheral or central, nature reserve, tourist attraction, supplier of raw materials) (Forget, 2015; Svampa, 2012).

- 3 Because people who live in mountain areas can see the impacts of climate change on their environment, they tend to be open to the idea of testing new energy systems. These areas are also often sparsely populated and house considerable reserves of renewable energies (e.g., hydropower). Thus, they serve the energy transition both by encouraging new energy initiatives and as sources of renewable energies. As a result, the energy transition is bringing mountain areas back into the centre of the energy stage. However, mountain areas are much more than repositories of natural resources (biomass, water, solar power, etc.) (Perlik, 2015), they also evoke very strong representations among the general public (e.g., Girault & Laslaz, 2018; Debarbieux & Rudaz, 2010), who want to preserve these landscapes and the “traditional” craft industries and forms of agriculture they associate with them.
- 4 In terms of energy, a site, whether a single house, group of houses, craft workshop, factory or service producer, is said to be isolated if it is not connected to the public electricity grid. Isolation not only describes a type of electricity distribution service (off-grid), it is also the name EDF has given to a specific off-grid service. The word “isolated” derives from the French word “isolé” and, ultimately, the Latin word “insula,” meaning island. Like islands, many mountain areas are cut-off from their surrounding areas and experience a lesser or greater degree of isolation that can affect many aspects of life, not just energy¹ (Gumuchian *et al.*, 1980). This makes isolated sites in the mountains (mountain huts, alpine chalets, etc.) excellent places to study the off-grid power supply solutions available to remote sites (Girault & Laslaz, 2018). The present paper explores the electricity supply solutions adopted or envisaged by “isolated sites” in the French Alps.
- 5 Due to geographical factors,² electricity grids in mountain areas tend to be less dense than those in other types of rural areas, and the poor return on the large investments needed to extend electricity grids, combined with the sometimes-seasonal nature of energy consumption, result in some consumers remaining unconnected. This energy isolation is often unwelcome, in which case, off-grid power supply systems (renewable or otherwise) can be used to obtain a similar level of energy comfort to that enjoyed in lowland areas. In contrast, for family, leisure, cultural, philosophical, ethical or spiritual reasons, some people choose to remain off grid and embrace “energy sobriety” as a way of developing a different type of relationship with the mountain environment. This choice, which involves living a more rustic lifestyle, is often a reaction to the “world down below.” Other people see being off-grid as an opportunity to embrace the energy transition and reduce their impact on the environment by converting to renewable sources of energy, becoming energy autonomous and reducing their energy consumption in-line with their production capacity. The distance of isolated sites from the electricity grid facilitates voluntary energy isolation and encourages experiments with energy models that are designed to have less impact on the environment and to be more in accord with the rhythms of nature (Walker, 2019).
- 6 Isolated sites in the mountains are generally occupied for only part of the year (“polytopic lifestyle,” see Stock, 2006), with the period depending on whether occupation is for tourism/leisure purposes (e.g., second homes, mountain huts) or for agricultural purposes (e.g., mountain farms, shepherds’ huts). Hence, energy isolation, whether unwelcome or chosen, is usually intermittent and involves short to moderately long periods of “uprooting ... from one’s usual living environment and social sphere, that of day-to-day life down below, in the valley” (Girault & Laslaz, 2018).

- 7 The present paper explores the ways isolated sites in the French Alps access energy and the factors influencing the choices made for sites on different scales, ranging from individual buildings to mountain hamlets to entire valleys (Fig. 1). Although Nicoud *et al.* (2008) examined access to energy in high mountain areas, few studies have looked at isolated sites in the alpine and subalpine stages. Our study focused on sites which fulfil both residential and tourism functions and whose stakeholders have very different views on how the site's energy needs should be met. Off-grid mountain chalets used as second homes or as agricultural buildings are affected by other dynamics and will be examined in a separate paper.

Fig. 1. Overview of access to energy in the isolated mountain sites studied

- 8 We begin by analysing the solutions, both home-built and official, many people/communities adopt in order to overcome energy isolation and live “as in the valleys.” We then look at sites that have embraced energy isolation as a way of demonstrating new energy trajectories. These analyses are based on fieldwork carried out over several years, but mostly during the summer of 2019, as part of the VEDETTE³ and TESLA⁴ projects. This fieldwork included 48 semi-structured interviews with elected officials, institutional stakeholders⁵ and local residents, to which we added data from additional interviews conducted in 2019 and 2020. We used transcription, text analysis and cartography to analyse the resulting corpus.

Off-Grid or On-Grid?

- 9 The electricity generating techniques developed during the 19th and 20th centuries⁶ favoured highly centralised energy production combined with distribution grids connecting production sites with consumers. These sociotechnical systems (Akrich *et al.*, 2006) shaped the way society is organised (Rumpala, 2019). Depending on how they are deployed, renewable energies can either increase this “grid dependence” (Aykut &

Evrard, 2017) or decentralise energy production and thereby reduce the weight of the current sociotechnical system. Decentralised technologies allow new resources to be deployed and pave the way for new spatial relationships between the system's components. The electrification of France's mountain territories is considered to be complete, even though some residential buildings and seasonal agricultural and tourist facilities are not connected to the national grid.

Off-Grid Electricity Production: Fossil Fuel and Home-Built Systems

- 10 There are two main ways in which isolated sites can obtain their electricity:
 1. Via France's electricity distributor, Enedis, which offers off-grid power solutions to isolated sites that cannot be connected to the National Grid for reasons of cost. These solutions are dimensioned according to needs and financed by France's Rural Electrification Fund (*Fonds d'Amortissement des Charges d'Électrification*). Enedis signs a specific contract with each site, under which it takes responsibility for operating and maintaining the production system and supplying electricity to consumers. However, it can be difficult for Enedis to meet these obligations in isolated mountain sites with no road access in winter.
 2. Via autonomous systems, which may be official or home-built, and which often combine fossil fuels with renewable energies. Property owners receive no assistance in covering the cost of these systems, for which they must obtain authorisation.
- 11 In reality, isolated sites generally combine the two approaches, because sites that are officially recognised as "isolated" have the right to an energy supply, subsidies and technical advice on sizing infrastructure. Many residents maintain and repair systems themselves, so they do not have to call upon the official electricity supplier. Most tourist accommodations and some private homes use diesel generators to produce electricity, as they are inexpensive to buy, compact and usable anywhere and in all weathers. This flexibility (Bustos-Gallardo *et al.*, 2021) is counterbalanced by the system's disadvantages (noise, smell), logistic complexity (helicopter to deliver fuel) and running costs. For example, before the Ricou mountain hut installed a 6 kW pico-hydropower plant, it used: "4,000 litres of fuel oil a year, twenty-eight 35 kg gas bottles and 25 cords of wood" (warden of the Ricou mountain hut).
- 12 Most isolated sites obtain energy from several systems, often home-built and installed with or without official authorisation (photos 1A and 1B). Hydroelectric turbines and photovoltaic solar panels are the most common sources of energy. Unauthorised water catchments can be problematic when they are installed in protected areas or if they supply energy to several buildings—although each catchment may not have much impact on its own, multiple catchments can have a substantial cumulative effect. In the Vallée Etroite,⁸ for example, numerous home-built water catchments have been installed to supply the two mountain huts and thirty private chalets with fresh water and to drive private turbines⁹ (photo 1A).

Photo 1A. Homemade water catchments in the Vallée Etroite, to the east of the hamlet of Les Granges (Hautes-Alpes); 1B. Homemade water catchment above the hamlet of Dormillouse (Ecrins National Park).

Source: K. Ayroles, 2019

- 13 Projects to provide collective access to energy are an opportunity for the government to eliminate fossil-fuel systems and to regulate and authorise home-built systems, which are non-controlled materialities. Nevertheless, these actions are taken for a variety of reasons, and the interviews we conducted show that they are more likely to be driven by the desire to reduce the energy insecurity of people who work in isolated sites and/or to save time on maintenance and logistics, rather than by environmental factors. Hydropower is considered the most reliable and mechanically simplest source of power, and it is cheaper and logistically easier than other systems. On the other hand, the application process for installing such renewable-energy systems is complex, expensive and very long. Indeed, the need to take into account legal, environmental and landscape constraints and to meet cultural expectations can sometimes be off-putting, as the warden of the Ricou Mountain found when he decided to convert to hydropower for environmental reasons.
- 14 Society's perceptions and representations of mountain territories, particularly isolated sites, has resulted in them becoming flagships for the energy transition (Debarbieux, 2010). Nevertheless, mountain sites have followed a variety of transition models covering a wide spectrum of objectives, ranging from attracting more tourists by offering a similar level of comfort to that found in the valleys to acting as models for reduced consumption and consensual energy sobriety.

Live As People Do in The Valleys?

- 15 Isolated sites are being reappropriated by ever-larger numbers of people, partly as a result of efforts to diversify tourist activities in the mountains and to meet visitors' growing demands for "naturalness" (Bourdeau *et al.*, 2011, Hagimont, 2017). At the same time, mountain huts are having to modernise their energy services in order to comply with stricter hygiene, safety⁷ and comfort⁸ standards. That hydropower is still the most widely used renewable energy, ahead of photovoltaic and thermal solar power, is a clear demonstration of "place dependence" and the energy materiality function of local natural resources (Chabrol, 2016).
- 16 Thanks to technological advances, renewable energies are now a viable alternative to a grid connection and make it easier for people to reside in isolated sites. Consequently, mountain hamlets that had been partly abandoned are once again occupied for part of

the year, if not all year round. This is the case for the fifteen chalets in the three hamlets that make up the village of Dormillouse, in the Freissinières Valley (photo 2), which are used as private residences and tourist accommodation (holiday rentals and bed & breakfasts) during the summer and winter. Some of Dormillouse's residents have been demanding a connection to the electricity grid for the last 40 years, but their demands have received little support from Freissinières Council. The fact that Dormillouse is in the Ecrins National Park further complicates the establishment of a grid connection because the National Park authority refuses to allow overhead power lines to be installed. What is more, the local council, National Park authority, local farmers and residents do not agree on Dormillouse's energy needs. Residents consider Dormillouse to be a "village" (retired resident) that has had to make do with a homemade distribution network built between the wars. The hamlets' private homes generally rely on diesel generators, solar panels and batteries (photo 3), whereas the Ecole mountain hut, which is part of a government off-grid energy pilot scheme, obtains electricity from a hydropower system fed by home-built water catchments. In contrast, most of the village's farm buildings do not need a permanent electricity supply.

Photo 2: The three hamlets that make up the village of Dormillouse: Les Enflous, Les Esclayers and Les Romans

Photo 3. Diesel generator, solar panel and batteries for storing solar energy (Dormillouse, Ecrins National Park).

Source: K. Ayroles, July 2019.

- 17 Dormillouse's residents currently disagree on what type of energy project to pursue. People who have inherited chalets from parents who lived in the village want Dormillouse to be connected to the grid, which would require building a new road and extending power lines: "When work was done on the drinking water supply, they offered to resurface the road. We could have buried the cables" (Eric, shepherd at Dormillouse). Other residents do not see the need for mains electricity ("If we can't get here, why have electricity?", retired resident) or are resigned to not having it ("We've been asking for electricity for 40 years," resident and former warden of the Ecole mountain hut). New arrivals often relaunch the idea of an autonomous energy system for the village: "The association was the local people's idea, but the problem is that we are having to do what the government should be doing" (temporary resident). New arrivals who run holiday rentals or bed & breakfasts are piloting a collective energy project centred round the Ecole mountain hut: "With the grid connection, they want to bring nuclear electricity here, when we have mountain streams" (warden of the Ecole mountain hut). One of the objectives of the government's pilot scheme for the hut is to regulate and authorise the unofficial water catchments. Other residents have sophisticated personal power systems and do not need a grid connection or a collective autonomous power system: "the CSM [a home automation system] tells us if there is an electrical or heating problem [in the gîte]. Here, we have everything they have in the valley" (owner of the L'Écrin de Violette holiday cottage). More occasional residents accept greater energy insecurity when they are in the village. The final section of the population, heir to the hippy community that lived here in the 1970s, is relatively open-minded, but wants the village to remain as it is. For example, they oppose street lighting: "When this project was first launched, with solar panels, the Park said: 'no light at night'; here there is no light pollution" (former resident).
- 18 Thus, attempts to set up a collective off-grid power system are undermined by differing conceptions of what would be an appropriate energy service, a lack of support from the local council and National Park authority, and the reluctance of some chalet owners to pay for the work needed to bring their electrical installations up to modern standards. Hence, regulations (authorisation applications and work to bring electrical, sanitary and safety equipment up to standard), the cost of new installations, and the effectiveness of individual systems (diesel generators, solar systems, home-built hydropower) are barriers to installing an autonomous collective energy system.

Energy Isolation: An Opportunity for Transition

- 19 Some administrators of isolated sites see the constraints associated with a remote location as an opportunity to turn the site into a model of energy autonomy and/or energy sobriety and, in some cases, to test technical innovations and modifications to legal and institutional processes. Changes to legislation in response to citizens' demands, technological advances, the gradual acceptance of energy sobriety (as part of the move toward sustainable tourism, driven by people's representations of the mountains) and, implicitly, development projects within protected areas, which oppose extensions to the grid, are combining to unlock the current sociotechnical system.

Cutting the Cable

- 20 Mountain huts are excellent places to test both the possibilities provided by renewable energies and methods of achieving energy sobriety (Roussillon, 2014). However, different huts have different types of clientele with different notions of what constitutes an "acceptable" level of energy service. Moreover, recent years have seen a tendency for huts to move upmarket. By expanding their use of renewable energies, huts can provide a similar level of energy comfort to that available in the valleys and thereby attract a wider clientele. This offer-driven approach involves oversizing energy production systems, rather than trying to reduce demand.
- 21 The Plan du Lac mountain hut (municipality of Val Cenis), in the Vanoise National Park, has followed this model. The hut was connected to the grid in the 1960s, via the 20 kV electricity cable that was installed to power the computer systems needed for the newly built Entre Deux Eaux water catchment (photos 4A and 4D), which feeds the Plan d'Amont and Plan d'Aval reservoirs, near Aussois (Jail, 1973). The road to the catchment, built at the same time, goes past the hut.

Photo 4A. Electric pylons connecting the water catchment to the Plan du Lac hut; 4B. The Plan du Lac hut, showing its roof-mounted thermal and photovoltaic solar panels; 4C. The Entre Deux Eaux water catchment; 4D. Cable cut prior to being removed.

Source: K. Ayroles, July 2019

- 22 However, the Vanoise National Park, which owns the hut, in conjunction with EDF and Enedis, decided to take the hut off-grid but without reducing the facilities the hut provides. The National Park's main aim was to remove the power lines, which it considered a "blot" on the landscape, and thereby improve the hut's image, while Enedis wanted to reduce maintenance and operating costs. EDF supported the project by installing an autonomous energy system to power the water catchment's computers. Funding from the French government, Rhone-Alpes regional council, Savoie *departmental* council and the water board enabled the Park to install solar panels (to power the hut's lights and electrical appliances and to heat water),⁹ a battery array capable of storing enough electricity to supply the hut for several days, and a wood-pellet furnace to provide extra hot water and heat part of the building. Bottled gas for cooking and a diesel generator complete the system. By using higher-performance materials, the hut, which was disconnected from the grid in July 2019, expects to reduce its energy consumption from 122 kWh/j to 28 kWh/j, while providing the same level of comfort.

In Sync With the Mountains

- 23 Numerous technical solutions are now available to make buildings energy autonomous, but recourse to these technologies is not always accompanied by reflection on the need for energy sobriety. Nevertheless, some huts try to increase awareness of environmental issues and to use their reduced and sometimes intermittent access to energy to encourage people to modify their behaviours and adapt their daily routines (Walker, 2019). For example, the warden of the Viso mountain hut told us: "We put in a

bike to recharge mobile phones, because there was a demand. But it is mostly an awareness-raising tool.” The Viso (Queyras) and Ricou (Clarée) huts, among others, voluntarily embrace energy sobriety: “The idea isn’t to have more energy in order to consume more and install more facilities” (warden of the Viso mountain hut). The Hautes-Alpes association of mountain huts, with support from its wardens, is lobbying for the administrative procedures governing the installation of renewable energy systems to be simplified, as the process currently takes at least two years and is too expensive for huts to meet on their own: “We want to be autonomous, without having to rely on an external supplier. They want to bill us as if we received the same service as in the valleys. Here, we have to do the maintenance ourselves” (warden of the Ricou mountain hut). Regulatory and environmental constraints are the same throughout France, but are tighter for sites in protected areas.¹⁰ For example, before installing its 6 kW pico-hydropower plant, the Ricou hut had to provide a biodiversity survey, an estimate of the waterflows within the catchment and a floral survey, go through a public enquiry and obtain approval from the Sites Commission.

- 24 In addition, huts wishing to develop a more “responsible” form of tourism by embracing energy sobriety and its associated constraints face restrictions on how far they can reduce their energy consumption due to the energy consumed by mandatory hygiene and safety equipment. The French government and hut wardens are currently discussing ways of relaxing authorisation procedures (notably under its Ecological and Solidarity Transition Contract), and a network of six energy-transition pilot huts¹¹ has been set up in the Hautes-Alpes *department* to provide feedback on the installation of solar water heaters and hydropower systems.

Pilot Systems

- 25 Stakeholders such as the Vanoise National Park are using the energy transition as an opportunity to convert their 13 isolated mountain huts to renewable energies and thereby eliminate diesel generators and their associated noise and air pollution. The Plan du Lac mountain hut is one example of this process, as is the Col du Palet hut, at Peisey-Nancroix, which has been using an experimental hydrogen fuel cell since 2015. The hut is doing everything possible to rationalise energy use and to optimise the production and storage of solar energy when the hut is closed so it can be used during the high season. The hut’s solar panels meet its day-to-day needs when the hut is open and supply the electrolyser when the hut is not staffed, notably during the winter.
- 26 Isolated mountain sites can be used to test new energy storage and restitution systems and to explore their materialities. One drawback of the Col du Palet’s fuel cells is that, due to the absence of telephone coverage, remotely monitoring the intelligent connections between the fuel cells’ components requires a satellite link. Moreover, because the hydrogen tanks contain very high pressure gas, they have to be placed in a separate building, far from the hut itself. The experience gained at the Col du Palet hut has led to similar systems being installed in an isolated hamlet in the Cirque de Mafate, on Réunion Island (Zélem, 2015), in an autonomous building in Nantes and in high schools in the Franche-Comté region of France.
- 27 Hydrogen fuel cells were also envisaged as a way of supplying electricity to the Vallée Etroite (municipality of Névache, Hautes-Alpes *department*), on the Franco-Italian border. In the end, the idea was abandoned because installing fuel cells would have cost

at least as much as connecting the valley to France's electricity grid.¹² In February 2021, the region's prefect described the Vallée Etroite, which Italy had ceded to France in 1947, following World War II, as "the last non-electrified valley in France."¹³ In reality, the valley houses just one true hamlet, comprising two mountain huts and around thirty private chalets, although it attracts large numbers of tourists in summer and winter. For the last ten years, the hamlet's residents and businesses have been demanding the valley be electrified, but any system would have to overcome major constraints, most notably the lack of road access in winter, when the Col de l'Échelle is closed. Residents currently obtain electricity from home-built systems, including four hydropower turbines, a few solar panels and individual diesel generators. A possible solution to this energy precarity was launched in 2015 but, after several years of negotiations, it appears to have been abandoned. The proposed system involved building a hydropower plant, operated by Enedis, to supply a micro grid connecting all the hamlet's chalets. Micro grids are not new, but none have yet been built in France's mountain areas because French legislation restricts this type of infrastructure to island territories and stipulates that they must be operated by EDF. The main challenges for Enedis would have been in maintaining the system and in fulfilling its undertaking to provide an equivalent service to that provided by the National Grid. In fact, the project included a 3 kVA limit per house, a limit that does not exist elsewhere in France. In addition, several administrative issues would have had to be addressed, notably whether consumers should continue to have the right to choose their energy supplier, whether operating costs could be shared via a national equalisation mechanism and whether consumers could be prevented from demanding a more powerful electricity supply in the near future.

- 28 In February 2021, the region's prefect announced that the valley will be connected to Italy's electricity grid. This will involve installing a 4.6-km-long, 15,000-volt underground cable linking three low-voltage substations in the valley to a hydropower dam a few kilometres downstream, operated by the Italian company ENEL. The lower cost of connecting the valley to the Italian grid, rather than to the French grid, will make autonomous energy projects economically unviable.

Conclusion

- 29 Isolated mountain sites are excellent places to test autonomous energy systems on a variety of scales, from single buildings to entire hamlets or valleys. They also offer opportunities to explore electricity supply models based on local energy resources and energy use in sync with available energy inputs. At the same time, the limited production capacities of autonomous systems oblige both permanent and temporary residents to accept at least a degree of energy sobriety and to test solutions relating to this dimension of the energy transition. The energy materialities of isolated sites in the French Alps can be grouped into four general categories: (1) **home-built systems** (whether or not based on renewable energies), in which case connection to the national grid is not envisaged; (2) authorised and normed off-grid systems operated by Enedis, which the company offers for individual buildings but not for entire hamlets or villages; (3) **mountain hut pilot schemes** aimed at simplifying legal frameworks and bringing private pico-hydropower plants in line with technical and administrative legislation; and (4) **extensions to the national grid**. Many isolated sites include

systems belonging to different categories, as is the case at Dormillouse, where home-built systems occur alongside a project to build a microgrid covering the three hamlets, a mountain hut pilot scheme and a project to connect the village to the grid.

- 30 Some projects have been successful, others less so. The stakeholders behind a project play a key role in whether or not it succeeds. For example, the Vanoise National Park's projects for the Plan du Lac and Col du Palet mountain huts have been implemented successfully and serve as models. Conversely, the various autonomous energy projects drawn up for the Vallée Etroite have failed to materialise and the valley may now be connected to the grid. In the case of Dormillouse, despite the formation of a residents' association, residents and institutional stakeholders are unable to agree on the village's energy needs and how they should be met, with different groups supporting different visions and different solutions.
- 31 Hence, there is room for projects centred round energy sobriety, energy efficiency and renewable energies, on different scales and according to different consumption modes. In this respect, mountain huts are particularly interesting laboratories, as they raise questions about both consumption and autonomous production practices. Each of the empirical examples presented in this paper has, in its own way, the potential to bring about changes to regulatory frameworks through cumulative innovations in the law, institutional governance and citizens' groups. These evolution allows us to rethink the technical organisation of electricity grids and the relationships between stakeholders. They also enable isolated sites to turn constraints into advantages and to move towards energy exemplarity. Nevertheless, isolated mountain sites are finite laboratories because the exportability of the sociotechnical models they test is limited.
- 32 Energy materialities currently tend to be considered in terms of the production and storage systems needed for single buildings (solar panels, hydropower, batteries). For sites as a whole, energy autonomy requires installing new cables to create a microgrid and laying pipes to collect and transport water to hydropower turbines. This infrastructure can impact the surrounding landscape and environment. The central challenge is to design projects on a much larger scale, which makes them much more complex technically (grid and grid balancing), legally, institutionally and socially.
- 33 But isolated sites can be understood only in relation to their wider area, notably through the emergence of new energy territories as a result of the synergy between distribution authorities (e.g., Syme05), local authorities (municipal, *départemental*, regional), public operators, renewable energy installers (especially solar) and energy forums (e.g., OCOVA). Moreover, although each site covers only a small area, the production of renewable energy generating and storage equipment¹⁴ is a globalised industry that raises other issues, notably with respect to the extraction of the huge quantities of raw materials (silicon, copper, lithium etc.) these technologies require (Bos & Forget, in press, 2021). Thus, the energy fronts centred round clean, autonomous solutions that are emerging in the Alpine arc's mountain territories (Carrizo & Forget, 2017; Forget *et al.*, in press, 2021) are fed by other energy and mining fronts whose purpose is to satisfy the growing demand for raw materials to manufacture energy production and storage systems. The result is a two-pronged movement of resource exploitation involving both local energy sources (pico-hydroelectricity, thermal solar, photovoltaic solar) and distant raw material deposits (Guibert & Sabourin, 2019). Indeed, although energy resources are social constructs, because renewable energy

production systems require large quantities of raw materials, the energy transition necessarily involves and impacts the territories in which these raw materials are found.

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NOTES

1. E.g., cultural, physiological, communicational, psychological.
2. E.g., population density, slope, altitude, weather conditions.
3. Barriers and Dynamics Within the Energy Transition in Mountain Territories, USMB, 2019.
4. Energy Trajectories in the Alps and Andes: Comparisons of Territories Undergoing Transitions, Labex ITEM 2018-2020. This work was funded by the Labex ITEM (ANR-10-LABX-50-01) within the National Research Agency’s “Future Investments” programme.
5. We conducted semi-structured interviews with municipal and inter-municipal councillors, representatives of protected areas (especially national parks), technical stakeholders, notably distribution authorities and ENEDIS, mountain accommodation managers and inhabitants of off-grid hamlets or valleys. The resulting interview data were combined with field observations.
6. Coal, gas, oil, nuclear and, to a lesser extent, hydroelectricity.
7. For example, food hygiene standards require kitchens in mountain huts to install fridges and freezers, which use a lot of electricity. Huts must also run telecommunication equipment and radios.
8. Most people who use mountain huts demand a certain level of comfort, especially hot showers, hot water and facilities for recharging electronic devices, such as mobile phones and, increasingly, electronic safety and navigation devices (GPS and digital mapping).
9. Their total power is 19 kWp, 6 kWp of which is used to produce hot water
10. Here, we define a protected area as a delineated space with social value within which the public authorities implement protection measures (regulatory or contractual, sometimes by acquiring land) and interdictions (Laslaz *et al.*, 2020).
11. The Chamoissière, Chardonnet, Buffère and Ricou huts are privately owned and run; the Pré de la Chaumette hut belongs to the French mountaineering and climbing federation; the Ecole hut belongs to the local council. Ownership is a key factor, as it is much easier for huts to take

initiatives if they belong to a larger organisation, such as the Vanoise National Park, than if they are privately owned.

12. Enedis estimated that connecting the Vallée Étroite to the national grid would cost approximately 1.2 million euros, excluding feasibility studies and project management.

13. Regional mountain convention, 23 February 2021 (live).

14. Solar panels, batteries, fuel cells, etc.

RÉSUMÉS

Les territoires de montagne ont une place particulière dans la transition énergétique, à la fois pour leur sensibilité au changement climatique et pour les ressources qu'elles renferment. La configuration géographique des territoires isolés leur donne un rôle clé dans le développement de solutions énergétiques déconnectées et une autonomie fondée sur le développement d'énergies renouvelables et de dispositifs de stockage efficaces. Ces sites permettent d'analyser les matérialités de ces solutions, les motivations qui les sous-tendent et de questionner la dépendance aux lieux et au sentier socio-technique fondé sur les réseaux électriques. Cet article interroge les matérialités énergétiques dans les sites isolés de montagne des Alpes. Il questionne les modalités de la (dé)connexion ainsi que leurs motivations par une approche multiscalaire, de l'échelle du bâtiment, à celle des hameaux d'altitude jusqu'à l'intégration de vallées. Cette analyse informe plus largement les matérialités de l'isolement dans la transition énergétique, créant des espaces catalyseurs d'innovations et d'expérimentation d'une transition fondée sur un modèle énergétique, sobre, efficace et décentralisé.

Mountain territories have a special role in the energy transition, because of their sensitivity to climate change and for the natural resources they contain. The geographical configuration of isolated territories gives them a key role in the development of disconnected energy solutions, through autonomous and renewable ones. These sites enable the study of the solutions' materiality and authorises questioning the place dependence and the socio-technical path based on electrical networks. This article aims at exploring the energy materialities in isolated mountain sites in the Alps. It questions the modalities of (de)connection as well as their motivations through a multiscalar approach, from the buildings, to high altitude hamlets, and to the integration of valleys. This analysis informs more broadly the materialities of isolation in the energy transition, creating catalytic spaces for innovation and experimentation of a transition based on a sober, efficient and decentralised energy model.

INDEX

Mots-clés : transition énergétique, site isolé, territoire de montagne, autonomie énergétique, refuge de montagne

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