The 'patchy' spread of renewables: A socio-territorial perspective on the energy transition process

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ABSTRACT

In the energy transition process the district heating networks and the wind power facilities play a key role. These two technologies can contribute to establish models of co-provision involving new social actors in the energy field. Despite that, the socio-organizational change appears patchy. In Italy, these options are dominated by large utilities and the few forms of energy co-production are to be found in specific contexts. The influence of socio-territorial features on the energy transition seem relevant. This paper aims analysing energy transition while focusing on the institutional, relational and territorial dimensions to unfold how energy innovations take place within territorial contexts. In this respect, energy transition is investigated considering both the district heating and the wind power in Italy. The analysis suggests that the transition is influenced by the way in which territorial context is destabilized by the perturbations of energy landscape.

1. Introduction

Renewables are spreading very rapidly across Europe, with an average annual increase of 5.3% over the period 2006–2016 (Eurostat data). District heating networks can play a key role in changing urban energy systems and wind power can largely contribute to the production of electricity. The relevance of these two technologies seems confirmed in the Energy Roadmap 2050 of the EU Commission, looking at their combination to accelerate the low-carbon transition.

Thanks to its versatility in being supplied through different sources, district heating networks can drive the transition away from heat production systems based on fossil sources. This is the case of Sweden where the share of fossils for heat production is below 5% and district heating covers 90% of urban consumption (Dzebo and Nykvist, 2017). Similarly, the technological flexibility of wind turbines be placed in onshore and off-shore windy areas (with small or large turbines), allowed to spread the rate of free-carbon energy in the electric demand. In Denmark, for instance, wind power covered around 43% of its electric consumption in 2017 (Energinet, 2018). These two green technologies can also work together thanks to their versatility. District heating networks, in fact, not only can acquire heat from various sources (i.e., biomasses, geothermal energy or industrial processes[1]), but in some cases, these networks are powered by wind farms (Lund, 2005), as in the Spandau district of Berlin. Furthermore, within certain limits, thanks of their socio-technical versatilities, they contribute to establish forms of co-provision models involving new social actors in the energy field (Osti, 2008; Watson, 2004).

Despite that, when considering how the diffusion of these energy technologies is evolving, we seem to face an ambivalent scenario because the socio-organizational change in the energy sector appears patchy. In Italy, for example, 90% of the heated volume in district heating is powered through non-renewable sources, especially in the case of medium-large cities where networks are managed by the main sector utilities (Carrosio, 2014). In the case of wind power, more than a third of the installed megawatts are owned by 4 large utilities and only in few rural-marginal areas forms of participatory ownership are recorded (Magnani et al., 2017). These differences seem influenced by the socio-territorial features where green technologies are implemented. In other words, how the resistances and innovations take place within territorial contexts and with which social forms the production and consumption of energy are restructured seems an issue not particularity analysed in-depth in the debate on the energy transition. For this reason, the paper aims to reflect on the energy transition focusing on the institutional, relational and territorial dimensions. In this respect, here we propose to investigate the energy transition process considering both the cases of district heating and wind power in Italy that, despite their differences, have some socio-organizational similarities.

The paper is organized as follows: the second paragraph provides

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[1] In this respect, examples are nuclear power plants that powered district heating networks (Leurent et al., 2018).

the conceptual framework to investigate the diffusion of green energy technologies in Italy and to understand the role that they play in the energy transition. The multi-level perspective, a dominant approach in these analyses, is integrated with the analysis of the local social network and a territorial perspective while the third part reports methodological notes. In the third section is reconstructed the diffusion of district heating in Italy, while the forth one deals with the wind power sector. In these two last sections the establishment of both district heating and wind farms in specific contexts are analysed considering the socio-territorial and socio-technical networks, in order to show how they co-evolve. This analytical perspective leads us to identify different relational models among the actors that compose the socio-technical networks, which influence the transition trajectories that take place in a concrete context. The conclusions will provide some elements of interpretation emerging from the previous parts.

2. Multi-level perspective, networks and territory

The theoretical approaches to the energy transition can be roughly grouped into two frames: those that stress the changes in institutional and technological aspects – such as the Multi-Level Perspective (Geels, 2002; Geels and Schot, 2007) or the Management Transition Studies (Loorbach, 2010) – and those interested in understanding the role of everyday practices in the maintenance and innovation of the energy provision processes, like the Social Practice Theory (Shove and Walker, 2010). Despite their differences, both of them are interested to unfold the 'local' analytical level of the energy issue, in the first case understood as the socio-technical niche in the second one as the everyday life. At the same time, these frames seem to underestimate the role of the socio-territorial aspects involved in the energy transition process which appear to influence the transition paths (both in terms of promoting and resistance to the socio-technical change) and their results at local level. For this reason, in our contribution we propose to deepen these aspects mainly through an analysis of secondary data.

For our purpose it seems useful to propose a complexification of the Multi-Level Perspective (MLP) because it interprets the underlying dynamics of the energy transition as the outcome of the interaction process between socio-technical specific levels. These levels are: niches (where radical innovations take shape), regimes (places of consolidated practices, rules and institutions that constraint subject actions in existing systems) and the landscape (the general background in which broader social processes take place). In this frame, innovations develop in niches, but they have a chance to spread in regimes – which tend to self-preserve – when landscape changes destabilise the regimes from the outside. When this happens, windows of opportunity emerge for niche-actors that can diffuse socio-technical novelties that resolve regimes instabilities in a new way. In short, the alignment niches-regimes-landscape produces technological leaps and promotes social change. However, according to several authors, this frame presents some problems, mainly deriving from the lack of an explicit focus both on the political economy dimension and on the self-preservation process of the existing regimes (Smith et al., 2005; Meadowcroft, 2011; Geels, 2014). The regimes resistance seems postulated as a form of technological automatism (i.e., path dependency, lock-in, etc.), as well as, the interaction among actors within the organizational field appears a technology-dependent variable (Arthur, 1989; Cowan, 1990; Islas, 1997; Liebowitz and Margolis, 1995; Hughes, 1983). Here, however, it is proposed to focusing on the relationship between socio-technical regimes and the techno-institutional complexes to analyse resistances and changes in the energy transition process.

About the socio-technical regime, we refer to the dominant energy system on a national scale, considering that any States have institutions and dominant technological paths that distinguish them from others (Ćetković and Buzogány, 2016). Also, on this level the variety of capitalisms counts, within which the transition is embedded (for a critical view, see Cherp et al., 2018). A techno-institutional complex, on the other hand, refers to the configurations that the energy system takes on a local scale, where utilities, businesses, consumers, local institutions have a pivotal role in defining both the mix of sources and the technological paths in the territories. In these configurations technological systems and public and private institutions become interconnected by nurturing one another (Unruh, 2000). Until an intermediate level between niches and socio-technical regimes is not identified, the MLP does not sufficiently take into account the territorial dimension (Bridge et al., 2012; Coenen et al., 2012) and the relational one (Osti, 2008). Without considering the territorial dimension, it is difficult to show how socio-technical regimes are fragmented into different techno-institutional complexes or how the transition has different speeds and forms depending on the territorial contexts (Carrosio and Scotti, 2018). At the same time, disregarding the relational perspective leads to ignore the role that social networks have in influencing the modalities of spread of technological energy devices across local contexts (Valente, 2005). Furthermore, studies considering the social embedding in the MLP scheme seem not give much weight to the relational dynamics in which the technologies fall (Geels and Johnson, 2018). As such, a model is proposed here that introduce an additional level in the MLP scheme (Fig. 1).

Considering that innovation niches interact with local contexts, the

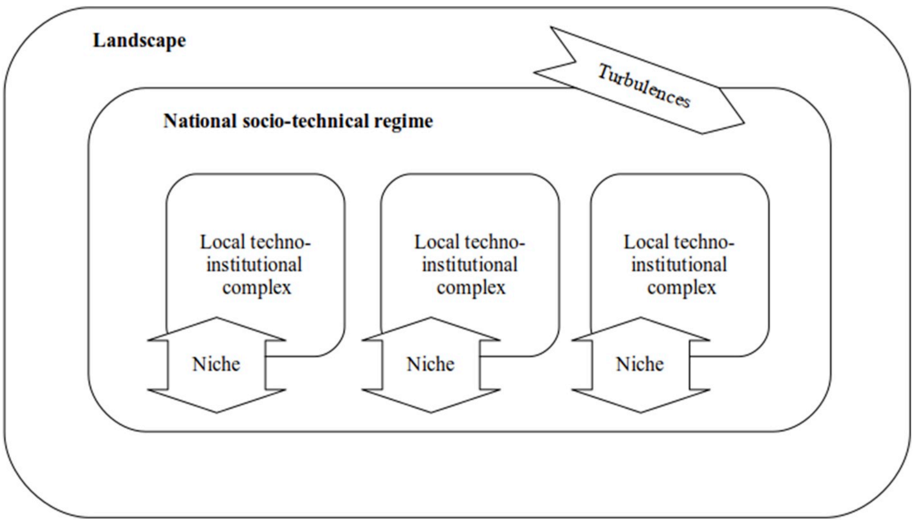

Fig. 1. A scheme of the revised MLP model.

Table 1
Analytical dimensions.
Source: our elaboration.

Dimensions	Variables
Technology	Power installed (in MWs), type of fuel used and its provenance (in the case of district heating), technological features/innovations (for wind farms).
Relation	Shareholder structure of the power-stations, the provision models and goods exchanged in the energy chain (i.e., information, money, knowledge, etc.).
Territory	Local outcomes (i.e., employment, royalties, etc.), decisional power of local authorities about the installation of energy facilities, local socio-territorial structure (i.e., rural area, etc.).

Table 2
Relational models of energy.
Source: our elaboration.

		Users/citizens involvement	
		High	Low
Involvement of producers	High	Co-provision	Hierarchical model
	Low	Self-organization of users on a collective level	Self-organization of users on an individual level

differentiation of national socio-technical regimes from local techno-institutional complexes appears crucial. In this frame, the sum of changes at the level of the local complexes determines changes in the regime and the regime aligns the local complexes in a dominant system when it is pushed by external turbulences (from landscape).

Engaging in the debate on the energy transition, in this paper we propose an investigation that tries to offer some insights of the expansion of the district heating networks and wind power in Italy through the territorial perspective and the networks scheme within the MLP model. According to the networks approach, every technological process is embedded and co-evolves within a system of relationships and, by the territorial perspective, socio-environmental features affect the transition differently from one place to another. Both the networks perspective and the territorial framework suggest there is no monolithic socio-technical regime. If we focus on the local level, in fact, it becomes clear that within a dominant regime there are different techno-institutional complexes, positioned in an ideal continuum of fossil-renewable systems. In the same national-State some territories have already introduced radical innovations regarding energy, while in others a local resistance puts a brake on the transition. This patchy reality begs for a closer look at 'how' and 'where' energy novelties have been spread bearing in mind the territorial perspective as a necessary step in this process. Below, after some methodological notes, an analysis of the spread of the district heating and wind power in Italy through this analytical approach is proposed.

3. Methodological notes

In order to analyse the energy transition in a relational and territorial perspective, we carried out a research during the first part of the 2018. The study is based on four sets of information: the available statistics of energy facilities (both for the district heating systems and wind power plants), data reported in official documents and websites of the major sector companies and local authorities – like towns or regions – in territorial contexts with the relevant presence of the green facilities (as installed MWs or heated volumes), legislation on energy issues (i.e., national public incentives, regional authorization norms, etc.) and interviews to key witnesses for the representative areas for both wind farms and district heating systems.

In particular, statistical data on district heating in this paper has been processed by the census of the AIRU (2017), an association of companies that manage the district heating networks in Italy. On the other hand, two sources have been used for the wind sector, the *Atlaimpianti*, a web-platform service of the GSE (the State-owned company that provides public incentives to support the renewables), that offers data about the power plants size as well as the localization of wind facilities, *The Wind Power database* (a paid database service), which allows to get pieces of information about sector companies (i.e., who owns and who manages wind farms), and the *ANEV* (the association of wind companies), that offers information about the wind sector.[2] Through the statistics have been identified both the most relevant sector companies and areas affected by the presence of the green energy facilities. In the case of district heating, the web sources of the A2A and IREN companies were queried cause they are the most relevant utilities in the sector, as well as, internet source of some local authorities in Northern Italy (i.e., the city of Milan, the region of Trentino Alto Adige, etc.) have been checked cause they present emblematic features in the district heating systems. About the wind power, annual reports of the major 5 wind enterprises in Italy (ERG, E.ON, Fri-El, E2i and Enel) have been found in their own internet sites and additional information have been detected in the official on-line documents of some Municipalities in province of Foggia, Southern Italy (i.e., Alberona, Rignano Garganico, Roseto Valfortore, etc.), the area where Italian installed wind MWs are concentrated. Through the intersection of the data collected by censuses and web information, 12 subjects were identified as territorial key witnesses in contexts characterized by the presence of wind power plants (6 persons) and district heating systems (6 subjects). They were interviewed: sector experts, company representatives, regional officials and representatives of local authority.

As it is summarized in the Table 1, data have been analysed to identify plausible relations among three analytical dimensions related to the energy issue: technological, relational and territorial aspects. These dimensions have been specified in few detectable information (or variables) that allow to highlight the technical and social networks at the territorial level. In this way was possible to stress in which way district heating systems and wind farms assume different configurations and features in local contexts compare to the macro-process of the sustainable energy transition (see Table 2).

4. District heating systems and local contexts in Italy

4.1. Utilities, fuels and territories

The first Italian district heating system was built in 1970 in the Giardino neighbourhood of Modena, North of Italy, as a direct intervention of the Municipality. In the following 30 years the development of district heating was relatively slow and it characterized some neighbourhoods of middle-large cities (i.e., Brescia, Reggio Emilia and Turin). Until the early 2000s, the expansion of district heating was mainly an enlargement of existing networks in the areas of influence of the first municipal companies that adopted this technology. The boom occurred in the period 2000–2016, with the construction of 186 new networks. The heated volume has grown exponentially in the last decade (+277%) and, in 2016, Italy counts 239 registered networks,

[2] For the 'GSE Atlaimpianti' see the website: https://atla.gse.it/atlaimpianti/project/Atlaimpianti_Internet.html. 'The Wind Power', here the website: https://www.thewindpower.net/index.php. For 'ANEV', see: https://www.anev.org/.

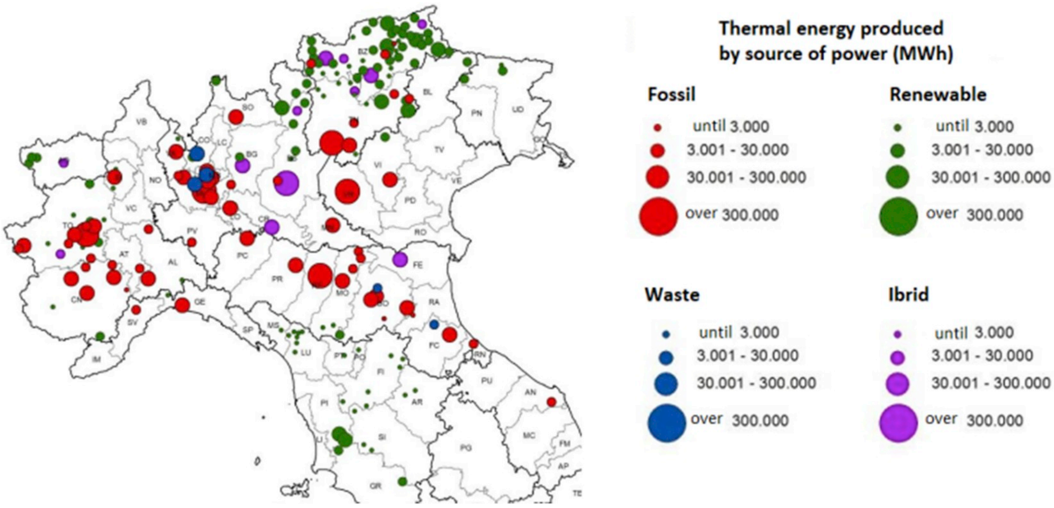

Fig. 2. Territorial distribution of district heating networks by source (from AIRU, 2017).

operating in 193 Municipalities, data that is expected to double by 2022.

To date, these networks prevail in Northern Italy (90% of the heated volume in 2016) and they are powered mainly by non-renewable fuels (84.8%) by cogeneration plants, like the waste incinerations or the thermoelectric facilities. The main operators of these networks are the largest multi-utilities of Northern Italy.[3] In particular, A2A and IREN hold respectively 26% and 25% of the Italian district heating volumes. A2A, which manages both the Milan and Brescia city networks, is working on doubling its district heating volume by the end of 2018 connecting the Cassano d'Adda thermoelectric power station (40 km from Milan) equipping it with a co-generation system. The heat recovered from this plant, whose electric production is threatened by the increase of renewables, is able to cover 30% of Milan thermal demand and to provide heat to the metropolitan area towns that are located along the rout of the duct. IREN, supplier to Turin and its metropolitan area, intends to enlarge its networks through the construction of two new facilities (a waste incineration and a methane power plant) to reach 84 million cubic meters heated. Generally these utilities propose to local authorities the district heating as a means of savings and energy efficiency for buildings. According to the agreements signed, utilities obtain the authorization to build the co-generation plants and the district heating networks while Municipalities receive the heating supply at favourable prices.

Renewables, instead, cover only 10.7% of the district heating volume, but their operators are the majority in Italy (73% of the total). The networks powered by biomasses prevail (102 out of 122). They are concentrated in Trentino Alto Adige region and in some scattered areas of the Alps and the Central-Northern Apennines. Other 19 networks located in Tuscany use local geothermal power and one, in the city of Varese, is powered by a solar thermal station mainly supported by a methane power plant. Almost all of these plants were created between 2000 and 2016. An interesting aspect is related to the organizational form of these district heating networks. In the Trentino Alto Adige region, as it is common in other areas of the Alps, the majority of district heating networks are built and managed by user cooperatives, and powered by virgin local biomass (see Fig. 2).[4]

From this description is evident that there is a distinction between heat networks in rural/mountain areas and urban zones. In rural areas most of the networks are managed by companies highly involved with local actors. They are mainly fed by biomass, through a supply network involving forest operators and local sawmills. Also, the users participate in the district networks as shareholders or members of the company that provides heat. In short, these networks are managed with an off-grid logic (Kueck et al., 2003), in a search of autonomy pushed by individual local communities. In urban areas, instead, the networks are managed by multi-utilities; they are fed by an interweaving of sources, such as fossil fuels and thermal waste of industrial activities. These networks also serve passive users, a configuration that results from the concentration of the techno-institutional complex of urban regimes. Here networks seem managed with a grid-dependent logic.

4.2. Technical networks and social networks

Technically, district heating networks can be organized in two ways: as a hierarchic provision net, characterized by a productive centre and many nodes/users, or as a decentralized network, with multiple productions centres that all contribute to dispatching heat in the system (the 'co-provision'). In Italy, district heating takes the form of the first type and the relationship between supplier and user, in the networks theory, assumes the connotation of an asymmetric relationship. Also, district heating in medium-large cities, the social network coincides with the technical network. Users passively receive the heat and the only element of dialogue between supplier and user is the definition of the price within a contractual relationship. An alternative relation can only emerge when users organize themselves to challenge the supplier on some issues. To this hierarchical network corresponds a technical-institutional complex dominated by industrial systems, in which technological innovation is applied to preserve the incumbent system. This complex has taken shape within urban contexts where:

[3] Among those, it is important to consider the development strategy of the French utility Engie (ex-Gdf Suez) in Italy. Through the construction of new methane co-generation plants and some agreements signed with municipal administrations, this multi-service company is spreading district heating networks in small and medium-sized cities of the North-West of Italy (between 10,000 and 60,000 inhabitants), and it has very ambitious expansion plans with a series of networks already authorized. In April 2013, Engie and A2A signed a convention with the Municipality of Milan for € 222 million, thanks to which the two companies are committed to connecting the major public buildings to the district heating network, and to supply methane-powered condensing boilers to structures too far from the main line of the heating network.

[4] Among the district heating networks fed by renewable energy, 20 are municipal-owned, 12 belong to private companies with an exclusively entrepreneurial shareholding, whereas all the other cases (90 facilities) run as limited liability companies or cooperatives owned by the local public entities, by citizens/users, or by local economic operators linked to the supply chain (AIRU, 2017).

- local authorities coordinate urban planning policies, in accordance with energy companies and utilities, oriented towards promoting efficient energy production that can lower emissions rather than reducing energy consumption. They also manage those initiatives in a top-down way considering citizen involvement in energy plans too tricky;
- socio-technical equipment (incinerators and thermoelectric plants) strategically use district heating as a tool to make their systems more cost-effective also using the public incentives on energy efficiency for co-generation (i.e., white certificates, de-taxing of the methane used, etc.)[5];
- the presence of primary energy sources in these areas, such as methane (due to the construction of new regasification plant and pipelines) and waste (generally imported by areas where separate waste collection is lacking[6]), combined with incentive policies, pushes for the construction of new co-generation plants or the conversion of existing ones.

The technical networks powered by renewables have a different organization. To a centralized technical network corresponds a distributed social net and the hierarchy among actors is weakened by the corporate structure of these district heat networks. Users are often members or shareholders of the company that manages the network, along with the local authorities and the many suppliers of raw materials (about the case of Austria see also Geels and Johnson, 2018), while biomass suppliers are both shareholders and co-producers of thermal energy (Carrosio, 2010a, 2013). In this case, the technical network arises from a social net already present on the territory, characterized by high spatial proximity and by the strength of social local ties.

These are heterogeneous networks formed by actors who have different roles and bonds among them, but the strength of these bonds lie always in the trust among all the actors of the system, that is also produced by a deep-rooted perception of common territorial belonging (on this: Fritsch and Kauffeld-Monz, 2010). Starting from an existing social net, the technical network has also favoured new bonds, connecting physically – and socially – actors who previously were not in contact. The pre-existing social net allowed the functional incorporation of district heating technology to the widespread interests of local actors, in fact, social relation contextualized in a well-defined territorial area has allowed local communities to achieve a radical technological leap (i.e., from domestic LPG plants to district heating networks powered by renewables). This distributed network corresponds to a techno-institutional complex in which various local actors participate and technological innovation is coherent with widespread interests. This techno-institutional complex took shape thanks to:

- local policies on the decarbonisation (certifications and marketing activities about the 'carbon-free territory' as socio-economic positioning) and a participative management of public deliberation on contrast strategies to climate change (i.e., the European initiative of the 'Covenant of Mayors');
- problems in the management of forest resources (i.e., the diversifying and improving the local economies related to the biomass) and in the disposal of sawmill waste;
- the presence of incentive systems about the production of heat from renewable sources (energy efficiency certificates) and co-generation (green certificates) as well as the very high heating costs of traditional heat production (i.e., domestic LPG systems);
- a local subculture that considers the autonomy and local production of energy as an opportunity to activate strategies of local development.

In short, district heating in rural/mountain areas caused a technological leap from a private system to a collective one. In urban areas, instead, it represented a slow expansion of plants built before the issue of decarbonisation became part of the political agenda and recently it was part of projects to develop urban circular economy. As a result, we can observe that rural networks demonstrate the ability of local actors to incorporate in their relational structure a technological innovation, which substantially modifies the positioning of the local system with respect to the energy transition. In the case of urban networks, on the other hand, the hierarchical network structure leads district heating to become a stabilizing device for the existing system, which defends itself from radical innovations and turbulence at the landscape level. From a relational viewpoint, the introduction of district heating networks produced patchy results depending on the local networks where they are implemented.

Also, in urban district heating, we have moved from a relational model that comprised users self-organized to one that assumes a hierarchical connotation, where conventional producers supply heat to passive users. In rural zones we have moved from the self-organization at individual level to forms of collective self-organization, through new utility participated by users, local authorities, and small businesses that form its supply chain.

This leads us to consider the role of social networks in the energy transition. Apparently, more distributed social nets should increase the systems flexibility in source differentiation. If a community is encouraged to collective self-organization, it should be possible for individual consumers to become co-providers of heat or to establish complementary forms of collective production, such as the solar thermal. For now, in Italian rural/mountain experiences, these organizational forms are not present and the only strong relationships are the corporate participation, the involvement in decision-making processes and the co-provision of biomass for the operations.[7]

5. Wind power and Italian windy territories

5.1. Installed power, companies and municipalities

Around the early 2000s, thanks to the energy market liberalization and public incentive, the wind sector has been pushed out of its test phase becoming an available market technology.[8] Italian wind power passed from 360 MW capacities in 2000 reaching about 9,750 MW in 2017.[9] Also, according to some outlooks, wind capacity could increase

[5] In small-medium cities, district heating networks are combined with new co-generators. This is for instance the business model of Engie, which proposes a standard technological package composed by co-generators and district heating networks as devices that can meet the commitments made to reduce emissions.

[6] In the case of incinerators, they are generally too large compared to the local waste production and utilities need to find waste outside to their own region. This is legally possible only if the facilities are classify as a high energy efficiency waste-to-energy plants (R1 class). The coefficient of 0.6, which certifies the energy efficiency of the systems, can be achieved by channelling the heat into the district heating networks. The facility classified R1 can import waste from outside the region and on the basis of this regulation rule, IREN is planning a new waste disposal plant in Turin to supply a new district heating network; the same is happening in Modena, where an already existing incinerator has obtained the R1 classification.

[7] In this regard, it is not clear, if the rural network users are more likely to energy saving. In fact, it has been shown that in urban areas, district heating is a lock-in element (Carrosio, 2015; Späth, 2005), because the techno-institutional complexes work to improve the heat production and limit the energy retrofitting of buildings (Osti, 2015).

[8] Before the 2000s, mainly the Enea (a Government-sponsored research agency) and the Enel (former monopolist energy state-owned company) installed some testing wind farms in blowy areas of Italy, like Sardinia. With the Decree Law 79/1999, that transposed the EU directive and established the 'green certificate' incentive, the sector rapidly expanded.

[9] Source: Terna SpA, the transmission system operator of the Italian national grid (www.terna.terna.it).

up to 12,600 MW in 2020 due to new facilities and the re-powering of the old wind farms (ANEV, 2017). All the Italian wind power is on-shore facilities and the majority of the installed capacity is located in the South of the peninsula, in particular in the province of Foggia (21.1%)[10]. Recently, however, the increase of small wind plants and the substantial stop of large wind farm construction seem to reveal a different scenario. In 2009–2017, the ratio of installed capacity on plants has constantly decreased, going from 16.7 MW to 1.8 MW. In Europe, Italy passed from the third position for installed capacity in 2009 to the fifth in 2017, and in 2017 only 359 MW were installed compared to 1,798 MW in France, 2,783 MW in UK or 6,440 MW in Germany.[11]

Some factors determined that trend. First, to install wind farms companies have to obtain the building permit by the regional authority through the meeting of local and national agencies (called 'Conferenza di Servizi'). This is a complex process not only because different authorities must issue a clearance on various aspects (i.e., environmental, legal and so on), but also because, pressed by protests of local committees, authorities tend to ask for changes and checks on the submitted projects, delaying the wind farms construction.[12] Available windy zones are also finite resources because of legal limitations (technical prescriptions, environmental protection, preserving archaeological areas, etc.) and the proliferation of large wind farms contributes to reduce them. These legal constraints are less stringent for the small wind plants (no more than 1 MW of power) which were an interesting investment option also because norms do not impose socio-territorial offsets in favour of local communities.[13] Furthermore, in 2012 a new support scheme for wind power was introduced in Italy for facilities over 5 MW capacities: the auctions. As pointed out (Cassetta et al., 2017; Anatolitis and Welisch, 2017), this scheme can reduce the cost of public support for renewables and increase technological efficiency due to competition to obtain incentives. On the other hand, it can cause stop-and-go cycles of the installed capacity discouraging the large wind farms. The auctioned capacity is often not sufficiently high compared to offers; as a result the competition reduces both the chance to build new plants and the smaller actors' competitiveness. As a result, at the same time large groups are favoured and the growth of wind power is restrained (Bissanti, 2018).

The sector is driven by a wide range of companies, from large national and international utilities, to smaller companies that sometimes have partnerships with large companies or investment funds. Therefore, the main installed wind power is owned by large limited companies in which Italian capitals prevail. In particular, more than 30% of installed capacity in 2017 was owned by 5 utilities:

- ERG Renew (Italian company, partnership with the financial and banking group UniCredit, 11,9% of MWs)
- Enel Green Power (Italian utility, the Ministry of Economy is a shareholder, 8.2% of MWs)[14]
- E2i Energie Speciali (Italian-French utility, the Italian F2i investment fund is the main shareholder, 6.2% of installed capacity).
- Fri-El Green Power (Italian company with European partnerships with German RWE and French EDF, 3.6% of MWs)
- E.ON Climate Renewables (German utility, 3.5% of installed capacity)

These utilities invest in innovation and aim to expand their capacity through the repowering of old facilities or experimenting storage systems, as the Enel Green Power experimental storage system coupled with a wind farm located in Pietragalla (Basilicata, Southern Italy). In addition, despite the that fact norms have clarified since 2005 that royalties to Municipalities are not due, the utilities tend to give funds to the territories avoiding higher social tensions. In these cases an 'enlarged exchange' takes place, since relationships are established between the company and the local communities, with mutual benefits that also determinate a reduction in the tax levy and improvement of local public services (Osti, 2012, 2016). The E2i Company, for instance, plus to the one-off environmental compulsory compensation, provides free contributions to support local social initiatives in the Municipalities where wind farms are located (€ 65,000 in 2016, according to its Annual Report). The utility supports monitoring the environmental impact of wind farms, offers job opportunities and, in some cases, although reducing its amount, continues to pay royalty. With regard to large plants, there are also a few cases of Municipalities that are shareholders of wind farms or wind facilities built by local companies that have sought to promote collaboration with communities in order to obtain greater positive effects at the local level (i.e., jobs, revenues, etc.).[15]

On the contrary, small wind power is more widespread compared to large wind farms (Fig. 3) and Italian enterprises prevail along the entire value chain (from the manufacturing sector of facility components to the plant maintenance services). These are often small-medium companies with limited financial resources but innovative and dynamic ones (Energy Strategy Group, 2012). According to some reports (Zanchini et al., 2017), the small wind plants are owned by private subjects (i.e., farmers) or public entities (like the Municipalities) which install few thousand of kWs with the intent of self-production. In particular, these plants are mainly located in the Centre-Northern Italy. However, as it was stressed, there are also little companies or fund companies that invest in the small wind plants to exploit the lower regulatory burdens and market advantages of this technological option.

5.2. *Technical networks and social networks*

Due to a legislation that does not allow selling renewable energy direct to customers, the wind technology is mainly driven by a grid-dependent logic, despite some participatory experiences. Through a territorial perspective it is possible to stress that wind power is held by large utilities or small-middle companies that operate mainly in the South of Italy as mere energy producers. Therefore, wind power is embedded in specific techno-institutional complexes in which the local features determinate the kind of the social networks connecting the wind power to the territories.

Often, in the case of large wind farms, the configuration of social network coincides with the technical network organized in a hierarchical and asymmetric way. In fact, consumers sign supply contracts

[10] Source: GSE (www.gse.it).

[11] Source: EurObserv'ER, a consortium dedicated to the monitoring of the development of the various sectors of renewable energies in the European Union (www.eurobserv-er.org).

[12] The literature on the social acceptability of renewables is wide. Here remind the remarkable work edited by Wüstenhagen et al. in 2007, mainly on wind power, and some recent works on the case of Italy: Caporale and De Lucia (2015) and Cavicchioli and Garofalo (2015). These studies also stress the lack of the public involvement in Italy about the decision process on the wind farms construction.

[13] In Basilicata region (Southern Italy), for example, has been established a set of rules to manage wind farms preserving the natural environment and obtaining offsets for local communities (i.e., funds for local development plans). These rules are not direct to the mini-wind plants that grew with no particular limitations. According to GSE (the Italian governmental agency that support renewables), on 2017, about 90% of the wind plants in Basilicata are facilities to sell energy that does not exceed 1 MW of power (Scotti, 2013).

[14] Source: ANEV database and company websites.

[15] The Municipality of Roseto Valfortore (province of Foggia), for example, has a 35% stake in the company 'Aria Diana', which operates a 4 MW wind farm. On the other hand, the small local company 'Gargano Energia', made up by almost 20 entrepreneurs of Rignano Garganico (province of Foggia), installed a 38 MW wind farm trying to sell 10% of stakes to local citizens (plant now owned by E2i). Another examples is the utility 'Fortore Energia' of Lucera (province of Foggia) that realized several wind farms establishing important collaboration with local Municipalities. Source: research data.

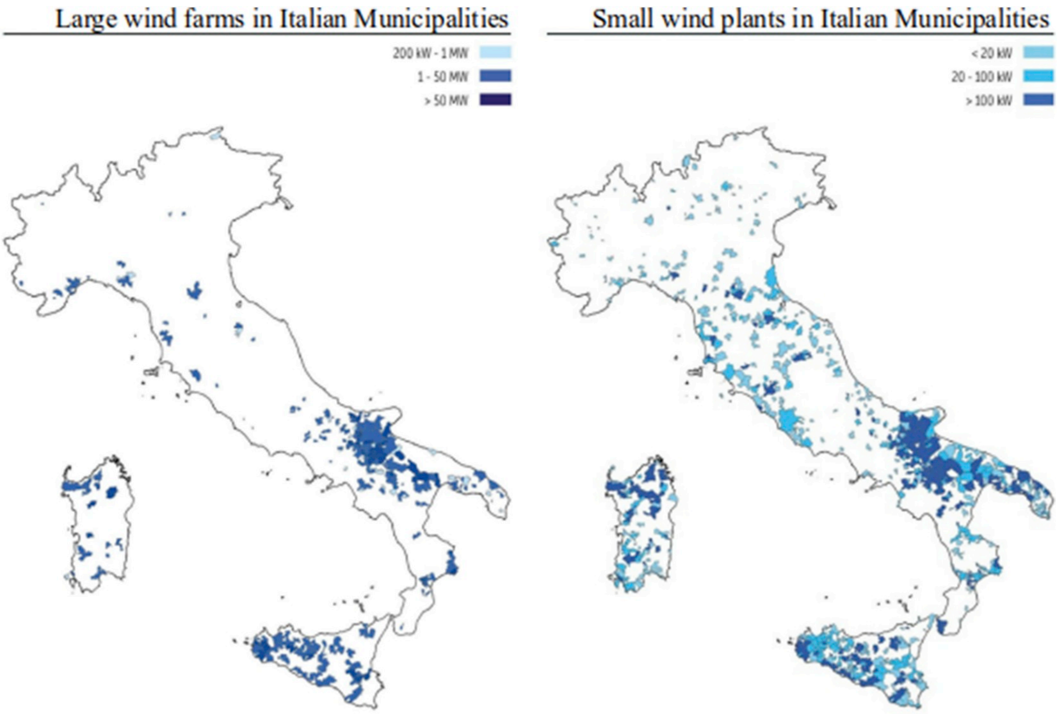

Fig. 3. Large wind farms and small wind plants in Italy, 2016 (from Zanchini et al., 2017).

with market operators that can offer green electricity, but with no direct link with the wind plants close to final users or the chance to influence wind companies. Also the relationships between communities and wind plants are indirect. They can be negative, conflictual, due to the protests of local committees on environmental problems, but also positive for some paternalistic actions (i.e., the sponsorship of local events) or contractual agreements (i.e., the Municipalities receive funds or technical support for environmental policies). In short, to a hierarchical technical network corresponds a rural techno-institutional complex in which the large wind facilities have both reinforced the incumbent provision system and slightly changed the energy model supporting the adoption of small self-production energy technologies (i.e., photovoltaic panels) or saving energy options (like thermal insulation systems) at the local level. More specifically, the intertwining of interests among local authorities and utilities can determinate mutual benefit in rural areas when public authorities set themselves up as the promoter of the transition (Magnani et al., 2017).

Conversely, the small wind plants can be potentially embedded in a decentralized technical network in which it is possible to establish a wider user participation. Despite the fact that only the self-consumers can take direct advantage from wind facilities, with this technology appears to facilitate the establishment of a collective or municipal ownership of the energy facilities. Participative small wind plants can generate greater direct and direct advantages for those who take part of their implementation, configuring a technical network that weaves social actors and diversified interests. In these cases, as it was stressed (Scotti and Minervini, 2017), the technical network develops within a pre-existing social network, in which the trust between the actors, the sense of territorial belonging and the ability to connect norms, technologies and socio-economic aspects allows the realization of wider positive effects at the local level. In the participatory plant experiences, the technical network seems to favour the creation of new social bonds based on wider economic and ecological interests, while the pre-existing social network appears to allow the incorporation of wind power into the widespread local interests. This promotes a technological leap: from passive consumers to co-producers of energy. Where renewables are managed in a participated way below, the techno-institutional complex takes shape from the interweaving of local policies of ecological sustainability and land management, as well as, a political subculture that considers the renewables as an important resource to promote the local development. (Carrosio, 2010b; Scotti, 2011).

In short, in Italy the large wind farms appear mainly as a 'green' innovation of the incumbent energy system, because their highly hierarchical technical network makes wind power a stabilizer of the existing provision system. On the other hand, the small wind turbine systems, developed more recently, appears to allow, at least in some conditions, a radical innovation of the energy system because they can meet broader local interests through a shorter energy supply chain. Anyhow, for the large as well as for the small wind facilities, the way in which energy innovations are incorporated into the local relational context appear subordinate to the initiatives that take place by the local actors and the local authorities. They can face the exogenous processes of the energy transition that affect their territories in different ways obtaining differentiated results.

6. Conclusions and policy implications

In this paper the networks perspective and the territorial frame has helped to show in a more clear way how socio-technical regimes can not be considered as consistent units, but as fragmented assemblages of different techno-institutional territorial complexes. In this way the transition process appears with different speeds and forms depending on the territorial contexts that influences the modalities of spread of technological energy devices across national local contexts. In our study the district heating and the wind power, produced ambivalent outcomes in the territories in which they were implemented. This leads us to take into consideration the role of the social networks in the energy transition process. Moreover, the analysis of Italian case-studies shows that a more distributed technical network seems able to increase the complexity of the energy system, namely, the used sources (renewables) and organizational models (co-provision).

To date, the experiences taken into consideration in this paper, even in rural or mountain areas show that a deep social change has not happened in the energy system except in a few cases. Generally, there still prevails an asymmetric relationships, basically because territorial actors are mainly involved in monetary exchange with the energy innovation agents. They can provide biomass for the district heating systems or land for wind farms (for which they receive a rent or compensation for expropriation), but only in rare cases they are energy co-providers (supplying heat or electricity to the network through their own plants) or co-proprietors of the renewable facilities. According to the analysis, this social configuration related to energy happens because the technical-institutional complex is enacted within an asymmetric relationship where energy production prevails, rather than favouring of local projects of energy reconversion of territories. This tends to create lock-in conditions that stop the radical change, as it was observed in the case of the district heating systems that lessen the spread of the buildings energy retrofitting initiatives (Carrosio, 2015; Osti, 2015).

Considering the link between the technical and social networks in a territorial perspective allow us to understand a little better the role of the local techno-institutional complex in the energy transition. Through the frame adopted it has been possible to pinpoint two alternative situations that can be considered as two alternative models within the energy transition process. In the rural areas, the district heating has caused a technological leap of the local techno-institutional complex because it was incorporated in a pre-existing social network with strong social bonds. In short, the technology strengthened the social local bonds by involving various actors in a collective project of energy chain. In urban zones, instead, the district heating worked as a stabilizer of the techno-institutional complex. First of all, it has enabled the fossil energy systems–that are no longer competitive–to profitably use their thermal waste in a circular economy model. Furthermore, it has consolidated the hierarchical local system by creating new bonds in the 'block' of producers.

The wind power, on the other hand, has allowed a radical technological leap only in few cases where the local techno-institutional complex have been joined with the technical network to exploit the economic advantages of the investment in wind energy. Briefly, the initiatives of private subjects (i.e., agritourist companies, supporters trust) and those of local authorities (like the Municipal shareholding to large wind farms or the Municipal ownership of small wind plants) have incorporated the technological option into the territorial context promoting the social innovation. However, the wind power (also because of a legal framework) worked as a stabilizing device of the local techno-institutional complex. As it was shown, in particular large wind farms did not transform the producer-consumer relationship, if not indirectly in the market exchanges, and they also consolidated the process of dependence of the rural economy by external investments, especially in Southern Italy.

In short, the analysis suggests that the techno-institutional complex tends to self-preserving and the energy transition is influenced by the way in which the territorial framework is destabilized by the perturbations of the landscape. However, further insights would be necessary to investigate in more details micro-dynamics on resistances and innovations in the energy transition at the local level and which role could play the different path-dependent local experiences of transition.

Declarations of interest

None.

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