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RESEARCH ARTICLE

The feasibility and relevance of a community-based energy autonomy: physical, social and institutional factors

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Abstract The issue of a community-based energy autonomy is increasingly present in policy discourses. Such initiatives are supposed to reduce carbon footprint, while lowering dependence on external energy and creating new jobs. However, it is not clear whether such initiatives are efficient or even feasible on a large scale. This article examines the different factors that need to be taken into account, from the physical resources for renewable energy to the social and institutional factors (such as the intensity of social life or political cooperation). This article attempts to fill the gap in the literature on the role of nonmarket factors in regional development and the flourishing literature on renewable energy. By examining the physical distribution of resources in France, we show that there are many different pathways for increasing energy autonomy. Only a limited part of the French territory can achieve true autonomy, and this could be detrimental to industrial development. Thus, there should be a close coordination between national, regional and local levels of the administration. In order to examine the role of social and institutional factors on community-based energy autonomy initiatives, we performed an econometric analysis on the results of a national program aiming at fostering them. The results suggest a significant role for these factors in the emergence of these initiatives, which implies that policy instruments should take them into account.

Keywords Bioeconomy · Energy autonomy · Renewable energy · Regional development

JEL classification A13 · O13 · P48 · Q49

Introduction

The IPCC (Intergovernmental Panel on Climate Change) report in 2014, followed by the COP 21 in 2015, highlighted the emergency of accelerating the energy transition towards less carbon-intensive production systems. This energy transition is generally considered at a global level, e.g. by assessing the path for renewable energy development, and the reduction in energy intensity that would be necessary to achieve a given global temperature objective (e.g. Alazard-Toux et al. 2015). It is also essential that the energy transition be reflected at a local level. The first reason is that the development of new technologies in energy production, and networks allows a decentralized production, especially for renewable energies. Consequently, the evolution of the production system relies heavily on local actors (firms, municipalities or even citizens). The second reason is that there is an important potential for the improvement in efficiency by adapting the local energy market and related infrastructure at a fine-grained level. For example, according to the French Ministry of Energy (CGDD 2015), the total primary consumption in France in 2014 was estimated at 257 million tonnes of oil equivalent (toe), while the final consumption was only 150 Mtoe. Even if more than half of this

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difference (80 Mtoe) is due to the energy conversion inside nuclear power plants (a French specificity), there is still much unused energy that is released as heat in the environment (mostly transmission losses). Knowing that heat represents almost half of the final needs, being produced mostly using fossil fuels, a substantial efficiency gain could be achieved by mobilizing local resources and a more efficient heat recovery.

The past decade has seen a multiplication of initiatives aiming at increasing energy autonomy at a local (community) level. One of the earliest examples is the case of the Austrian city of Güssing. Beginning in the 1990s, it slowly built a local energy system leading to a total energy autonomy, even becoming an exporter of its surplus energy (Müller et al. 2011). This type of initiative began to flourish in the mid-2000s in several countries. One often cited example is the town of Okotoks, Alberta (Cornford 2008). One of its residential districts, the Drake Landing Solar Community, is now almost self-sufficient in heat, using a smart combination of thermic solar energy and underground storage. Some governments started implementing policies to foster and generalize this type of initiative. In Germany, the *Bioenergiedörfer* program was launched in 2010 so as to promote energy autonomy at a community level (Eigner-Thiel et al. 2013). Almost a hundred municipalities are now recognized as Bioenergiedörfer. Networks of communities have organized themselves in some countries. In Europe, the 100%-RES (renewable energy sources) community network brings together ten national networks with the support of the European Union. Its objective is to assist the local communities in their move towards total autonomy through a renewable energy and even the production of an exportable surplus.

How far are these experiments generalizable? Are they just "greenwashing toys" or can they be implemented on a large scale? In line with the "think global, act local" philosophy, community-based energy autonomy initiatives were first considered as ways to reduce carbon emission (Kellett 2007). Yet, these can also help to answer significant economic issues. Energy is an important trade deficit factor for many European countries, and in particular in France where the energy sector deficit roughly equals the total trade deficit. Developing local energy sources can therefore reduce trade deficit, create new jobs and exploit idle resources.

Most community-based energy autonomy initiatives rely heavily on a strong commitment of public actors (Rae and Bradley 2012). Despite a remarkable improvement of cost-efficiency in the past few years, renewable energies generally still need public subsidies to be profitable, except in cases where a resource is particularly abundant, such as very sunny regions for solar power. Renewables may also be a more efficient alternative to fossils for areas poorly connected to main grids such as islands. This is why most developed countries have devised support schemes to foster their development. But more than these national policies, it is a local public action that is often a determining factor, for several reasons. Firstly, the implementation of renewable energy facilities is often linked to issues of land planning (finding available land for implementing spatially dispersed plants, building transportation networks). Secondly, beyond the local production of renewable energy, significant gains are to be expected from more efficient buildings and local transport organization. Thirdly, renewable energies are often prone to acceptability problems. Wind and solar power plants are reputed to spoil the landscape, while anaerobic digestion plants are reputed to bear olfactory nuisance and risk explosion. Wood biomass plants are criticized due to the risk of ruining forests and heavy truck traffic.

The aim of this article is to shed light on the development conditions of community-based (or territorial) methods for increasing energy autonomy. It attempts to fill the gap in the literature on the role of nonmarket factors in regional development and the flourishing literature on a renewable energy. It also discusses the interaction between different geographical levels (national, regional, local), which is a crucial issue for public policies. The paper is organized as follows: in section 2, the main issues related to energy autonomy in the context of a regional development are first reviewed and analysed. We argue that the relevance of energy autonomy at a local level is highly context specific and depends in particular on the available resources, regional comparative advantages and the ability to build a common vision of local development. The role of institutional and sociological factors is also highlighted. This framework is then applied to the French case (section 3). An analysis of the potential of bioenergy at different geographical scales is presented. It shows that different visions of energy autonomy need to be developed in different regions, and that a strong coordination must exist between national and local public authorities. Section 4 presents an empirical investigation of the factors underlying the involvement in a community-based energy autonomy approaches in metropolitan France, by studying a recent program led by the Ministry of Energy and Environment named "TEPCV" ("positive energy territories for green growth"). The econometric analysis suggests that the institutional and sociological factors need to be considered to understand the emergence of these initiatives. Section 5 discusses these results and suggests the implications for public policies.

Local development and energy autonomy: the issues at stake

The term "community-based energy autonomy" may seem suspicious to a mainstream economist. It can easily suggest the utopia of autarkic communities (Born and Purcell 2006), which opposes one of the most basic economic principles: the specialization of regions in their comparative advantages.

However, seeking to increase energy autonomy at a local level could be justified by at least four different reasons:

– The use of idle resources for creating new business and jobs,
– The reduction of the trade deficit in the energy sector,
– The reduction of the carbon emissions,
– The improvement of the social cohesion at a community level.

The first three arguments are commonly heard in discourses about renewable energy, although all of them are questionable, as they generally lack global perspective. The fourth argument, the improvement of social cohesion, may seem less obvious but may be the most interesting aspect, as we shall see below. In particular, community approaches may have a more efficient demonstrative effect to help reduce energy demand and optimize consumption.

Even if the significance of the energy sector in GDP is not very high (2% of the value added in France), energy is crucial to all human activities, with three main forms: heat, electricity and transportation fuel. Until recently, the greatest part of energy production was concentrated in large plants (refineries, nuclear power plants, dams and so on). The development of decentralized systems of energy production implies a very different organization, which bears many implications for land and network planning. Several integrative frameworks have been proposed to model the organization of production and distribution at a regional level. For example, Müller et al. (2011) propose a general conceptual model, whereas Schmidt et al. (2012) attempt to estimate quantitatively the production potential and costs associated with regional energy autarky in the case of a small Austrian region. In the same vein, a new strand of literature is emerging to apply the methods of industrial ecology to territorial development (Barles 2010). The purpose of this research program is to assess the different energy and matter flows inside a given territory and to analyse how to optimize them from a sustainable development perspective. This endeavour is of course particularly complex, as beyond the complexity of the system per se, the very definition (and ranking) of sustainability of different technical options is multicriteria by nature (Eigner-Thiel et al. 2013).

In this paper, instead of focusing on the technical organization of production systems, we adopt a territorial development perspective and focus on human factors (i.e. social and institutional) that determine the effective possibility of implementing technical organizations associated with a community-based energy autonomy. Coupling physical and social factors are essential to assess the actual potential of renewable energies development, and some modelling approaches have already been proposed and applied to the local communities (Trutnevyte et al. 2012; Trutnevyte 2014). As stressed by Scheer (2006), the transition to energy autonomy calls for deep changes in both technical and societal spheres. McCormick et Kåberger (2007) consider that barriers to the development of bioenergy are mostly nontechnical. According to institutional economics, the relevant form of the organization to meet an economic need depends both on the characteristics of the resources and on the human factors such as group structure, social values and legal framework (Ostrom, 2005). The evolution of technologies and vision of development requires a learning process and changes to human organization, not only at a firm level but also for society as a whole, as emphasized by Åkerman et al. (2010), Parkhill et al. (2015) and Dvarioniene et al. (2015).

Following Ostrom's Socio-Ecological Systems (SES) approach, we shall focus on four main types of attributes (Poteete et al. 2010):

– Resource system: system's size, productivity, predictability,
– Control on the resource: mobility, property,
– Local governance system: autonomy of choice at a local level, leadership, decision rules,
– User characteristics: knowledge of the resource, capacity of collective action, importance of the resource to them.

Whereas wind and photovoltaic power are the best-known renewable energies, they have the clear drawback of being intermittent, although a lot of research is currently devoted to the improvement of storage technologies and to the development of smart grids to improve the match between production and demand. In contrast, geothermal energy and biomass are much more predictable. There seems to be a lack of discussion regarding the choice of the type of energy that should be used in energy autonomy initiatives. However, in Europe, most of the literature focuses on biomass, given its nonintermittent nature and the importance of unused wood and agricultural residues (Demirbas et al. 2009).

Beyond the physical potential for renewable energies, one big issue is its geographical dispersion. In many cases, a renewable energy development implies significant quantities of land to be found, be it for wind or solar facilities, or to grow/collect biomass. When the necessary land can be rented from a small number of owners, this makes a big difference to the projects' feasibility. However, generally speaking, this is not the case. Fields, forests and roofs often belong to a large number of owners and are embedded with other land uses, leading to negative externalities, conflicts and transaction costs. While this situation does not make projects unfeasible, it may deter investors when transaction costs can be considered to be too high.

This issue brings us to the role of the governance system. Given the importance of possible land-use conflicts, efficient mediation procedures and a clear political will are necessary for initiatives to materialize. Another essential aspect is that the jurisdiction capable of assisting the projects covers a geographical area that is coherent with the project's size. There is a considerable debate on the optimal size for biomass projects. As Hain et al. (2005) note, much public support has been devoted to large facilities that require huge amounts of land for biomass supply (or imports). Esteban et al. (2015) compare different industrial models and conclude that small units can be profitable provided that an efficient organization prevails. In the same vein, Milder et al. (2008), using a more integrative approach, assess that small units have a better global (economic, social and environmental) performance. This is also the case for Krajnc and Domac (2007), who assessed the global socioeconomic impact of projects in small regions in Slovenia and Croatia. Fuelwood plants are considered to be small when they deliver less than 1 MW, which means an annual supply of less than 4000 t of wood. Knowing that primary production of a forest is in the order of 10 t/ha, such projects can be feasible within the scope of a few municipalities. The situation is very different for big plants (up to more than 50 MW), which implies collecting biomass from long distances.

The choice of technology and plant size is highly dependent on the location and needs of the population. Obviously, the current context of low oil prices hinders the development of renewable energies, although fuelwood is still cheaper than fuel oil. Therefore, organization is a key factor in the production system transition. A smart local organization can tackle the opportunities of meeting local needs and optimizing efficiency by:

- Avoiding energy waste by recuperating as much heat as possible, as well as by-products (ashes, digestate from anaerobic digestion), in a logic of circular economy,
- Organizing public transportation so as to reduce total traffic,
- Devising a mediation (or even compensation) system for the aggrieved parties,
- Inform and train the relevant (present and potential) public on the new local energy system: users, workers and other citizens.

Urban planning and public infrastructures are not sufficient ingredients for success: all the above aspects imply a high level of interaction within communities. Improving a social interaction is an important positive externality, especially when it involves people from different social circles. Above all, new jobs can be created, especially in the biomass sector, whereas wind and solar energies mainly require maintenance. For example in France, the fuelwood sector generates about 60,000 jobs for a production of 10 Mtoe (Ademe 2007), about half of which are jobs linked to biomass collection in forests. Concerning anaerobic digestion; the estimation is one permanent job every 300 kWel (roughly the needs of 300 households) (ATEE Club biogaz 2011).

For all these reasons, the notion of a community-based energy autonomy is appealing for local leaders, as it can renew the production system, create new jobs and build a new sense of community. Obviously, it strongly depends on the characteristics of the resources and the needs of the population and firms in place, as well as the current structure of property and public infrastructures. However, its success should be facilitated by the preexistence of a capacity of cooperation and social interaction. In the following sections, we discuss the relevance and possibility of these initiatives for metropolitan France. In section 3, we first focus on the distribution of the resources and the relevant scale of management. In section 4, we tackle the issue of social and institutional factors as well.

To what extent is energy autonomy possible? The French case

As mentioned in the introduction, primary energy consumption in France amounted to 250 Mtoe in 2014: 43% of nonrenewable electricity, 47% of fossil fuels and less than 10% of renewable energy. Renewable energy mostly consists of fuelwood (39%), hydroelectricity (24%) and first-generation biofuels (12%). Wind, solar and geothermal energy represent a negligible share of the total production. Despite the poor development of these sectors compared to national objectives, a recent study from the French national agency for energy (Ademe 2015) shows that France can reach a total autonomy with renewable electricity by 2050. This achievement mostly rests on photovoltaic (40 Mtoe) and wind power (32 Mtoe plus 23 Mtoe for offshore wind power). Optimistic scenarios for fuelwood range from 15 to 30 Mtoe and from 7 to 15 Mtoe for anaerobic digestion (for biomass, production can combine power, heat and gas/fuel) in 2050.

From global theoretical potential to in-the-field reality

While the objective of energy autonomy at a national level seems technically possible, its materialization strongly depends on political, institutional and social factors. In the case of solar and wind power, the structure of the sector in France clearly depends on fixed prices guaranteed by the government. In the case of biomass, the development of anaerobic digestion is still in its infancy (300 farm biogas plants in France versus 8000 in Germany), whereas the development of fuelwood is still far behind what it could theoretically be. While the first policies were implemented in 1994, only about 20 Mm^3 of wood is used as fuelwood. In parallel, only 55 Mm^3 of the 100 Mm^3 of net annual growth in forests is collected. This apparently paradoxical situation is due to several factors. Firstly, most fuelwood (over 50%) is linked to the timber industry. In the context of a sluggish timber market, coupled with a high trade deficit, the use of forestry waste is not optimal. In some cases, “noble wood”, normally used as timber, is burnt as a fuelwood in order to meet demand. One of the key reasons for this paradoxical situation is the inefficient organization of the forest sector. In particular, many private owners are not willing to exploit their forest for economic purposes. There is also a high dispersion of ownership (Sergent 2014): most French forests (12 out of 16 million hectares) are private, and most owners (2.8 out of 3.8 million) own less than 4 ha. This situation led public authorities to implement regional coordination bureaus in order to provide information and advice on biomass-based energy projects (Tabourdeau 2014).

Besides the insufficient organization of the forest sector, the fuelwood market per se is also insufficiently organized. About 70% of approximately 10 Mtoe produced annually in France supplies individual household equipment (fireplaces, stoves), mainly outside formal markets (direct collection in forests and hedges, informal exchange). While such a situation is not necessarily inefficient, it makes it difficult to have an accurate accounting of forest biomass and thus provide investors with relevant information on the potential resource. Concerning collective plants (about 4.000), using the *Bioénergie international* (http://www.bioenergie-promotion.fr/) database, we see that there is a wide spectrum of plant sizes. Half the plants have a capacity of less than 2 MW, which corresponds to a supply radius of a dozen kilometres (typically the size of a grouping of municipalities). This is also the case for anaerobic digestion plants, where the supply radius rarely exceeds 20 km, due to the poor ratio between energy potential and transport costs (ANCRE 2015).

At the other end of the spectrum, some big plants exceed a capacity of 30 MW, which implies a supply radius larger than 50 km (typically the size of a *département*, the basic administrative division over the municipality, whose average area is about 6000 km^2). Whereas about 60% of all plants are owned or managed by local public authorities (municipalities or groupings of municipalities); these big plants are generally associated with big industrial units and rarely with big cities. The largest of all projects, which gave rise to a passionate local debate, is the Gardanne project in the South of France, currently in its starting phase. The project consists of converting an ancient coal power plant to a wood power plant of 150 MW with a need of 885,000 annual tons of wood. The debate not only focused on the depletion of local forests but also on the competition for sourcing local fuelwood plants, the nuisance due to the traffic (one lorry every 2 min on average) and the massive importation of wood from North America.

Bigger plants are currently being studied for the production of second-generation biofuels, using agricultural and wood residues, which are virtually unused at present. The typical supply of such projects could range between 300,000 and 1,000,000 t of dry biomass. The supply radius would then reach about 200 km, possibly covering up to a dozen départements as in the Gardanne project. The collection area would often not correspond to any administrative unit, although the *region* (the third main level of the local administration in France) is a natural candidate for coordinating such projects. Simon et al. (2010) assess the potential of the development of the biorefineries in metropolitan France, and conclude that under rather optimistic hypotheses, there could be a room for a dozen projects of about 200 million litres of biofuel (i.e. about 600 million tons of dry biomass). Such projects would require the coordinated supply of different types of biomass: farm residues, dedicated crops (such as miscanthus) and forest residues.

Three typical geographical planning ranges emerge from this discussion. Firstly, the intermunicipal scale for wind or solar power and small fuelwood and anaerobic digestion projects. Secondly, the *département* scale for big fuelwood projects or even anaerobic digestion projects when resources are scattered or highly heterogeneous (alternatively, for areas that are rich in biomass supply, smaller scales may be relevant, such as natural parks, see section 3). Thirdly, the regional scale for big fuelwood is CHP (combined heat and power) or biofuel projects.

Naturally, there can be a competition between initiatives at these three levels, as exemplified by the Gardanne project mentioned above. Small projects at an intermunicipal level are generally the easiest to materialize, as they imply less transaction costs due to proximity and a stabilized institutional environment (Amblard et al. 2012). They are also generally linked to well-identified needs (e.g. grouped housing, high schools, swimming pools, factories and so on). However, it would be a mistake to only consider projects at this scale. Firstly, it is clearly too small in urban environments, and so this could exclude a large fraction of activities from renewable energies (Madlener and Vogtli 2008). Secondly, the spatial distribution and accessibility of resources often do not coincide with intermunicipal boundaries (Gan and Smith 2011). Thirdly, intervention at a higher level may be necessary to overcome institutional and technological barriers (McCormick et Kåberger 2007; Madlener 2007). Lastly, even if biofuels may only produce a marginal part of the national needs (3.5 billion of litres according to Simon et al. 2010, compared with the annual consumption of more than 100 billion of litres), the existence of these projects is necessary for the development of the national biosourced industry, including green chemistry for instance.

In conclusion, the variety of constraints implies a specific approach for each local situation, with regards to the presence and accessibility of resources, local needs and institutional configurations (administrative boundaries, capacity of cooperation in particular). In the following section, we illustrate the diversity of situations encountered in metropolitan France.

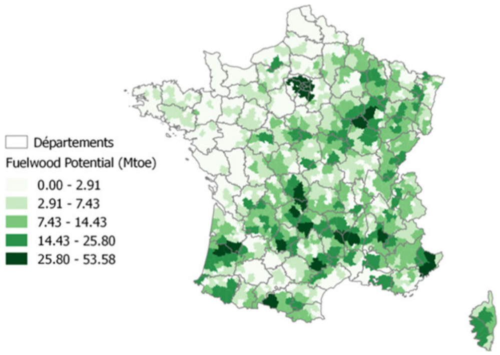

Fig. 1 Fuelwood potential (source: Sion 2015)

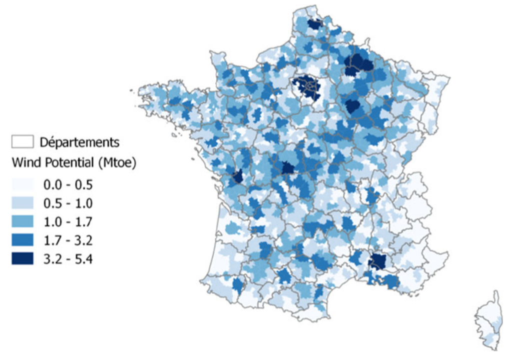

Fig. 3 Wind power potential (source: Ademe and Corine Land Cover)

The diversity of local situations

Several methods for estimating the potential for renewable energy on a community have already been proposed (e.g. Kellett 2007; Kellett and Hamilton 2009). In this paper, we mainly focus on analysing the geographical variability of this potential at a national level.

For biomass-based renewable energies, it is quite easy to have an idea of the physical quantity of biomass, at least at a crude (*département*) level. It is however much more difficult to translate it into actual energy potential, because biomass has multiple uses (the famous four Fs: food, feed, fibre, fuel) or can simply be left on the ground. The development of the remote sensing techniques for estimating biomass will soon allow for a much more precise measurement at a fine level, but this will not dispense us from analysing its actual use.

In order to map the potential of bio-based energy, we used the studies realized by Colin et al. (2009) for wood resources and by Ademe (2013) for anaerobic digestion resources (agricultural residues, green waste, sludge from water treatment plants). We then used data on a land cover from Corine Land Cover 2012 (http://www.statistiques.developpement-durable.gouv.fr/clc/fichiers/) to extrapolate at a municipal level. The detailed method is presented in Sion (2015). It consists of adding estimates for all types of biomass weighed by an energy equivalent factor. Figures 1 and 2 give the spatial distribution of energy potential for fuelwood and anaerobic digestion at a *bassin de vie* level, which is a statistical (not administrative) division that divides the French territory into about 1600 units that are coherent with regard to house-to-work daily travels.

Taking wind and solar power into consideration, French available data are provided by Ademe as an average wind speed and kWh/m^2 for solar power (Figs. 3 and 4). For consistency, we need to adapt these data into energy power that takes into account a potential available land. We suppose that for both types of energy, the available land is approximately given by the agricultural land areas, obtained from the Corine Land Cover 2012 database. Taking into account artificialized areas to account for the possibility of solar panel on roofs does not change the results much. For solar power, the computation is quite easy, as we know the potential per surface unit. For wind power, the situation is more complicated, as we need to transform wind speed potential into energy. We follow the methodology used by Hélimax (2004), which estimates the wind potential in Québec with similar type of data. Compared to the latter study, we do not introduce the legal constraints on potential available land, as we deal with theoretical rather than the actual potential, but we keep the same territorial classification for taking into account the local variations of the average wind speed.

One noticeable feature of these maps is that they display very different patterns. For biomass for instance, production potential is respectively high for agricultural (Paris region, Brittany) and forestry regions (Aquitaine, Eastern and South-East France). This implies very different production models across regions.

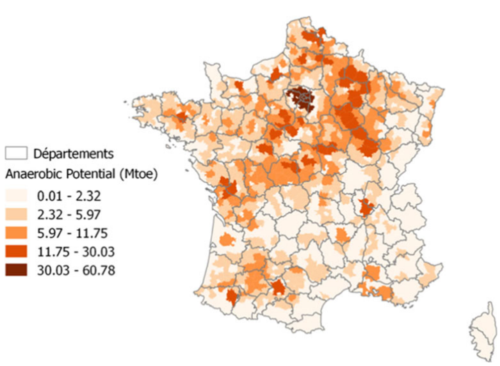

Fig. 2 Anaerobic digestion potential (source: Sion 2015)

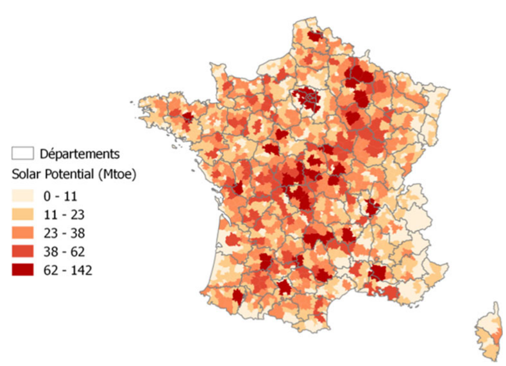

Fig. 4 Solar power potential (source: Ademe and Corine Land Cover)

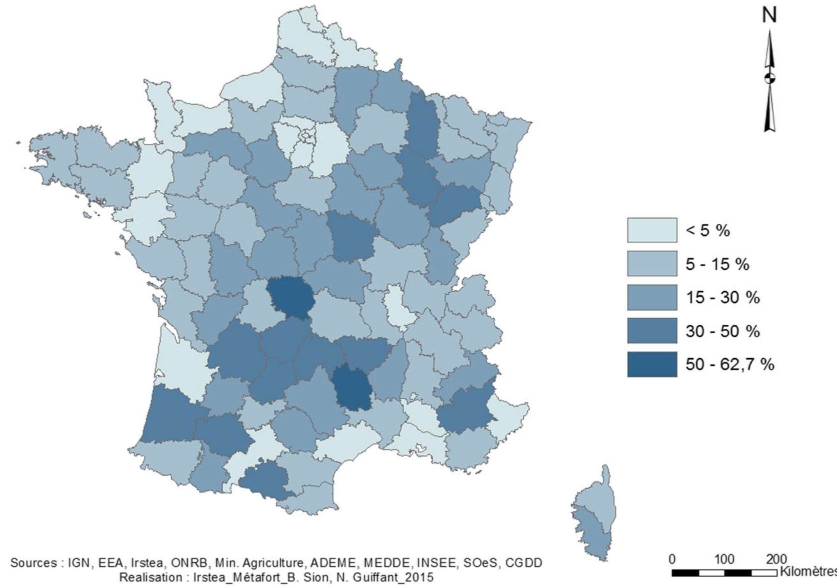

Fig. 5 Energy autonomy potential based on biomass, a *département* level (source: Sion 2015)

The next step is to take into account a local energy demand. To achieve this, we use data from the CGDD (2015) report on an average consumption by the type of use (residential, tertiary, farming, industrial, transport) and by the energy nature (power, heat, fuel), which are available at a regional level. We extrapolate a demand at a municipal level by using population and sectoral employment data and aggregate it at a *département* or a *bassin de vie* level. Estimated demand is calculated by using a population ratio for a residential demand and using employment data for other types of demand. This allows us to estimate the ratio between a potential renewable energy and an actual consumption. Summing all types of energy does not make much sense, as it is unlikely that full potential of all energies could be developed. Taking only a biomass potential, Fig. 5 gives the distribution of potential/demand ratio at a *département* level. For 5 of the 96 *départements*, theoretical coverage of energy needs exceeds to 40%. Unsurprisingly, these are all very rural *départements*.

Next, we perform the same exercise at the *bassin de vie* level (Fig. 6). At this scale, the theoretical degree of energy autonomy exceeds to 200% in some units. This is of course mostly due to a statistical effect (smaller grouping implies higher dispersion), but it is interesting to note that some areas can at least theoretically rely on bio-based resources.

Admittedly, this is mostly an academic exercise, whose main virtue is to highlight the spatial variations of the energy autonomy potential. In reality, a community-based initiative should not take these figures at a face value, but try to optimize both supply (materializing the potential true) and demand (lowering needs of energy importation). Moreover, these maps also show the potential conflict between the types of projects mentioned above: a community with a high territorial autonomy potential could try to deter the implementation of a big biorefinery project (and vice versa). There is clearly a coordination problem between geographical scales, and a need to build social consensus on the development priorities.

For wind and solar power, the nature of the dilemma is quite different than for bio-based energy. It is more linked to the divergence of interests between the different categories of stakeholders, most notably regarding the landscape issues, with a particular importance of the distance to the facilities. For example, a high power wind turbine (more than 1 MW) can generate a lot of nuisance for direct neighbours (noise, vibrations). Compensation mechanisms could be organized at a higher geographical level in order to render the different types of plants more acceptable.

In conclusion, there is a crucial issue of coordination between geographical scales, not only for technical reasons (area of biomass collection) but also to manage the different

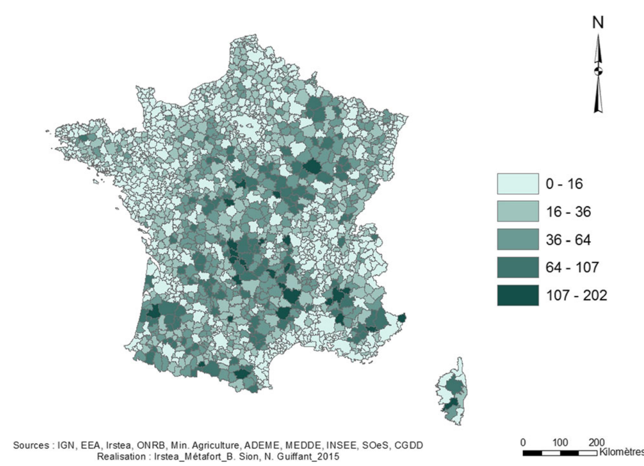

Fig. 6 Energy autonomy potential based on biomass, a *bassin de vie* level (source: Sion 2015)

conflicts regarding the use of resources and externalities generated by the production plants. In the following section, we examine a particular type of a community-based energy autonomy initiative, and we try to identify the main factors that explain its emergence.

Actual community-based initiatives and their determinants: the case of the "TEPCV" policy

We saw in the last section that while the notion of energy autonomy is appealing intellectually, its effective development is hindered by various factors, in particular accessibility to resources (and of the land that supports them) and coordination between management scales. What is the actual potential for community-based initiatives and their geographical scales? Such initiatives are too recent to generate general results on their efficiency, but some lessons can be learnt from studying the localization and scale of the existing projects.

The French administrative system rests on three basic levels: municipal (about 36,000 municipalities), departmental (96 *départements*) and regional (13 *régions*). As municipalities are very numerous (and often very small), they are grouped into about 2100 intermunicipal groupings that pool certain responsibilities (notably water and waste treatment and land-use planning for economic activities). In addition, intermunicipal groupings can themselves join together to form cooperation entities dealing with specific development stakes:

- PETR (rural and territorial development poles) which aim to develop a common vision for rural development
- SCOT (territorial coherence schemes) which aim to conduct development projects associating a city and its surrounding hinterland
- PNR (regional natural parks), that cover areas rich in natural heritage and aim to both protect it and develop economic activities using it as an asset.

Typically, there are four to six such entities in each *département*. PETR and SCOT can be borne by the same entity, while PNR and PETR frequently overlap. In the mind of the legislator, these intermediate entities are supposed to build a shared vision of the development and ensure coherence at a more operational level larger than intermunicipal groupings.

In 2014, the Ministry of Energy and Environment launched a program to generalize the concept of energy autonomy as promoted by the 100%-RES community network, labelled TEPCV ("Positive Energy Territories for Green Growth"). It consists of a call for proposals open to all kinds of territories: intermunicipal groupings, PETR, SCOT, PNR, *départements* and even individual municipalities and ad hoc groupings of municipalities. The selected territories enter into a contract with the ministry, for a program of actions that tends to energy autonomy, and receive funding of up to €500,000.

A total of 528 territories applied to the TEPCV call for proposals, half of them emanating from intermunicipal groupings, about 25% from individual municipalities, 10% from PETR/SCOT, 10% from national parks and 5% from *départements*. A total of 212 territories were selected, with a variety of types: 59% were intermunicipal groupings, 4% individual municipalities, 22% SCOT/PETR and 6% *départements* (http://www.developpement-durable.gouv.fr/Les-laureats-des-TEPCV.html). If we assume that there is a link between selection and quality of the project, this suggests that energy autonomy initiatives are more relevant at an intermunicipal level, or at the level just above. Indeed, initiatives emanating from individual municipalities mostly consist of isolated actions such as housing restoration to improve thermal efficiency. Projects from départements are mostly sets of studies on energy efficiency.

The TEPCV program can fund various types of actions contributing to lowering energy demand (developing "soft modes" of transport or carpooling), enhancing energy efficiency (especially through thermal renovation) and of course establishing renewable energy plants. The types of energy targeted in projects are, in decreasing order: photovoltaic, biomass, wind, solar heat and (marginally) geothermal energy. In order to understand the factors that explain the involvement in this program, we conducted an econometric study based on three types of factors: renewable energy resources, local energy demand and social/institutional factors.

A simple choice model

To analyse which factors may influence the decision to engage into a community-based energy autonomy initiative, we assume that the public decision-taker balances gains and losses with regard to a situation without action. If a local entity n decides to apply, the result depends on the success or failure of the application. In case of success, the utility drawn by the decision-taker is $U_n^{\text{Success}} = \text{Subsidy} + \boldsymbol{\delta}_1\text{Gain}\mathbf{s}_n - \boldsymbol{\delta}_2\text{Cost}\mathbf{s}_n$ where the subsidy can be considered as constant since it generally reaches the maximum value (€500.000). Other gains can be economic (improvement of energetic system) or with a political value. In case of failure, the utility would be $U_n^{\text{Fail}} = 0$, if we consider that the costs for project submission are negligible.

As one must choose to apply before knowing the issue of its application, we define the expected utility as $EU_n = p_n U_n^{\text{Success}} + (1-p_n) U_n^{\text{Fail}} = p_n(\text{Subsidy} + \delta_1 \text{Gain}s_n - \delta_2 \text{Cost}s_n)$, where p_n is the probability of the decision-taker n to obtain the subsidy. One can assume that the chance of success of a project depends on its quality. So, we ran a simple submodel where we estimated the probability of success for the territories that applied to the program, expecting that their characteristics (energy potential and needs, social and political characteristics, etc.) will influence the output. Contrary to our expectations, the model had a very low explanative power (McFadden pseudo R^2 close to zero), and no variable is significant. Thus, we can consider the probability and the expected subsidy as a constant (approximatively equal to 1/3). Being a constant, the expected subsidy represents a fixed effect that would be included in the intercept. In a nondeterministic context, the territories will compare the expected utility of getting into a project versus null utility, which corresponds to a standard random-utility choice model:

$$V_n^1 = EU_n = p(\text{Subsidy} + \boldsymbol{\delta}_1\text{Gains}_n - \boldsymbol{\delta}_2\text{Costs}_n) + \varepsilon_n,$$

if application is decided

$$V_n^0 = 0$$

else.

As we do not dispose of any information about the gains or the costs, instead of a conditional logit framework, where the choice is made based on alternative characteristics, we use the multinomial (binomial) logit modelling, which uses the individual's characteristics as explanatory variables. The assumption of using a multinomial framework can be justified as the gains, and the costs of implementing a project are directly influenced by the territorial characteristics $\mathbf{x}_n$: $V_n^1 = EU_n = p(\text{Subsidy} + \boldsymbol{\delta}_1\text{Gains}(\mathbf{x}_n) - \boldsymbol{\delta}_2\text{Costs}(\mathbf{x}_n)) + \varepsilon_n$. The individual choice can be rewritten:

$$V_n^1 = \beta_0 + \boldsymbol{\beta}\mathbf{x}_n + \varepsilon_n,$$

if application is decided,

$$V_n^0 = 0$$

else,

where $\boldsymbol{\beta}$ is a vector of regression coefficients and $\mathbf{x}_n$ a set of individual descriptive variables. The unobserved term ε_n is assumed to have a logistic distribution and thus the probability that a local territory applies to the TEPCV program is $P_n^1 = (1 + \exp(\boldsymbol{\beta}\mathbf{x}_n))^{-1}$.

Let us briefly discuss the expected impacts of explanatory variables. The political advantage of the initiative may depend on two aspects: the degree of proenvironmental values in the political assembly and the level of need of improving access to local energy. The first aspect may be measured by the vote for ecological parties. The second can be proxied by a local demand in energy.

Costs are mostly transaction and administrative costs. A local leader must convince his fellow elected representatives and also citizens through meetings for example. We expect that the presence of ecological parties in local assemblies, the existence of a rich social life (as measured by the number of associations) and a high level of intermunicipal cooperation will lower the transaction costs and thus raise the probability of application to the program.

Lastly, we expect that existing renewable energy plants could lower transaction costs (by giving local experience) but also make them higher if they happen to have negative externalities. The impact is thus ambiguous and should be tested. For fuelwood and anaerobic digestion, we bought data provided by http://www.bioenergie-promotion.fr/, providing a list with postal code of existing plants. For wind and solar power, data come from the French ministry of environment http://www.statistiques.developpement-durable.gouv.fr/energie-climat/s/energies-renouvelables.html).

The data

The analysis is conducted at the *bassin de vie* level, which has the advantage of being fine enough to capture the diversity of a potential energy autonomy level. The dependent variable is a dummy variable that is equal to one when a given *bassin de vie* includes the administrative headquarters of a territorial entity that applied to the TEPCV program. Several submodels are tested:

– All types of territories
– Intermunicipal groupings ("EPCI")
– PETR and SCOT (which are very similar types of territories/projects)
– PETR, SCOT and natural parks. Natural parks are not tested separately, as they correspond to a very specific type of area, and it would have been necessary to identify first the types of area suitable for natural parks.

There are 1644 *bassins de vie* in metropolitan France, and the analysis was conducted on both rural communities and large cities. For each type of territory, we constructed one dummy for the "presence of a territory that applied to the TEPCV program", and another for the "presence of a territory that was selected in the TEPCV program".

The explicative variables are grouped by a category of interest. Firstly, we look for a local energy potential, considered as a standard incentive factor for energy autonomy initiatives. For the renewable energy potential, we use four variables, corresponding to fuelwood, anaerobic digestion, wind and solar power potential. As explained at the end of section 4.1, we also include the corresponding variables for installed power. These variables are measured with the methodology presented in section 3, at a *bassin de vie* level. Some descriptive statistics are reported in Table 1. We confront this supply potential with a local demand, as defined in section 3

Table 1 Descriptive statistics

Variable	Measure	Source	Min	Max	Mean	Std dev
Population	K habitants	INSEE	1.91	10,713.6	38.50	278.60
Demand	Mtoe	Sion (2015)	3.10	24,887.6	89.52	659.01
Fuelwood potential	Mtoe	Sion (2015)	0	53.58	4.62	5.67
Anaerobic potential	Mtoe	Sion (2015)	0.01	60.78	2.97	3.61
Solar potential	Mtoe	Ademe and Corine Land Cover	0	141.60	17.71	14.84
Wind potential	Mtoe	Ademe and Corine Land Cover	0	5.45	0.73	0.62
Fuelwood power	MW	Bioenergy promotion	0	196.42	1.73	7.62
Anaerobic power	MW	Bioenergy promotion	0	36.25	0.16	1.24
Solar power	MW	Ministry of environment	0	63.92	2.74	4.01
Wind power	MW	Ministry of environment	0	237.1	8.34	24.66
Artificial	Points	Corine Land Cover	0.001	0.51	0.06	0.06
CIF	Points	Ministry of Interior Affairs	0	0.84	0.36	0.09
Joly	Points	Ministry of Interior Affairs	0.01	0.07	0.02	0.01
Green	Dummy	Ministry of Interior Affairs	0	1	0.02	0.12
Income	kEuro	FiLoSoFi (2012)	15.37	39.51	19.38	2.15
Shannon	–	Pop. census (2012)	1.09	1.77	1.53	0.07
Associations	/1000 habitants	INSEE	0.40	17.85	2.24	1.17

(aggregation of all types of use: residential, tertiary, farming, industrial, transport). We note that generally, there is a very low statistical correlation between these variables except a strong correlation between variables that were computed based on agricultural land: between wind and solar potential, and in a lower level with an anaerobic potential. We conducted a variance inflation factor analysis to test the multicollinearity of the model, and as expected the VIF factor is high for solar and wind potential (14.95 and 17.34). The problem is solved by deleting one variable, but as the results do not change, we opted for consistency to keep both potentials.

A second group refers to the general characteristics of the territory of the *bassin de vie* that could influence its participation to the TEPCV program. Traditional size variables, population and geographic area, are both dropped for reasons of correlation. Indeed, the population of the *bassins de vie* are highly correlated with the local demand (0.998). This is not surprising, as the population influences directly the residential demand and economic activity (except for farming). Moreover, methodologically, we extrapolate the regional demand data at a local level using population and sectoral employment data. Finally, the only general descriptive variable that we have kept is the rate of artificialization (percentage of artificialized land) in order to verify the hypothesis that rural territories are more susceptible to converge to energy autonomy. The variable is calculated from Corine Land Cover 2012 data base, as a ratio between artificial and total area of the *bassins de vie*.

Another group of variables are called "political" variables. On the one hand, we are interested in the integration of the grouping of municipalities, because as we described previously, the TEPCV projects seem more compatible for groupings of municipalities. To measure this, we use the coefficient of fiscal integration (*CIF coefficient d'intégration fiscale*), which is an indicator of the share of municipality powers transferred to the grouping (Callois and Schmitt 2009). It is calculated as the ratio of taxation collected by a municipality and all tax levied on its territory by the municipalities and their groupings. We tested different ways of calculating fiscal integration at a *bassin de vie* level (simple mean, weighted by municipalities area and by population). As they are highly correlated (between 0.96 and 0.96), we only kept the simple mean of the coefficient of fiscal integration.

As the political convictions of the electorate can influence local policies, we introduced two variables of "green" political orientation of the population. The first is calculated as the rate of the votes for Eva Joly, the "green" candidate, in the first round of the French presidential election in 2012. The second refers to the presence of "green" elected representative after the 2008 local elections at a *bassin de vie* level. As the presence of a green local councillor is very rare (25 out of more than 1600 *bassins de vie*), the variable is defined as a dummy. This rarity could also be explained by the fact that in the French system, local candidates need to belong to a national party only for municipalities of more than 3500 inhabitants.

The last group of explicative variables concerns social factors that can influence local energy policies. The data about income distribution among the population comes from FiLoSoFi 2012 data (*Fichier Localisé Social et Fiscal*– Fiscal and social local database, https://www.insee.fr/fr/metadonnees/source/s1172). Since we need to measure income distribution at a *bassin de vie* level and the available data is subject to statistical confidentiality and is only partially available, we used a weighted mean of median income of municipalities. We are also interested in the impact of social diversity and segregation. We have tested several indices, and no one was significant. We kept in the model as an example socioprofessional diversity measured by the Shannon index using eight socioprofessional classes, defined by INSEE (French National Statistics Institute, http://www.insee.fr/). The index is calculated at a *bassin de vie* level, using data from the 2012 census. The last social variable is the number of associations for 1000 inhabitants, used as a proxy for the social interaction inside a *bassin de vie*.

Results

As the dependant variable is a binary variable, we use a standard binomial logistic model to estimate the probability that a territory participates in the TEPCV program. As the local energy demand produces a quasiperfect separation on the outcome variable, we use the logarithm of the demand to solve the problem. This is confirmed by the plot of the modelled probability as function of the demand, as presented in Fig. 7.

We tested other statistical solutions, such as the different forms of penalized regressions or models for binary rare events,[1] but as the results remain stable, we kept the binomial logistic model in the article. The advantage of this method is its simplicity and easy interpretation. The parameters are estimated using the likelihood maximization techniques. We ran two types of models: one with energy variables measured in energy units and the second one where these variables were normalized per capita. For the second model, we could reintroduce the population to capture the territorial size effect. Both types of models are convergent, with similar results, but per capita models have lower significance.

The results for the territories that applied to the TEPCV program are given in Table 2. We realized several regressions, to identify specific factors to different territorial types.

The first finding is that application to the TEPCV program seems driven by a local energy demand, which is positive and highly significant for all regressions: the higher the demand (or the population size of the *bassin de vie*), the higher the probability of participation to the TEPCV program. The negative significance of the intercept for almost all models means that there are several barriers or fixed costs related to the candidacy to the program.

When considering the energy potential, the results are not as obvious. Fuelwood potential plays a significant positive role for the general model, but when comparing different types of territories, this role seems to come from the natural parks (fourth model). Anaerobic digestion potential plays a little role on local decision and only for natural parks. The solar potential has a positive and significant sign in the general model that comes from the EPCI submodel. The wind potential has a negative impact (generally significant) that could be counterintuitive. A possible reason could be that the presence of a strong wind potential strengthens the conflicts associated with that form of energy This result can also be explained by the quality of the variable, which could be improved by taking into account technical and land constraints. But if we look to the existing power, wind energy is the only variable that plays a positive and significant role in the general model, which suggests a form of "learning effect" for this controversial energy.

As expected, fiscal integration in a grouping of municipalities plays a significantly positive role for all territorial types. The "green" political preferences of the population, expressed by voting during national elections, also have a positive effect, but only for the global model and not for specific territorial types. On the contrary, the presence of green representatives in the local structures has a significant negative impact, especially for the PETR/SCOT and PETR/SCOT/PNR territories. A natural (but admittedly controversial) interpretation is that these elected representatives adopt radical positions, which in the end is detrimental for application to the program.

The results regarding the role of median income distribution on the probability of a territory to apply to the TEPCV program are more difficult to explain. Median income has a negative impact and is significant for all territories, except for groupings of municipalities. This means that low income territories have more interest or need for receiving central compared to richer ones. Socioprofessional diversity, measured by the Shannon index, has a significant positive role only for PETR/SCOT territories. The number of associative structures has a significant impact only in the global model.

Next, we conducted regressions for the determinants of selection in the TEPCV program. The results are given in Table 3.

First, we remark that except for EPCI, the models have less explanatory power, because as we saw previously, the choice of candidate projects is completely independent of this set of variables. We also notice several changes compared to the first set of regressions, but the main effects remain the same. Demand is still the most stable explanatory variable, for all territories, and the intercept is negative and significant for the PETR/SCOT/PNR model. Energy potential variables lose their explanatory power, but installed facilities occasionally have significant impacts: the solar power is positive for EPCI and PETR/SCOT/PNR models, while wind power has a negative role only for PETR/SCOT/PNR. Artificialization rate is generally negative and it gains in significance,

[1] We tested three types of regressions that all give similar results: Binary Generalized Extreme Value Additive Model (bgeva), Lasso and Elastic-Net Regularized Generalized Linear Model (glmnet) and bias-reduction method developed by Firth (bglrm)

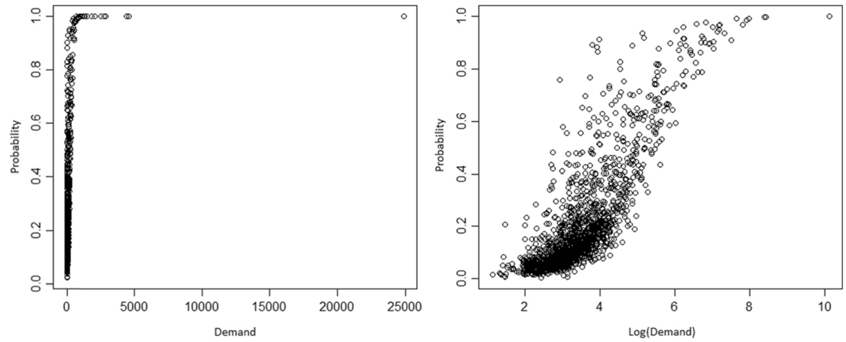

Fig. 7 Modelled probability to participate to the TEPCV program as a function of the local energy demand

especially for PETR/SCOT/PNR, which makes the variable significant also for the global regression. Fiscal integration loses significance except for PETR/SCOT model, while national elections preferences become insignificant for all models. The same negative effect of the presence of local "green" municipal councillor arises for the global and PETR/SCOT models. Income distribution has a more reduced impact except for the grouping of municipalities, while social diversity is positive and significant only for the EPCI model. The number of associations now plays a positive role in the global regression.

All in all, these results suggest a significant role of social and institutional factors in the emergence of community-based energy autonomy initiatives. A high level of political cooperation and a preexisting rich social life seem to play a role in the existence and quality of these initiatives. Naturally, these results do not guarantee that the selected projects will indeed initiate a path to energy autonomy. However, these results suggest that the implication of the local public authorities is in great part driven by nontechnical factors, more than the physical potential for renewable energies.

Table 2 Determinants of the presence of a TEPCV project per type of territory (coefficients)

	All types		EPCI[21]		PETR/SCOT		PETR/SCOT/PNR	
Coefficients	Estimate	Std. error	Estimate	Std. error	Estimate	Std. error	Estimate	Std. error
(Intercept)	−5.864**	1.988	−7.876**	2.510	−8.241*	3.535	−5.906*	2.989
Log (demand)	0.965***	0.120	1.093***	0.145	1.075***	0.219	0.874***	0.184
Fuelwood potential	0.060***	0.014	0.004	0.016	0.022	0.019	0.052**	0.017
Anaerobic potential	0.046	0.037	−0.018	0.040	0.076	0.049	0.093*	0.044
Solar potential	0.039*	0.018	0.048*	0.020	0.024	0.025	−0.001	0.022
Wind potential	−1025*	0.455	−1.043*	0.513	−1.198°	0.661	−0.622	0.576
Fuelwood power	0.002	0.012	−0.001	0.014	0.022°	0.012	0.015	0.011
Anaerobic power	0.065	0.071	0.011	0.088	−0.136	0.107	−0.017	0.120
Solar power	0.005	0.003	0.007*	0.003	0.000	0.004	0.003	0.004
Wind power	0.002°	0.019	−0.016	0.023	−0.008	0.027	0.015	0.021
Artificial	0.642	1854	−0.722	2.169	−10.200*	4.084	−6.935*	3.299
CIF	2.166**	0.823	2.058*	1.025	2.945*	1.336	2.886*	1.159
Joly	22.686*	11.473	11.773	15.039	−18.670	21.730	13.685	16.490
Green	0.075	0.597	0.153	0.570	−2.372°	1.275	−2.030*	0.935
Income	−0,149**	0.051	−0.094	0.061	−0.333**	0.109	−0.230**	0.086
Shannon	1.100	1.454	1.425	1.840	4.862°	2.592	2.014	2.196
Associations	0.144*	0.068	0.103	0.081	0.068	0.113	0.098	0.088
Observations	1642		1642		1642		1642	
Success	342		196		86		121	
McFadden R^2	0.226		0.215		0.145		0.156	
Cragg and Uhler R^2	0.322		0.280		0.172		0.193	

****P* value <0.001, ***P* < 0.01, **P* < 0.05, °*P* < 0.1

Table 3 Determinants of the presence of a selected TEPCV project per type of territory

	All types		EPCI		PETR/SCOT		PETR/SCOT/PNR	
Coefficients	Estimate	Std. error	Estimate	Std. error	Estimate	Std. error	Estimate	Std. error
(Intercept)	−3.915	2.628	−7.865*	3.564	−10.023*	4.601	−5.885	3.887
Log (demand)	0.920***	0.158	1.302***	0.201	1.070***	0.303	1.051***	0.252
Fuelwood potential	0.019	0.016	0.030	0.019	0.002	0.027	0.026	0.021
Anaerobic potential	−0.004	0.040	−0.069	0.048	0.068	0.069	0.032	0.058
Solar potential	0.029	0.020	0.036	0.023	0.027	0.034	0.033	0.030
Wind potential	−0.621	0.532	−0.600	0.603	−1.071	0.894	−1.125	0.795
Fuelwood power	0.011	0.011	−0.009	0.016	0.006	0.023	0.004	0.017
Anaerobic power	−0.013	0.077	0.125	0.084	−0.109	0.282	−0.043	0.143
Solar power	0.003	0.004	0.003**	0.004	−0.005	0.007	0.002°	0.005
Wind power	0.008	0.020	−0.090	0.028	−0.061	0.052	−0.082*	0.048
Artificial	−4.879 °	2.622	0.314 *	2.893	−12.529*	5.891	−12.039*	5.026
CIF	1.194	1.114	3.001	1.375	3.758*	1.666	3.176	1.482
Joly	11.239	15.995	12.779	21.175	−1.511	26.932	18.256	21.567
Green	−1.801*	0.787	0.468	0.631	−15.065°	720.571	−1.054	1.123
Income	0.056	0.060	−0.418***	0.102	−0.255	0.141	−0.215°	0.118
Shannon	−2.681	1.959	4.472°	2.643	4.490	3.398	1.319	2.902
Associations	0.198*	0.083	−0.101	0.152	0.046	0.132	0.048	0.110
Observations	1642		1642		1642		1642	
Success	141		113		46		63	
McFadden R^2	0.138		0.296		0.102		0.109	
Cragg and Uhler R^2	0.175		0.350		0.114		0.125	

***P value < 0.001, **P < 0.01, *P < 0.05, °P < 0.1

Conclusion

Community-based energy autonomy initiatives have several advantages for local development. They can bring valuable synergies between efficient use of local resources, reduction of carbon emissions, social interaction and local democracy. However, they are not without drawbacks: they can generate several types of nuisance and conflicts of use. The role of human (social and institutional) factors is thus essential to determine which model is the most appropriate for a given situation.

This paper, combining considerations of resource properties, institutional and social aspects, shows that these kinds of initiatives are not right for all territories. Moreover, the transition to a higher level of autonomy will take very different forms in different regions, not only because of the high variations in the production potential between forms of energy but also because of the differences in the local needs and institutions. The intensities of socialization, as well as the degree of intermunicipal cooperation, are key factors in the emergence of initiatives.

These results have several policy implications. The first is that there should be a close interaction between national, regional and local initiatives in favour of energy autonomy. A national view of desirable development pathways is necessary to determine the importance of local projects versus big industrial plants that require large amounts of land. The regional scale is the natural level of coordination between different project sizes and for developing the necessary expertise for assisting communities. The intermunicipal scale requires a subtle alchemy between land/infrastructure planning, social and institutional aspects to be worked out. A second implication is that communities that lacks the capacity to cooperate should be targeted first by the upper planning levels in order to reinforce their social and institutional capital. As the development of energy autonomy is supposed to generate a virtuous cycle of better socialization, the regional level could be appropriate to allocate targeted assistance according to this criterion. One possibility would be to focus assistance on cooperative aspects for territories with low social capital and on technical aspects for territories with higher social capital, thus creating a demonstrative effect on the advantages of energy autonomy.

This paper is just an initial approach to tackle the role of social and institutional factors. Of course, the crudeness of the data does not make it possible to identify precisely the diversity of possible configurations in the development of renewables. However, it does offer some general trends and robust results that need to be confirmed and specified by field studies.

Several developments could be made to deepen our results. Firstly, a more explicit model of how these territories function could help quantify the positive impacts on a local economy. Secondly, the possible optimization of energy needs through smart infrastructure and public transport planning is yet to be estimated in a general case. Thirdly, the synergies between biomass types (agricultural, wood, fisheries, organic waste) and the interaction between their possible uses are also important (and growing) topics for rural development. This would call for detailed case studies in contrasted situations (intensive farming, field crops, mountain farming and so on), in order to understand the varieties of possible interactions. At any rate, the study of energy issues at a community level bears a lot of implications in terms of renewal of rural development.

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