District heating and ambivalent energy transition paths in urban and rural contexts

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ABSTRACT

Most institutions and industrial actors believe that district heating infrastructure can play a key role in accelerating the transition to low-carbon energy systems. In this article we test this belief in Italy, starting from a census of all existing plants, subdivided by sources of supply and business organization models. We isolate two types of district heating (urban and rural) and find that they are different with respect to their approaches to energy transition. In rural areas, networks constitute systems that can empower the local techno-institutional complex to achieve a technological leap. Set in a pre-existing social network, district heating reinforces a sense of community and facilitates the involvement of various local players in a collective project. In the case of biomass, we are faced with local systems that have almost completed the transition with regard to the production of thermal and sometimes electric energy. In urban areas, on the other hand, networks represent functional devices for the stabilization of the techno-institutional complex. They allow cities to work on the circularity of some economies, generating added value from the same factors of production. The discrepancy between urban and rural contexts thus highlights the need to consider the ambivalence of district heating technology.

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1. Introduction

District heating networks are spreading very rapidly across Italy and the rest of Europe (Connolly et al., 2014; Di Lucia & Ericsson, 2014; Gabillet, 2015; Geels & Johnson, 2018; Hawkey, 2012; Magnusson, 2012, 2016; Webb, 2015). Most institutions and industrial actors believe that such infrastructure can play a key role in enabling urban systems to become more sustainable as well as in accelerating the transition to more efficient and low-carbon energy systems. One only needs to consider the strategic role that the National Energy Strategy (SEN) assigns to district heating in the decarbonization of Italy's energy system, or the relevance attributed to it in the Energy Roadmap 2050 of the European Commission (Connolly et al., 2014).

Thanks to their versatility in being supplied through different sources, district heating networks in some countries have accompanied the transition away from heat production systems based on fossil sources towards systems where renewable sources account for more than 50%. This is the case in Sweden, for example, where the share represented by fossil fuels in heat production is below 5% and where district heating accounts for 90% of urban consumption (Dzebo & Nykvist, 2017).

District heating networks are flexible systems for the acquisition of heat from various sources. In fact, a district heating network can be powered simultaneously or alternatively from various sources and different heat production technologies, including fossil fuel cogeneration plants, thermal waste from incinerators and industrial processes, biomass power stations, stations producing only hot water from renewable and non-renewable

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sources, heat pumps, concentrated or distributed thermal solar panels and geothermal heat. In some countries, these networks are connected to nuclear power plants for the use of excess energy (Cowan, 1990; Leurent et al., 2018), such as in the case of the new reactor of the Leningrad II power plant in Russia, which is equipped with a district heating network. In other cases, these networks are functional to the storage of energy produced from renewable sources: this is particularly the case for wind power that exceeds the instantaneous network demand (Lund, 2005), as in the Spandau district of Berlin, whose network is powered by a wind farm. Thanks to this technical flexibility, district heating networks are considered functional to accelerating the energy transition. Indeed, they are not only flexible towards a plurality of sources (Lake et al., 2017): unlike domestic heating systems, they also allow for the simultaneous actions of a large number of users.

Despite these positive aspects, the evolution of the diffusion of district heating networks in Italy seems contradictory. In this country, 90% of the heated volume in district heating is obtained through non-renewable sources. The main sources of energy utilized are methane and waste, which are especially found in district heating networks that serve medium-large cities. By contrast, renewable sources like biomass and geothermal energy excel in some small rural centers. Due to this differentiation in the mix of sources and such a clear difference between urban and rural contexts, it is necessary to discuss this issue in terms of the ambivalence of district heating, which takes on different connotations with respect to the energy transition. In cities, where large utility conglomerates are often headquartered, district heating networks represent an instrument for restructuring urban technical-institutional complexes. The networks here serve as a form of ecological modernization of energy production and as dispatching systems based on non-renewable sources. Networks become stabilization devices, facing the turbulence that comes from the landscape and from niche innovations. In rural areas, on the other hand, where the pervasiveness of utilities is historically more contained, district heating networks seem to be able to increase local energy autonomy, helping to build more flexible energy systems based on renewable sources. Networks become devices capable of making the technological leap towards localized energy systems.

Faced with these considerations, the questions that motivate this paper are the following. For what reasons does a socio-technical device take on such different connotations in different socio-territorial contexts? What are the dimensions that explain these differences? Are the variables contained in the multilevel perspective (MLP) model (Geels, 2014) – which generally provides the theoretical framework in studies on energy transition – sufficient to bring out territorial distinctions?

The article is organized as follows. In the first part, the article provides a methodological and conceptual framework to investigate the diffusion of district heating networks in Italy and to understand the role they play in the energy transition. MLP, a dominant approach in these types of analyses, is integrated with a relational approach and a territorial perspective. The second part reconstructs the diffusion of district heating in Italy. The description of the networks reveals two different models (urban and rural) that take on different connotations from the point of view of the technical and social energy transition. In the third part, the article analyzes the establishment of district heating in different territorial contexts, where social networks assume a co-evolutionary role with respect to technical networks. The network perspective leads us to identify different relational models among the actors that constitute the socio-technical networks. The conclusions provide some elements of interpretation emerging from the previous parts as well as some scenarios on future evolutions of district heating *vis-à-vis* the issue of energy transition.

2. Theoretical framework: multilevel perspective, networks and territory

A widespread approach to understanding the dynamics that underlie the energy transition is the multilevel perspective (Geels, 2002; Geels & Schot, 2007), which interprets transitions as being the results of interactions between different levels: niches (places where they take shape as radical innovations), socio-technical regimes (places of consolidated practices and systems of rules, norms and institutions that enable and constrain historical actors in relation to existing systems) and the socio-technical landscape (generally discussed as the landscape) that serves as the background and that represents the general framework within which these broader processes take place. According to this approach, innovations develop in niches, but encounter hostility on the part of socio-technical regimes that seek their own self-preservation and try to avoid being destabilized.

When changes at the landscape level are so strong that the regimes are destabilized from the outside, windows of opportunity present themselves and allow actors to disseminate the radical innovations originally generated in the niches. The alignment between niches, regimes and landscape allows radical innovations to assert themselves, producing technological leaps and opening new spaces to promote social change.

According to several authors, this approach presents some problems. First, it lacks an explicit focus on the political economy and on existing regimes' struggle for preservation (Geels, 2014; Meadowcroft, 2011; Smith et al., 2005). The regimes' stability is often conceptualized in terms of lock-in (Arthur, 1989; Islas, 1997), path dependence or inertia (Liebowitz & Margolis, 1995), sometimes with reference to the 'technological momentum' metaphor (Hughes, 1983). These approaches seem to postulate the regimes' resistance as a form of technological automatism, where the interaction between actors within the organizational field becomes a technology-dependent variable.

Moreover, it has been stressed (e.g. Bridge et al., 2013; Devine-Wright & Wiersma, 2013; Hui & Walker, 2018) that the MLP approach does not sufficiently consider the local territorial dimension of techno-institutional complexes. With the concept of socio-technical regimes, we perceive the dominant energy system on a national scale, taking for granted the fact that different states have institutions, systems of rules and dominant technological paths that distinguish themselves from others (Ćetković & Buzogány, 2016). National differences are conditioned by the various forms of capitalism within which the transition is embedded (for a critical view on this point, see Cherp et al., 2018). Landscape, on the other hand, refers to global processes, which derive from slow changes in macroeconomics, cultural trends and macro-political developments.

Therefore, this approach does not seek to identify an intermediate level between niches and socio-technical regimes and landscapes. For this reason, it is unable to account for the territorial (Bridge et al., 2013; Coenen et al., 2012) and the relational dimensions (Osti, 2012) of social innovation processes. Multilevel dynamics are hence investigated without any reference to how the transition takes different forms and has different speeds depending on the spatial context. At the same time, disregarding the relational perspective leads scholars to ignore the role that local social networks play in influencing the modalities with which technological devices are spread across local contexts (Valente, 2005).

This investigation into the expansion of district heating networks in Italy regards it as necessary to introduce a territorial and relational perspective within the MLP model. According to many authors (Avelino & Wittmayer, 2016; Chilvers & Longhurst, 2016; Osti, 2012; Walker & Cass, 2011), every technological process is incorporated and co-evolves within a system of multiple relationships. Moreover, there are environmental conditions and localized characteristics that affect the transition differently from place to place. Both the networks approach and the territorial perspective suggest that there is no monolithic socio-technical regime. There is certainly a dominant socio-technical regime at the general level, but when moving the analysis to the local level, it immediately becomes clear that within it there are different techno-institutional complexes, positioned in different points of an ideal continuum that places fossil energy systems and renewable energy sources at its two extremities.

Local techno-institutional complexes are locally based configurations of technological infrastructure, organizations, government institutions, businesses and consumers, in which technological systems and public and private institutions become interconnected in social networks by nurturing one another (Unruh, 2000). As stressed by Walker and Cass (2011), sociology must consider the ways in which certain spaces and localities attract or favor certain socio-technical configurations and reject others.

Indeed in this article we consider socio-technical regimes as being fragmented into different local techno-institutional configurations.

It is the sum of changes at the level of local complexes that produces changes at the regime level. The regime aligns local complexes in a dominant system when it is urged to do so by external turbulence. Some territories have already introduced radical innovations with respect to energy production and consumption, while in others the resistance of local techno-institutional complexes and regimes puts a brake on the transition. This multifaceted reality begs for a closer look at how and where district heating has spread in Italy as well as for a description of its main characteristics.

3. Methodology

To this end, we combine the systematization of data deriving from the national census of district heating plants for the year (*Associazione Italiana Riscaldamento Urbano*, AIRU, 2017) with interviews with key informants. The census data concern all the district heating plants in Italy. Information regarding the location, energy source, size (district heating family number) and characteristics of the company that manages each plant is available. Through the intersection of the data collected by censuses and web information, 12 subjects were identified and subsequently interviewed as territorial key witnesses in contexts characterized by the presence of district heating systems. These figures included sector experts, company representatives, regional officials and local authority representatives. In particular, interviews were carried out regarding the plants in Brescia, Milan, Dobbiaco and Campo Ligure. The first two are cases of district heating in medium-large cities, with systems dependent on fossil fuels and the presence of incinerators and the main protagonist is the multi-utility that manages water, energy and waste services in Lombardy. By contrast, the other two cases are located in medium-small mountain municipalities. Their networks are powered by plant biomass and the main protagonists are user cooperatives, in which most of the locals participate. In terms of the socio-organizational model, the type of supply and the territorial dimensions, the four cases are representative of the variety of case studies that exist at the national scale.

4. Distribution and characteristics of district heating in Italy

District heating was introduced to Italy in the 1970s. The first network was created in 1970 in a single neighborhood of Modena with the direct intervention of the municipality, which entrusted the management of the service to the company AMCM, merged years later into the Hera group (Esposito, 2017). In the following year, the Brescia network was created, which today serves 70% of the city's buildings (both residential and business), mainly thanks to a heat production plant that uses waste as fuel. Together with Brescia, another important example of a district heating development is Reggio Emilia, where the network was built in 1981 and today is capable of providing district heating to approximately 50% of the homes in the city. Turin's network was established in 1984.

As demonstrated in Figure 1, in the first 20 years of district heating in Italy, the technology grew relatively slow. The networks involved some neighborhoods of medium-large cities and slowly multiplied in the areas of influence of the first municipal companies to adopt this technology to distribute thermal energy. From 1971 to 1995, 45 networks were created, but only eight networks between 1995 and 2000.[1] Up until 2002, district heating grew largely as an expansion of existing networks. The real boom in terms of district heating volume was from 2000 to 2016, with the construction of 186 networks. In 2016, 193 municipalities had at least one district heating network within their borders; this figure was just 27 in 2000. Heated volume has also grown exponentially over the last decade. To date, it is estimated to be equal to approximately 360 million cubic meters (in 2000 it was around 130 million), with a projected doubling of volume by 2022. In fact, there are several projects for new district heating networks as well as for the expansion of existing ones.

In terms of geographic distribution, Northern Italian regions (especially Lombardy and Piedmont) are characterized by higher degrees of urbanization and industrialization and also have the greatest district heating volumes. However, in terms of district heating volume in relation to resident population, rural and mountain areas (especially Trentino-Alto Adige and Val d'Aosta), characterized by the importance of agriculture and rich in natural biomasses, emerge as significant.

Most of the plants that produce heat are fueled with methane (71.1%), followed by waste incineration plants (13.7%). The contribution of renewables is still marginal (10.7%), although in numerical terms there are many rural and mountain areas that use biomass and geothermal power plants to produce heat.

The types of systems vary, including cogeneration plants, thermoelectric plants and boilers that produce only heat. In recent years, cogeneration plants and power plants that use thermal waste have grown considerably, additionally thanks to policies of incentivization for the efficiency of energy production systems.

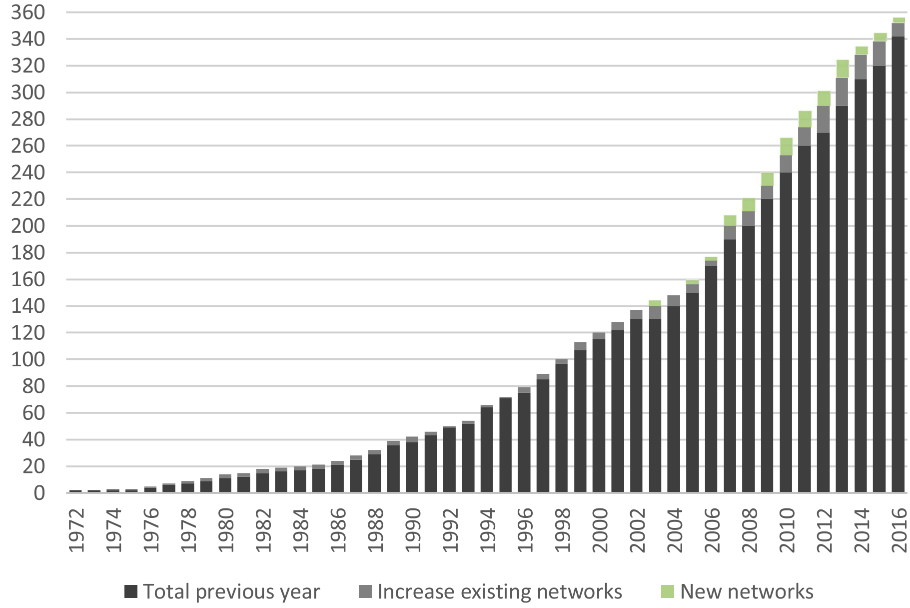

Figure 1. District heating volume per year in millions of cubic meters in Italy (1971–2016).
Note: Elaboration on AIRU 2017 data.

The main operators of these networks are the largest multi-utility conglomerates of Northern Italy, such as A2A, Hera, EGEA, IREN, Agms and Acea. Together, these operators hold 75% of the district heating volume, while the remaining 35% is divided among 140 operators. In terms of district heating volume, the most important company is A2A (26%), which manages both the Milan and Brescia networks. This is followed by Iren (25%) and Hera (6%).

A2A is working on doubling its district heating volume by the end of 2018, thanks to the connection of the Cassano d'Adda thermoelectric power station – currently not equipped with a cogeneration system – which is 40 km from the center of Milan (Dénarié et al., 2019). The heat recovered from the power plant is able to cover 30% of the city's thermal demand and also supply heat to inhabited areas of the municipalities in Milan's metropolitan belt that lie along the pipeline's route. Moreover, the operator IREN intends to reach 84 million cubic meters through the expansion of its networks and the construction of a new waste incineration plant and a new methane plant, expanding its services in a number of municipalities belonging to Turin's metropolitan belt.

Even if its volume is still not very relevant, the growth strategy of Engie (former Gdf Suez) is also very interesting. Through the construction of new methane cogeneration plants and the stipulation of agreements with municipal administrations, this multi-service company is spreading district heating networks acros small and medium-sized cities of the North-West (Wollmann et al., 2010). Today it operates in 12 municipalities with populations between 10,000 and 60,000 inhabitants. The French group has also built and managed the Turin Spina 3 district network, built during the 2006 Winter Olympic Games to serve a new housing conglomerate for the event. Engie stands as a partner of the municipal administrations, proposing district heating as a means of energy saving and efficiency for both public buildings and private homes. In the agreements stipulated between municipalities and companies, Engie undertakes the building of cogeneration plants and district heating networks, obtaining concessions to use public land for 25 years. The municipalities, in exchange, usually receive the heating supply at rates far below market prices. 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 major public buildings to the district heating network as well as to supplying methane-powered condensing boilers to structures too far from the main line of the heating network.

There are 122 plants powered by renewable sources, of which 102 are powered by biomass, 19 are geothermal and one is a solar thermal plant, part of a very extensive network within the city of Varese and fuelled primarily with methane. Biomass plants are mainly concentrated in Trentino Alto Adige (there are 66 in the province of Bolzano and 17 in the province of Trento) as well as in some scattered areas of the Alpine mountains and the central-northern Apennines. By contrast, the geothermal plants are all located between the provinces of Pisa and Grosseto, in the area of Larderello. Almost all renewable energy plants were created between 2000 and 2016. An interesting detail is the number and the nature of the operators of renewable energy plants.

Renewables account for only 10.7% of the district heating volume, but they represent 73% of the total number of operators active in district heating. On the other hand, fossil fuels account for 89.3% of the volume, concentrated in the hands of just 26% of the operators.

Among the renewable energy networks, 20 list a municipality as their owner, 12 belong to private companies with an exclusively entrepreneurial shareholding, whereas all the other cases (90 facilities) are 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. In particular, in Alto Adige, like in other regions across the Alps, the district heating networks are for the most part built and managed by user cooperatives and are powered by virgin biomass. These networks are managed with an off-grid logic (Kueck et al., 2003), in search of the greater autonomy demanded by individual local communities. Urban heating networks, on the other hand, are managed with a grid-dependent logic, where the local network is connected to very large and complex supply networks (e.g. methane, coal, waste).

From the census of the plants alongside the territorial map depicted in Figure 2, it is evident that a distinction is necessary between heat networks in urban areas and heat networks in rural/mountain areas.[2] In urban areas, the networks are managed by multi-utility companies and are fed by an interweaving of sources including the methane, waste, coal 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. In rural areas, on the other hand, most of the networks are managed by companies that are highly involved with local actors. Moreover, they are mainly fed by biomass, through a supply network involving forest operators and local sawmills. Furthermore, the users participate in the district networks as shareholders or as members of the company that provides heat.

The territorial collection of data has shown that there is a very wide variability in the adoption of heating technology. This necessitates consideration of the energy transition in a national context, as the sum of many transition models that take shape on a local or sub-regional scale. Here is one of the critical points pertaining to the MLP model, which instead adopts a method attributable to 'methodological nationalism' (Beck &

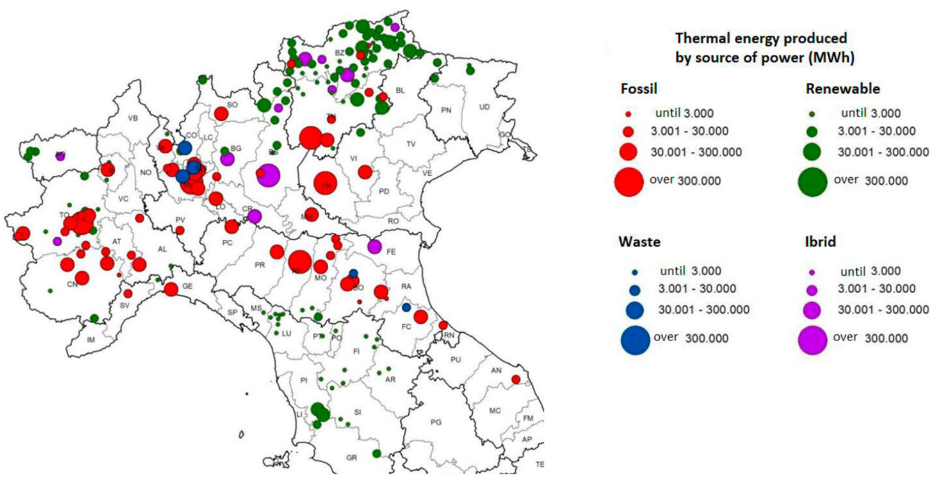

Figure 2. Territorial distribution of district heating networks by source (AIRU, 2017 data).

Levy, 2013), unable to look at the different transition models that occur on a local and trans-border scale. For this reason, in the next section we try to consider two variables that could permit the integration of the MLP model: the territorial dimension and the relational one.

5. Discussion: analyzing technical and social networks across territories

From a technical point of view, district heating networks are usually hierarchically organized networks, characterized by a productive center that distributes heat to many nodes/users. In some cases they can take the form of decentralized networks, with multiple production centers that contribute together to deliver heat within the same dispatching system. However, at least in the networks present in Italy, there are no cases of co-provider systems that can inject heat from domestic production devices into the network. The general working relationship is therefore the classic one between supplier and user, which in the language of networks assumes the connotation of an asymmetric relationship. As emerged from the interviews, despite these common characteristics in the technical network, key territorial differences can be identified on the one hand in the underlying social networks (i.e. in the relationship between producers and consumers) and on the natural sources they use on the other.

In the case of networks serving medium-large cities, they are mostly powered by fossil sources, waste and a set of industrial sources. Here the configuration of the social network coincides with that of the technical network. Users passively receive the heat in their homes within the framework of an exclusively contractual relationship, where the only element of dialogue between supplier and user is represented by the definition of the price of heat. The relational bonds available to the users all point to the production center. The only bonds that might arise between users are associative, in the event that some users organize themselves to assume a unionized position and challenge the supplier on some grounds. This very hierarchical network is complemented by a corresponding techno-institutional complex decidedly dominated by industrial systems, where technological innovation is consistent with the preservation and strengthening of the system that has been created over time. This socio-technical complex is the result of the interaction of a variety of factors (Figure 3).

As stressed by the interviewees, first of all a role is played by local institutions that coordinate urban planning policies with utilities and energy companies. Local institutions, which regard the organization of citizen involvement in energy-saving plans too complex, use district heating networks as a privileged tool to address climate-changing emissions in a managerial way. This clearly occurs in the use of a local planning tool like the Covenant of Mayors.

The presence of socio-technical equipment, such as incineration plants and thermoelectric plants, also contributes to a technically and socially centralized district heating system. Local institutions' conservation strategies consider a district heating an instrument capable of making the system more efficient.

A role is additionally played by incentive systems that reward the construction of high-efficiency methane co-generators, for which a series of facilitations are envisaged: assignment of white certificates, de-taxing of the methane used, exemptions from obligations to purchase green certificates and priority in dispatching electricity. In particular, in small and medium-sized cities, district heating networks are combined with new co-generators, whose construction represents an interesting business opportunity for electricity companies. This is for instance the business model followed by one of the major utilities, Engie, which proposes a standard technological package composed of co-generators and district heating networks as devices that can meet the commitments made to reduce emissions. Linked to this, the availability of primary sources of energy such as methane (following the construction of re-gasifiers and new pipelines) and waste also impels the construction of new cogeneration plants (Upham & Jones, 2012).

If we look at rural areas, a different socio-technical complex emerges. In rural areas, technical networks are mostly powered by renewable sources, especially biomass from sawmill waste or forest management. In these cases (and as emerged from the interviews), a centralized technical network corresponds to a distributed network from a social standpoint, where the hierarchy between actors is weakened by the structure and constraints that regulate the corporate structure of these realities. In fact, users are often also members or shareholders of the company that manages the network, along with the local authorities and the many suppliers of raw

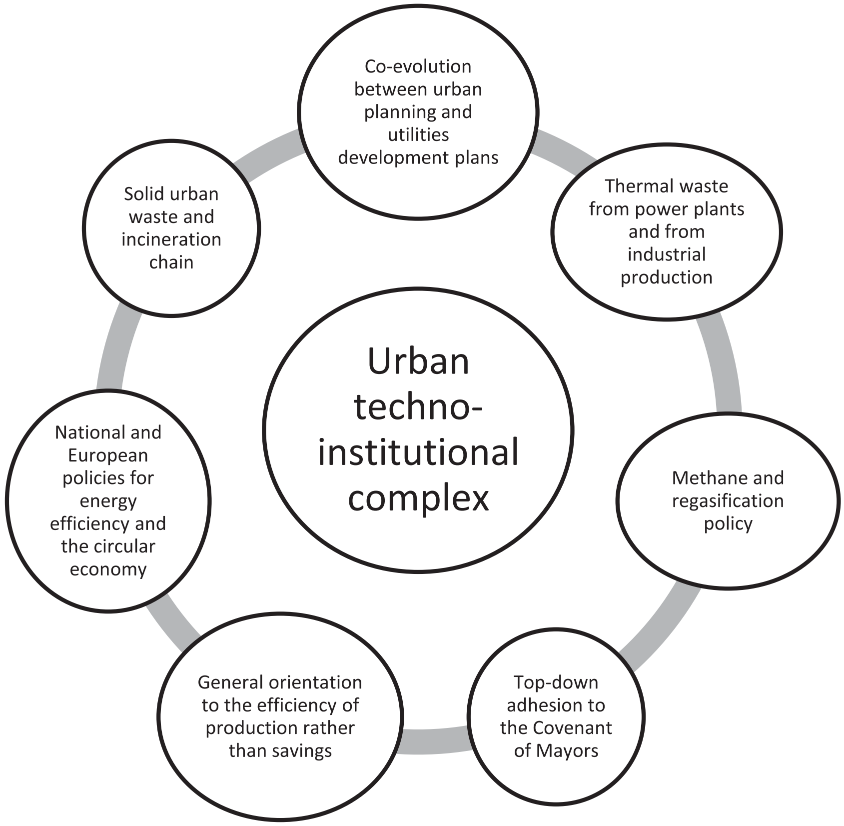

Figure 3. The local techno-institutional complex of district heating in urban areas (own elaboration).

materials (see also Geels & Johnson, 2018, on the diffusion of Austrian biomass district heating systems). The users participate as shareholders, while the biomass suppliers operate as both shareholders and co-producers of thermal energy (Carrosio, 2013). There is no strict determinism between the construction of a technical network and the formation of a social network. In most rural areas, the technical network arises from a social network already present in the territory, characterized by close spatial proximity, the coexistence of heterogeneity and the strength of local ties. These are heterogeneous networks because they are formed by actors who have varied roles and differentiated bonds between one another. Nevertheless, the strength of these bonds is determined by trust between all of the system's actors, which is also made possible thanks to a deep-rooted sense of territorial belonging. Starting from an existing social network, the technical network favors the creation of new bonds, physically (and consequently socially) connecting actors who previously were not in contact. The pre-existing social network, however, enables the incorporation of district heating technology, making it functional to the widespread interests of local actors. The structure of social relations, contextualized in a well-defined territorial dimension, allows local communities to achieve a radical technological leap. Rather than domestic plants remaining based on liquefied petroleum gas (LPG), diesel oil or methane, many have moved to district heating networks powered by renewable sources. This distributed network corresponds to a techno-institutional complex in which various local actors participate and where technological innovation is coherent with widespread interests. As shown by Figure 4, this techno-institutional complex has taken shape thanks to various factors.

A key role has been played by local policies that support decarbonization, through the pursuit of certifications as well as marketing activities in the territory that regard the idea of a 'carbon-free territory' as an element of value and socioeconomic positioning. A distributed district heating network also responds to a

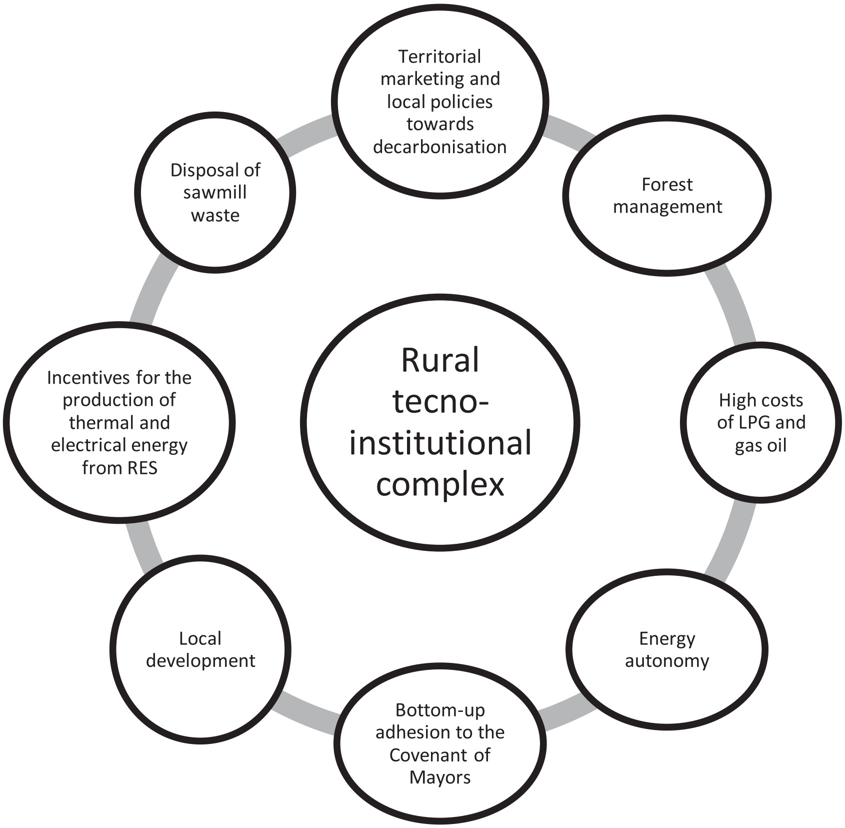

Figure 4. The local techno-institutional complex of district heating in rural areas (own elaboration).

problem in the management of forests as well as sawmill waste, which requires the diversification of economies related to biomass in order to extract greater added value, starting from the same commodities. Moreover, in rural areas, a bottom-up adhesion to the Covenant of Mayors prevails, thanks to a territorial dimension that facilitates the management of public deliberation on strategies to combat climate change. Furthermore, the presence of incentive systems that reward the production of heat from renewable sources (energy efficiency certificates) and biomass cogeneration (green certificates), in the face of very high heating costs for other technologies like domestic LPG or diesel systems, have enabled the emergence of decentralized rural district heating. Other contributing factors include a local sub-culture that welcomes autonomy with regard to energy supply and the production of energy from localized resources being seen as an opportunity to initiate local development chains.

In sum, this analysis shows that in relation to the energy transition, the introduction of district heating networks has produced ambivalent results depending on the local social networks where implementation has occurred.

As shown in Table 1, district heating can assume different relational models: user involvement can be high, where the users themselves are suppliers of raw materials for the operation of the plant, or are members of the company that manages the plant; or it can be low, where the relationship between producer and consumer is hierarchical. When the involvement of utility companies (conventional producers) is low, we find forms of self-organization. In these cases, the users – whether individually or collectively – organize themselves to produce and consume heat.

Whereas district heating in the countryside has spread widely in recent years, imposing a technological leap from domestic devices to a collective system, in the case of urban contexts, this process can be best described as

Table 1. District heating models (own elaboration).

		User involvement	
		High	Low (or non-existent)
Involvement of conventional producers	High	Co-provision	Hierarchical model
	Low (or non-existent)	Self-organization of users at a collective level	Self-organization of users at an individual level

the slow extension of existing plants that were created when the issue of climate change and decarbonization were not yet part of the political agenda. As a result of these dissimilar development paths, we can observe that rural networks demonstrate the ability of local actors to incorporate within their relational structure a technological innovation. This substantially modifies the positioning of the local system with respect to the energy transition. In particular, in rural or mountain environments, the introduction of district heating has stimulated energy systems to shift from the self-organization of users at the individual level to forms of user self-organization at a collective level, through the formation of new utility providers with the participation of users, local authorities and small businesses, which together form its supply chain. In the case of urban networks, on the other hand, the hierarchical network structure has caused district heating to become a stabilizing device for the existing system, which defends itself from radical innovations and turbulence at the landscape level. In urban contexts, district heating has prompted a shift from a relational model that formerly comprised users who were individually self-organized within condominiums, to a relational model that assumes a hierarchical connotation. This model entails the presence of a conventional producer that dispenses heat to a passive consumer.

Nevertheless, one point that requires verification is whether among the users of rural networks there is greater propensity to save energy in homes. Some studies (Carrosio, 2015; Späth & Rohracher, 2005) have shown that in urban areas, district heating networks represent a lock-in element with respect to the energy efficiency of buildings. This occurs because the technical-institutional complex works to improve the production of heat, instead of encouraging collective home retrofitting projects (Osti, 2015).

6. Conclusions

This analysis of the overlapping of technical and social networks and the territorial perspective has enabled us to better understand the role of these socio-technical systems in the energy transition. We have isolated two types of district heating. They differ in terms of their approaches to energy transition. In rural areas, networks constitute systems that can empower the local techno-institutional complex to achieve a technological leap. Set in a pre-existing social network, district heating reinforces a sense of community and permits the involvement of various local players in a collective project. In the case of biomass, we are faced with local systems that have almost completed the transition with regard to the production of thermal and sometimes electric energy (if the plants work by cogeneration). In urban areas, on the other hand, networks represent functional devices for the stabilization of the techno-institutional complex. They allow cities to work on the circularity of some economies, generating added value from the same factors of production. Electricity production systems that are no longer competitive, for instance, can stay on the market by finding new functional outlets for their thermal waste. Furthermore, urban district heating operates within (as well as reinforces) a very hierarchical local system, often producing new bonds among the producer block. From the point of view of energy transition, to date urban systems remain anchored to fossil fuels, with growing trends towards waste and methane and a retreat from coal. This present reality does not foreclose the opportunity that district heating might help with the transition in the future. In the event that the urban techno-institutional complex is destabilized by the spread of renewables, it is likely that it will be able to act on the transition in a very sudden and direct manner.

In the case of rural district heating, on the other hand, networks built upon strong bonds render it possible to implement technological leaps in a consensual way, but at the same time these can exclude or limit external subjects that wish to introduce new co-supply systems, such as solar thermal energy. For instance, the techno-institutional complex linked to biomass, like the urban one, tends to work towards its self-preservation.

Our analysis has shown that at the local level there are different paths of energy transition. From a methodological point of view, this analysis of relational and territorial systems may prove useful in building a better understanding of the transition dynamics involved, which are conditioned by a series of factors rooted in the local dimension. Therefore, it is not enough to investigate energy regimes at the national scale; rather, it is useful to break them down into different territorial declinations. This is a useful lesson for energy policies, which are often blind with respect to the variety of places in which they would like to bring about changes. Recognizing the diversity of places provides an opportunity to build policies that are more effective and more rooted in the socio-technical trajectories of local development.

Notes

1. All the data contained in this paragraph have been processed by the authors starting from the census of the district heating systems present in Italy. The census is managed by the association of Italian district heating plants (*Associazione Italiana Riscaldamento Urbano*, AIRU).
2. The map of Italy in Figure 2 represents only the part of Italy where biomass plants are present. Indeed, in Southern Italy there are no biomass plants of any sort.

Disclosure statement

No potential conflict of interest was reported by the authors.

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