Chapter 12
Making Energy Grids Smart. The Transition of Sociotechnical Apparatuses Towards a New Ontology

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> *For when asceticism was carried out of monastic cells into everyday life, and began to dominate worldly morality, it did its part in building the tremendous cosmos of the modern economic order. This order is now bound to the technical and economic conditions of machine production which today determine the lives of all individuals who are born into this mechanism, not only those directly concerned with economic acquisition, with irresistible force. Perhaps it will so determine them until the last ton of fossilized coal is burnt.*
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> Weber (2005: 123)

Abstract The analysis of the assemblages and the functioning of conventional energy grids is the starting point of any process of smartness. Even if smarter elements already exist in energy grids, a full transition towards smartness is still far away. To investigate the starting conditions of a claimed process towards smartness, we realized an investigation in the city of Turin exploring the socio-technical development of its district heating network. The social elements it is composed of have been the object of an empirical investigation, based on 38 interviews and 3 focus groups and aimed at depicting its features from the various perspectives of the many roles that are played in it, from the professionals of the energy utility to the end users. We use two main perspectives. The first one is to conceive energy grids as technological zones, in which metering standards, communication infrastructures, and social evaluation assemble. The second one is to conceive energy grids as apparatuses or dispositives in which asymmetric lines of power, knowledge, information, decision-making, intensity and artefacts, constitute the ontology of the grid itself. An apparatus is an assemblage or a hybrid of technical and social elements, which has the strategic function to respond to an urgency. Foucault refers to the apparatus as a device consisting of a series of parts arranged in a way so that they influence the scope. This device exerts a normative effect on its "environment" because it introduces certain dispositions. In their effectiveness, energy networks

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are apparatuses made of variable and disparate assemblages of natural, technical, and social elements, a continuous process fostering differences and repetitions. Based on our outcomes, we can consider thermal grids as a kind of complex system or network of agents in which energy power circulates in a way very similar to the circulation of social power.

Introduction

In this chapter, we describe the assemblages and functioning of conventional energy grids at the beginning of the smartness process. This exercise is useful because it makes possible to pinpoint obstacles, barriers, resistances, conflicts, differences, necessities in the process of energy grids' democratization and aligning. Usually, the description of an energy smart grid consists of a list of properties that the grid needs to get to be called "smart". Thus, smart grids are tools that can make imaginable the management of "direct interaction and communication among consumers, households or companies, other grid users and energy suppliers" (European Commission 2011). A smart grid gives smart information, allows for savings, allows for good and real-time information, connects providers and users. Yet, what is still lacking in the claim for smart grid is an ontological dimension of both energy and grid. In our idea, it is not enough to enunciate an amount of technical characteristics that should mark the grid and its smartness. What we are trying to do is to provide a deeper and more complex frame for the energy smart grid implementation.

To accomplish this task, we use two main perspectives. The first one is to conceive energy grids as technological zones, in which metering standards, communication infrastructures, and socio-technical evaluation assemble. The second one is to conceive energy grids as apparatuses in which asymmetric lines of power, knowledge, information, decision-making, intensity and artefacts, constitute the ontology of the grid itself. This "irreducible inequality", this transcendental injustice, which marks the grid—likely any grid or network of relations—is what the smartness has to reduce but also to convert in new qualitative characteristics of the grid itself and of its components. A smart grid that wants to align or flatten the original disparities making itself more effective must change by actualizing its creative potential. Insofar as an apparatus such as an energy grid is constituted by heterogeneous components such as corporate actors, people and devices, its ordering is always unstable and challenged by the mutating conditions of the environment. However, despite the fluctuating orders capable of entering into communication, everything that happens and everything that appears into the grid is correlated with orders of differences: differences of level, temperature, pressure, tension, potential, intensity. These differences, when aligned, produce new configurations between agents of the grid. This is what policymakers and technical makers have to take in mind when they foster the smartness of the grid. These new alignments are what allows the smartness of the grid.

In the first section, we depict the present discourses aimed to foster smart grids. In the second, we illustrate the characteristics of conventional energy grids how we knew them during our investigation. In the third section, we enter the description of a thermal grid, more specifically, the thermal grid constituting the district heating system of the city of Turin in Italy. This grid has been the object of an empirical investigation, based on 38 interviews and 3 focus groups, aimed at depicting its features from the various perspectives of the many roles that are played in it, from the professionals of the energy utility to the end users. Some of the socio-technical features of the district heating network are thus described in that section, while the conceptual framework of this work mainly derives from, and was mainly tested against, the results of our empirical investigation. In the fourth section, we resume the transitional perspective towards the smartness. In the fifth, we introduce the problematic of technological zones by pinpointing three different configurations that might support the transition towards smart thermal grids: metrological zones, infrastructural zones, zones of interoperability. In the sixth, we introduce the concept of apparatus, trying to using it to understand the very nature of energy grids. In the seventh paragraph, we underline the distribution and formation of asymmetries of power inside the grid. In the eighth, we claim for a deep change in energy apparatuses and we provide some advice for policy and technical makers.

Energy Smart Grids

To manage the transition to a more sustainable energy system based on fluctuating and asymmetric energy production and consumption, a new highly complex, self-balancing energy system called ‘smart grid’ has been designed. Though elements of smartness already occur in many parts of existing grids, the difference between today’s grid and a smart grid of the future is mainly the grid’s capability to handle more complexity than today in an efficient and effective way (European Commission 2011). The European Commission described smart grids as “energy networks that can automatically monitor energy flows and adjust to changes in energy supply and demand accordingly”.[1] Smart grids are regarded as an upgraded energy network to which two-way digital communication between supplier and consumer, intelligent metering and monitoring systems have been added. Combining information on energy demand and supply can allow grid operators to better plan the integration of renewable energy into the grid and balance their networks. Smart grids also open up the possibility for consumers who produce their own energy to respond to prices and sell excess to the grid. In a few words, the smart grid is a process of defining and developing intelligent control technologies to control and coordinate flexible consumption in order to maintain over time a

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[1] http://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters [Last accessed: 07-11-2016].

balance between production and consumption in the overall energy system. It should open up possibilities for consumers to directly control and manage their individual consumption patterns, providing, in turn, strong incentives for efficient energy use if combined with time-dependent energy prices. Improved and more targeted management of the grid translates into a grid that is more secure and cheaper to operate. Smart grids should be the backbone of the future decarbonised power system. They can enable the integration of vast amounts of both on-shore and off-shore renewable energy and electric vehicles while maintaining availability for conventional power generation and power system adequacy.

The development of smart grid visions and solutions are influenced by many different interests, ideas and actors, which contribute to a high degree of complexity within the field. However, despite the plethora of R&D and demonstration projects, only little has been achieved in terms of actually realizing the smart grid visions fully. The smart grid system is still much in the making, and there is still a gap between the ideas of the future system and the practical realization of these ideas (Gram-Hanssen 2009). In order to get an effective transition towards smart grids, important aspects that are so far considered merely technological have to be managed, faced and, where possible, overtaken. To understand the particular form smart grids requires, detailed empirical and historical analyses are needed. Moreover, the evolution of these technical configurations is not predetermined. The particular circumstances of their development are of considerable significance, and these particular circumstances depend on the construction of a whole series of inter-relations which all agents or stakeholders are involved in.

Conventional Thermal Grids

Our chapter gives an understanding of the current functioning and potential evolution of conventional thermal energy grids. As said before, elements of smartness already exist in many parts of existing grids. But these elements have to be integrated, harmonized and pushed at work. Conventionally, thermal grids convey energy by using water as a carrier. Water, hot or cold, is conveyed through underground hubs, which then distribute water throughout different buildings' thermal plants or boilers and then among final users. This is the reason why they are often seen as composing the district heating system. Thermal energy grids are technically different from electric smart grids, mainly regarding final users. For example, from the point of view of metering, given the current infrastructure in Europe, it is easier to provide feedback on electricity consumption than on thermal energy consumption (EEA 2013). Residential thermal energy consumption (as well as gas consumption in the case of domestic autonomous consumption) is determined principally by structural dwelling characteristics, while electricity consumption varies more directly with household composition and social standing—and thus may be more responsive to behaviour change programmes (Brounen et al. 2012). Heat consumption practices, when enacted through thermal grids, i.e.

through centralized heating systems, differ for some other aspects from the electricity consumption practices, notably from those which are not aimed at providing warmness or coldness. First, heat consumption practices are marked by a temporal dimension. Indeed, unlike what happens with electric appliances (again, excluding those which are not designed to modify temperatures), the required energy service is not obtained, nor it ceases, instantaneously. As it is well known, radiators only gradually gain and lose heat. Moreover, switching radiators on or off is only effective when enacted within the building heating time. Second, differently from electricity consumption, which is paid only based on singular household consumption, the apportionment of heating costs is based on different criteria. Where heat costs allocators are not put in place, they are apportioned only based on the cubic meters of the apartments. Where heating costs allocators have been installed, heating costs are partly apportioned based on cubic meters and partly based on heat consumption. It is in the last few years that, as the installation of thermostatic valves and heat costs allocators became mandatory, the costs apportionment procedures have been moving from the former to the latter. Under the former system of apportionment, thermal energy consumption is characterized by a process of compensation. Differences in thermal energy efficiencies of apartments and in thermal energy consumption behaviours among final users do not directly translate into differences in heating expenses. People who spend more time at home (e.g. homemakers, the elderly, sick persons, part/full-time unemployed) thus benefit from an advantageous price per unit of thermal energy they directly enjoy. The same happens to people living in the coldest sections of buildings. It means that a sort of “thermal equity” issue is (was) in some way addressed or implied. Thermostatic valves and heat costs allocators are thus pulling towards a more individualized way of consumption that erodes the former compensation process described here.

Based on our investigation we can say that conventional thermal grids are not only a set of technical devices aimed at the provision of warmness or coldness, but are a more complex arrangement of technical objects, practices, rules, and aims regulating, driving and compensating the actions performed by agents. In our case, the thermal energy grid regulates and performs the comfort condition in relation to two aspects: (a) by determining and deciding prices, conditions of use and provision of thermal energy and (b) by providing people with some tools in order to freely and autonomously control the energy apparatus. This latter aspect, at least in our investigation concerning the district heating system of Turin, is very limitedly addressed. Temperature, schedule, time, starting and stopping, are often not controlled by the final user. Compared with electric energy grids, thermal grids are so unmanageable by the final users that we got the idea that they are still victims of a centralized and untouchable power. This condition generates an asymmetry of power that is at the core of socio-technical apparatuses developed in the context of modern society and that is often managed and controlled by corporate actors. Before starting the smartness processes, agencies, public authorities, providers and final users have to be aware of the complex arrays of relations and configurations that make possible a smart energy grid. Here we provide some possible interpretation of smart grid development in order to foster an interplay among technical and social agents and agencies to reach a real smartness.

The Turin District Heating System

Despite all the existing literature and pilot projects on smart energy grids, their actual implementation seems to be far from giving effective results. As revealed in our case study, i.e. the district heating system of a medium size city, the implementation of the smart grid is not happening quickly enough. The reasons why this case study looks interesting are varied:

- it relates to an energy system under transition: from the actual situation to a virtual or desired one;
- it shows some of the difficulties characterizing the process. For instance, the problematic interactions between the agents of the grid;
- it shows some of the frictions that final users have with technical apparatuses.

As already mentioned, the Turin district heating system has been the object of an empirical investigation based on 38 interviews and 3 focus groups aimed at defining its features from the various perspectives of the many roles that are played in it, from the professionals of the energy utility to the end users. Some of the socio-technical features of the district heating network are thus described in this section, while the conceptual framework described in the following mainly derives from, and was mainly tested against, the results of our empirical investigation.

The process of smartness implementation is not at its first stages. It can be said that it had already started with the remote monitoring of substations as well as of other heating network components. The district heating network in Turin is quite huge, supplying 56 millions of cubic meters to 550,000 inhabitants, out of a population of almost 900,000. At present, the point of saturation, given the current infrastructure, has been almost achieved. Not differing from other district heating systems, Turin's processes trying to implement smartness in thermal grids has to be assessed against its capacity of leading to consumption peak shaving. Being the most part of the delivered thermal energy produced by means of CHP (Combined Heat and Power), shaving the peak would mean that the number of hours in which the integrative HOBs (Heating Only Boilers) have to be used should be reduced, leading to a more efficient heat delivery with reference to the primary energy used. Such an outcome would also be positive for the metropolitan area as a whole. Indeed, it would decrease the pollutant emissions, at the same time allowing more cubic meters to be connected to the network.

There are two ways in which more and/or enriched information and data could be used to achieve this outcome. Firstly, a more reliable model of the functioning of the network could be used by the heating company for peak smoothing purposes, meaning for optimization interventions (invisibly) carried out by the heating company itself. Secondly, this information could be used to foster changes in the way the other actors act. In order to understand which information and data could serve to this aim, let us have a look at the features of the actors of the socio-technical system represented by this district heating network by selecting two main categories of buildings connected to this network: private (residential) buildings and public buildings (owned by the Municipality).

Private Buildings

The management of private buildings is run by professional building administrators. They manage the great majority of apartment buildings in Turin. It means that they need to be annually and formally appointed as building administrators by the residents' assembly. With reference to heating aspects, building administrators receive and pay (to the supplier) the heating bills, receive any heating reports, communicate with the district heating company which is the desired heating time schedule and set point for the building, answer to complaints coming from residents, and so on. Building administrators also act as mediators between the district heating company and final users.

Residents' heating practices are much thinner. Indeed, many final users have almost completely delegated the heating practices to the building administrators. As a result, they only have vague or wrong ideas about which is the heating system of the building as well as about the building heating time schedule. Moreover, they usually only receive an annual report containing the heating costs as they were apportioned among apartments according to different methods (cubic meters alone or in conjunction with metering performed through heat cost allocators, where available). In sum, residents have, by default, very few possibilities to make comparisons with previous years, self-metering being one of them. Understanding if any improvement or worsening in heat expenses is attributable to their behaviours, to other residents' behaviours, to errors, to insulation measures, to tariff changes, to supplier's policies, to a mild or harsh winter, etc., is even more difficult. On the other side, they are in charge of the management of the thermal comfort in their apartments, even if they have very few (or dependent on income and on homeownership) ways to reduce heat consumption.

Public Buildings

With a few exceptions, the management of thermal issues is only in a limited way part of the tasks of public buildings managers. They do not receive any heating bill, nor do they receive any heating report. They are not given guidance or objectives to reduce thermal energy consumption either. Seen from a public building managers' perspective, thermal issues are thus essentially related to guaranteeing the thermal comfort for workers and employees. Indeed, the management and setting of the thermal systems, as well as the decisions related to refurbishments and maintenance, are left to an external company managing all energy aspects for all public buildings owned by the Municipality. Neither the managers of the public buildings, nor the employees using them, are asked on a regular basis, or they are not asked at all, to monitor and steer the heating practices as they manifest in these buildings. Nonetheless, this does not prevent some employees to adopt in their workplace some of the elements constituting the heating practices as carried out in their private buildings (thermometers, complaints and clothing). As we are going to show in the following sections, public buildings are the least flexible and the interactions between actors and technical devices are problematic.

Thermal Grids Transition: Interpretations, Visions, Dynamics

Notwithstanding their differences, smart thermal grids are claimed to play, as smart electric grids do, an important role in future smart cities by ensuring a reliable and affordable heating and cooling supply to various customers with low-carbon and renewable energy carriers like waste heat, waste-to-energy, solar thermal, biomass and geothermal energy. Smart thermal grids allow adapting to changing conditions in supply and demand in the short, medium and long-term, and facilitate participation of final users, for instance, by allowing supplying heating or cooling back to the network. To do so, they need to be spatially integrated in the complete urban energy system and to interact with other urban infrastructures, such as networks for electricity, sewage, waste, ICT (Lund et al. 2012, 2014). By optimising the combination of technologies and enabling a maximum exploitation of available local energy resources through cascade usage, smart thermal grids can contribute to improving the efficiency of urban heating and cooling, while increasing the cost efficiency and increasing the security of supply at a local level. The scale of smart thermal grids can range from neighbourhood-level systems to citywide applications, depending on heating and cooling demand and urban context.

The technical elements of smart thermal grids cover thermal generation systems like small-scale low-carbon heating and cooling systems, combined heat and power systems (CHP), thermal storage technologies and innovative network improvements. Network-integrated sensors and smart heat meters allow for more effective and efficient use of the separate components when supported by overarching energy management (Schmidt et al. 2013; Lund et al. 2014). This so-called 4th Generation District Heating concept is interesting, but it lacks some key elements, the main ones being the final users involvement in the idea of smartness and, consequently, a broader and smarter design of the grid that includes these users.

The design of the 4th Generation District Heating concept is enlightening because it clearly shows that the technological dimension is widely overriding the future scenario. Here, institutional planning policies, social motivations, economic incentives, costs/benefits perspectives, are compressed and superposed to the technical architecture. Moreover, the juxtaposition of sectors and parts of the grid and the imaging of their amalgamation is not enough if the processes, in virtue of which they integrate, are not decomposed and analysed in their effective dynamics, oppositions, and tensions.

Technological Zones

Thermal energy grids are situated socio-technical systems that combine hard technical infrastructures and devices with expectations of ordinary and pre-established actions and behaviours from both distributors and final users. In this sense, their working needs repetitive interactions among all human agents and technical devices involved and locally composing the grids. Often thermal grids do not need to be large to be conventionally efficient. Their spatial dimensions are often coincident with the urban dimension, covering large sectors of urban settlements but not embracing entire regions. The situatedness of thermal grids is also understandable when looking at its implementation. Grids are carriers of energy (electric or thermal as in the case of district heating), better they are carriers of energy intensity and their performance is based on an ontology of difference. The energy intensity conducted by water coming from the provider's station is very different from the energy intensity arriving at the final user location, and then to the station again. Generally, the water leaving a heating station is around 100–120 °C, it reaches buildings boilers at around 80–90 °C and it comes back at the heating central station around 60 °C. This intensity can be measured by different standards such as Joule/second/m^2 or also in more trivial terms of initial (power plants) and final (end users) temperature. However, we would like to suggest a revision of the classical thermodynamic interpretation of energy flowing into grids, as well as of conventional engineers' interpretation of grids.

Embracing an idea coming from Gilles Deleuze's philosophy, we understand intensity as the force that determines difference and produces repetition (Deleuze 1994; Crockett 2013). Every phenomenon is marked by differences. For Deleuze, "Every phenomenon refers to an inequality by which it is conditioned. Every diversity and every change refers to a difference, which is its sufficient reason. Everything that happens and everything that appears is correlated with orders of differences: differences of level, temperature, pressure, tension, potential, difference of intensity" (Deleuze 1994, p. 222). What is interesting here is the fact that the different agents of the grid are connected via difference (of energy/power obviously, but also of status, role, control, income). The difference in intensity conveyed by the grid, and the way it is flattened, is very crucial for the efficiency of the grid itself. Energy intensity dissipates along the grid, producing entropy. The process, "from more to less differentiated, from a productive to a reduced difference, and ultimately to a cancelled difference" (Deleuze 1994, p. 223), is immanent to the grid's dynamic (will the grid never come to deliver customized temperatures?). The smartness process, *how is until now designed*, strengthens the process of annulment of difference, without thinking that new qualities emerge from it. This is the reason why fourth generation smart thermal grids are designed to cut down the water's temperature they are carrying and to shave daily, weekly, seasonal peaks. Actions and applied devices are implemented in different zones of the grid to smooth this difference in intensity. These devices and operators vary from smart metering to home appliances, from dynamic tariffs to network management, focusing on different technological and social areas as shown by JRC studies (Mengolini and Vasiljeska 2013). Thus, thermal grids, as we collected information on its establishing, functioning and deploying, are areas where differences and asymmetries between the agents of the grids are often present, but where these ones tend to be shaved. Energy grids can thus be viewed as technological zones that work as operators or "differentiators" aimed to reduce differences, transforming intensity into extensity, as said by Deleuze (1994, p. 223).

> We know only forms of energy which are already localized and distributed in extensity, or extensities already qualified by forms of energy. Energetics defined a particular energy by the combination of two factors, one intensive and one extensive (for example, force and distance for linear energy, surface tension and surface area for surface energy, pressure and volume for volume energy, height and weight for gravitational energy, temperature and entropy for thermal energy …). It turns out that, in experience, intensio (intension) is inseparable from an extensio (extension) which relates it to the extensum (extensity). In these conditions, intensity itself is subordinated to the qualities, which fill extensity (primary physical qualities or qualitas, and secondary perceptible qualities or quale). In short, we know intensity only as already developed within an extensity, and as covered over by qualities.

In this perspective, a technological zone can be understood as an extended space where differences and intensity are reduced thanks to standardized techniques, procedures and forms. As suggested by Barry (2006), such technological zones take broadly one or a mix of three forms: (1) metrological zones associated with the development of common forms of measurement; (2) infrastructural zones associated with the creation of common connection standards; and (3) zones of qualification that come into being when objects and practices are assessed according to common standards and criteria. Smart grids visions such as those developed by different European Commission DGs and agencies such as JRCs are made of varying combinations of these traits. An analytical approach to such technological zones that forge thermal grids is required in order to pinpoint hotspots where intervening to trigger a grid transition.

Metrological Zones

At the core of a smart grid there is a metrological zone based on smart metering. Intelligent metering is usually an inherent part of smart grids, forming a common form of measurement. Without a homogeneous metrological zone where power metering is standardized in order to make all agents aware of their contribution to the grid functioning, we find no smartness. When coupled with smart metering systems, smart grids reach consumers and suppliers by providing information on real-time consumption. This process is called feedback. Feedback is claimed to be a strong condition for the grid's smartness (Pullinger et al. 2014). With smart meters, consumers can adapt—in time and volume—their energy usage possibly avoiding different energy peaks throughout the day, the week, the month, the season, and so on, fitting different prices for saving money by consuming more energy in lower price periods. Smart metering systems support devices that give feedback aimed at encouraging behaviour changes, specifically to reduce energy demand and spending on energy. Detailed standards specify the minimum technical capabilities of the smart meters and feedback devices. It means that the adoption of smart metering systems should raise specific functionalities for the final users, providing readings from the meter to the customer and to equipment that he/she may have installed, and updating these readings frequently enough to allow the information to be used to achieve energy savings. Moreover, the establishment of a smart metrological zone allows all customers to possess and control meter data and to transmit these data to in-house devices. Finally, a smart metering allows the provision of messages or other information to the users from the energy supplier.

All aspects here evoked have the goal to reduce energy consumption that in terms of thermal energy provision and consumption means that the indoor comfort have to be managed in a more smart and flexible way, adapting to the variability of daily life circumstances, such as outdoor weather conditions, people time-use patterns, services provision's patterns in the case of public buildings. The development of common measurement standards and practices that make information comparable between different locations, agents, and final users aims clearly to change the so-called thermal behaviour, or in other words to change the final users pursuing of thermal comfort. The assumption behind a smart metrological zone is that energy consumption behaviours can be altered by reminders on energy consumption data provided by ICTs devices, and that consequently behaviour can be monitored and changed where needed (Cakici and Bylund 2014).

However, research on feedback information effects illustrates its own limits for fostering behavioural change. For Hargreaves et al. (2010), householders interaction with feedback is marked by different and contrasting aspects. For one side, overtime, smart energy devices gradually become 'backgrounded' within normal household routines and practices, increasing the householders' knowledge of and confidence about the amount of energy they consume. For the other side, beyond a certain level and for a wide variety of reasons, these devices do not necessarily encourage or motivate householders to reduce their levels of consumption. Once equipped with new knowledge and expertise about their levels of energy consumption, household practices may become harder to change as householders realize the limits to their energy saving potential and become frustrated by the absence of wider policy and market support.

In the course of our investigation, we did not notice of feedback devices used by users. We found that conventional energy grids are far from the use of these devices, and that they completely miss metrological zones and common modes of measurement. Final users, being private flat owners or public services workers or costumers, are blind about their consumption. Often, also institutions get not comprehensive data about their consumption. Moreover, we think that detailed, different and adjunctive indicators are needed to meet smartness, even though it is plausible to think that people do not want to pay too much time to the reading of data provided by these indicators. In any case, indicators of energy mix, energy time using, primary and secondary energy consumption, energy prices variability, CO_2 emissions, and of the making of communities that practice the distributed energy production, have to be considered and deployed. In short, the deployment of smart metrological standards requires in depth adjustments of the conventional and existing metering systems in order to meet the needs of different stakeholders and make all agents aware of their reciprocal and ontologically differential contribution to the grid.

Infrastructural Zones (Connection and Communication Standards and Feedback)

The development of common connection standards makes it possible to integrate systems of production, distribution, and communication, as well as to exclude consumers and producers who do not conform to the standard. Connection standards establish infrastructural zones that have a critical importance in the development of smart energy grids governed by information and communication technologies. In this case, it allows remote reading of meter registers by metering operators and by third parties. Moreover, these functionalities allow on-demand frequent regular readings by the meter operator. The provision of meter reading information by the supplier to the customer is thus very crucial. This would include regular readings of peak demands where the tariff is based on these; ability of linking several meters (electric, gas, water, etc.) into a single smart Meter System in order to facilitate communications; data storage within the meter; correct billing, both on a regular basis or on demand (say on the change of occupier or energy supplier). In this perspective, smart energy grids imply infrastructural zones associated with the creation of common connection standards. Infrastructural zones are areas of interoperability among different agents. It means that the thermal system must be monitored using sensors, collecting data, crossing data, performing algorithms, building platforms, enabling feedback processes. These infrastructural zones serve to make social practices of heating and cooling possible and possibly less disordered or redundant compared to what they already are. Infrastructural zones also serve to reduce the power disparity and differential among agents that is an ontological condition of energy grids. These have a critical importance in the development of information and communication throughout the grid, in order to facilitate agents' exchange of information on conditions, settings, socio-technical arrangements, and final users' practices performances.

Zones of Qualification and Improvement

Smart energy grids imply at the end the existence of a zone of assessment, in which evaluations related to grid quality and to its capacity to generate comfort while saving energy are performed. The decoupling between comfort and energy consumption is the core of smart energy grids goals and it has to be detected by using metering, devices and some comfort indicators. The development of common regulatory or quality standards has become critical to the governing of energy. Such standards govern the quality of practices enabled thanks to energy, which may exist within a particular domain. Necessarily, such standards depend on the development of various technical devices, which make it possible to assess and compare the qualities of technical devices and practices performed. However, we may speak of the existence of a zone of qualification when the technical devices allow for practices that meet common criteria, such as environmental standards. Here the role of final users such as households becomes the core component in the smart grid. The role of dynamic users that support the energy system by e.g. being flexible in their consumption and able to produce autonomously warmness or coldness, thus helping the grid to face peaks of consumption is now increasingly acknowledged (Nyborg and Røpke 2011; Strengers 2012). The changing role of final users in the transition and functioning of energy grids to smartness is year-by-year revaluated, not only at the academic level, but also in the more important documents of EU and other European bodies (European Environmental Agency 2013).

The problem is that, the way for facing the human scope in energy grids is mainly psychological or behavioural, what has been termed by Elizabeth Shove the ABC syndrome (Shove 2010). Our exploration of conventional thermal grids towards smartness confirms that this is the main vision shared by designers, engineers, and administrators. Behind this approach is the idea that individuals are fully rational beings and that they should be aware of what they are spending, consuming, and dissipating not only in monetary terms, but also in thermodynamics terms. As it has been demonstrated by several studies, not only money is for people a volatile and sometime invisible object, but also energy is difficulty understandable in its nature and ontology. Energy flows are in many ways invisible to residential energy consumers. This makes energy management and conservation practices both difficult and unusual. The more modern energy systems provide increasingly invisible means of meeting demands for heating and cooling. Warm water that flows seamlessly and silently into homes meeting our demand of comfort makes it without any notable trace of their presence (Ehrhardt-Martinez et al. 2010; see also Schwartz et al. 2013). The only way to get an account of energy use is the practices that people perform thanks to energy, such as heating. Household's everyday practices are indicators of how much energy is consumed and dissipated, the involuntary way to make energy visible. In our case of district heating, shaving the peak loads and avoid primary energy consumption is a consequence of comfort practices performed by households' agents, whereas technologies and nature of households' engagement and a new displacement of time for heating play a very crucial role. This time shift in governing energy production, distribution, and consumption, plays an important role in European energy policies. Energy saving is also the expected outcome of the evolution of this reincorporation of a time-based perspective into technological zone.

The introduction of these new perspectives, such as the temporal ones, poses the question of the useful function of economic incentives to drive the behavioural change. The idea that everything can be obtained given the right incentive is an appealing idea. However, it is not enlightening enough. What is becoming clearer is that a rational and informational view of energy users is not enough to foster change in energy system and related social practices. An approach based on theory of social practice to address this problematic is far more useful. Practice theory contributes to understanding how thermal energy is used and how this changes over time by focusing not on energy per se, but on the everyday routines of space heating through which energy is used, and on the roles of technologies, material environment, skills, rules and habits in constraining or enabling change. Practice theory is providing insights into the likely effectiveness of feedback devices and the forms of feedback they provide (Shove and Walker 2014; Schatzki 2011; Pullinger et al. 2014).

Sociotechnical Apparatuses

The technological zones as previously described are mainly technology-oriented. It is not wrong to depict energy grids in terms of technical standardization but this seems to exclude something else. Here we broaden the Foucauldian perspective suggested by Barry embracing the very interesting concept of dispositive or apparatus forged by Michel Foucault along all its oeuvre (see Agamben 2009; Raffnsøe 2008; Bussolini 2010). An apparatus is "a thoroughly heterogeneous set consisting of discourses, institutions, architectural forms, regulatory decisions, laws, administrative measures, scientific statements, philosophical, moral, and philanthropic propositions—in short, the said as much as the unsaid. Such are the elements of the apparatus" (Foucault 1980, 194). The apparatus itself is the network that can be established between these elements, but it is also an assemblage or a hybrid of technical and social elements, which has the strategic function in a given moment to respond to an urgency. Foucault refers to the apparatus as a device consisting of a series of parts arranged in a way so that they influence the scope. An apparatus indicates an arrangement that exerts a normative effect on its "environment" because it introduces certain dispositions.

According to Foucault, there are two important moments in the apparatus's genesis. A first moment is that oriented to a prevalent strategic objective.

In a second step, the apparatus as such is constituted and enabled to continue in existence insofar as it is the site of a double process. On the one hand, there is a process of "functional overdetermination", because each effect—positive or negative, intentional or unintentional—enters into resonance or contradiction with the others and thereby calls for a readjustment or a reworking of the heterogeneous elements that surface at various points. On the other hand, there is a perpetual process of "strategic elaboration" that allows the apparatus to establish and reproduce different fields of power relations (Foucault 1980, 195). Being its nature essentially strategic and goal-oriented or teleological, it implies a certain manipulation of relations of forces, a rational and concrete intervention in the relations of forces, either to develop them in a particular direction, or to block them, to stabilize them, to utilize them. Finally, an apparatus is also always linked to certain limits of knowledge that arise from it and, to an equal degree, condition it. In short, an energy grid is a set of strategies of the relations of forces supporting, and supported by certain types of knowledge.

Foucault applies his concept of apparatus to asylums, prisons, schools, factories, and hospitals, as apparatuses of disciplining and transformation of practices. In our view, it appears reasonable to apply the concept of apparatus, as depicted here, to energy grids. Norms are thus developed and inscribed in the case of energy grids into a play of power, aimed to overcome resistances, or to change inertial habits, or again to orient future choices. Data standardization and collection is crucial to monitor the functioning of the energy grid, to drive it towards more efficient ways to provide and use energy, and to discipline agents of the grid for more appropriate behaviour, as for example the harmonization of demand and supply. Infrastructures provide the architectural frame in which power and prescriptions flow. Moreover, in the case of the energy grid, "functional overdetermination" refers to the interactivity between effects of constructive or destructive interaction/interference that might create a need to adjust or rework the connections between elements. A perpetual process of "strategic elaboration" happens whereas the strategic objective is the reduction of energy dissipation alongside the grid favoured by different changes of agents' practices. This energy grid transition is not peaceful or irenic, but constellated by more or less critical contradictions that ask for perpetual adjustments and strategic elaboration. It is a process that never ends. This holds for example the interest of provider to supply increasing energy (and not reducing it) or the aspiration of the final user to freely use the desired amount of energy without constraints, or again the right of a final user to exercise a quasi-total control on his/her piece of apparatus.

What we discovered is that our final users would take place inside the apparatus, cooperating in it, sharing the power circulating in it. The problem is that they cannot do it because they are off-grid, separated from the apparatus or deprived of their potential or virtual agency to act on it. Moreover, when they are incorporated into the grid, they fight with the grid's devices, that resist any intervention and intrusion. Final users expect to be active grid supporters and not only passive objects of grid, aiming to drive and sway technological improvement dynamics. They also are not really persuaded that "dynamic pricing" should manage their enrolment in the grid as anticipated by the EU and enclosed in the Commission Staff Working Document SWD 442 (2013). We got insights also from the energy provider, underlining that they are very disappointed with other grid's agents behaviour. They think that energy managers and facility managers are an obstacle to innovation, that people do not understand their proposals such as to provide thermal energy during the night or to shave energy peak early in the morning when they start to warm buildings. Therefore, they show a clear distrust in potential behavioural changes, and human agents are the problem not the solution.

A more general question arises regarding the role of technical devices and artefacts in the evolution of the apparatus. As already pointed out, Foucault uses this term to designate a configuration or arrangement of elements and forces, practices and discourses, power and knowledge, that is both strategic and technical. He mentions material arrangements as part of the apparatus, but he does not pay much interest in developing this, as it would deserve. As observed by Karen Barad, he does not provide a satisfying and articulate explanation of the precise nature of the relationship between discursive practices and material phenomena. The dynamic and agential conception of materiality that takes account of the materialization of all bodies (nonhuman as well as human) and that makes possible a genealogy of the practices, is not examined by Foucault (Barad 1998, 2007). He only alludes to the ways in which technical apparatuses provide intimate, pervasive, and profound reconfiguring of the practices performed by agents, and that this reconfiguring is often unstable and unfixed. The definition of apparatus provided by Deleuze sounds more fitting our idea of energy grid, underlining the disconnected and rather precarious character of such ensemble of heterogeneous elements.

> But what is a dispositif? In the first instance it is a tangle, a multilinear ensemble. It is composed of lines, each having a different nature. And the lines in the apparatus do not outline or surround systems which are each homogeneous in their own right, object, subject, language, and so on, but follow directions, trace balances which are always off balance, now drawing together and then distancing themselves from one another. Each line is broken and subject to changes in direction, bifurcating and forked, and subject to drifting. Visible objects, affirmations which can be formulated, forces exercised and subjects in position are like vectors and tensors. Thus the three major aspects which Foucault successively distinguishes, Knowledge, Power and Subjectivity are by no means contours given once and for all, but series of variables which supplant one another (Deleuze 1992, 159).

Our issue of energy grid might be a clear example in which a satisfactory transformation of practices should be understood only in the light of new assemblages of technology and human activity. The notion of apparatus, readjusted and moved towards a consistent materiality where the inseparability of objects and subjects is acknowledged, can give energy grid a different interpretation, allowing the pinpoint of a surface where to attach a strategy of transition. In short, a conventional energy grid is an apparatus in which humans act as depending from devices driven by incorporated knowledge and language. A smart energy grid is an apparatus in which devices and humans try to communicate to adapt to new conditions.

Asymmetries of Energy and Power

In their working, thermal grids bring and convey both energy power for heating and social power in forms of rules, norms, and dispositions. They apply on subjects, but in doing it they also change the current state of affairs. Our investigation rises up the problematic of the flows and links between energy and power, the problem of how energy is appropriated, transformed, converted, distributed, used and disposed and the way in which these processes change the actual configurations. The agents of those processes that all contribute to the building and functioning of the grid, and how their nexuses and relationships work out, become a matter of investigation. How is the "power of power" maintained, conditioned and disputed by coalitions of agents, dominant and resistant, performing different but interlinked social practices from which these emerge? (Mitchell 2011). This asks for analysis of how power flows through complex systems, how it supports and makes existing positive and negative feedback loops between production and consumption of energy, how technical devices, knowledge, enunciations, build up energy machines, regimes, apparatuses, that make society likely. Social forms, as living systems, depend upon flows of energy maintaining their systemic viability far from thermodynamic equilibrium (Smil 2010). Since only the simplest forms of energy may be harnessed without infrastructures, energy resources are always mediated through socio-technical systems (Smil 2010, p. 12; quoted in Tyfield 2014, p. 61). Keeping different forms, energy is central to a social system's metabolic reproduction (Padovan et al. 2015; Padovan 2015a, b).

In their effectiveness, energy networks are analogous to social networks, been made of the same substance: a variable and disparate assemblage of natural, technical, and social elements, a continuous process fostering differences and repetitions. Based on our outcomes, we can consider thermal grids as a kind of complex system or network of agents in which energy/power circulates. This power and the way in which it works have very great similarities with social power. As stated by Bertrand Russel, "The fundamental concept in social science is Power in the sense in which Energy is the fundamental concept in physics. Like energy, power has many forms, such as wealth, influence, communication. No one of these can be regarded as subordinate to any other, and there is no form from which the others are derivative" (Russell 2004, Or. ed. 1938 p. 4). As in the social networks in which power flows reproduce asymmetries and differences (but also negating them), in these technical energy networks energy flows reproduce asymmetries and dissimilarities. The analogy can go further whereas we pinpoint dynamics of energy/power circulation, disciplining, and control: how is the grid governed? Who benefits in terms of energy provision, consumption and comfort? Is the smart energy grid a dispositive that assures a win-win mechanism? Our investigation tries to give some answer to these questions, not looking at thermal grids as a vertical apparatus going from the centre to the periphery, but understanding energy/power circulation by looking at its extremities, at its outer limits where it becomes capillary (for this perspective see Foucault 2003). For instance, we discovered continuous attempts made by final users to understand how much they are consuming, how to save energy, how to regulate temperature, how to intervene on devices, how to make the apparatus more flexible, how to manage a common thermal comfort in public spaces. Our goal, similar to the Foucault one, has been to analyse energy/power regulation at the point where it is invested in real and effective practices, where it relates directly and immediately to what we might call its object, its target, its field of application, or, in other words, the places where it produces its real effects. So the question is this: what happens in the continuous and uninterrupted processes that go throughout the grid making energy circulate and investing bodies, directing gestures, and regulating forms of behaviour? In other words, rather than asking ourselves who simply rules or governs the grid, we should try to discover how multiple bodies, forces, energies, matters, desires, thoughts, are gradually, progressively, actually and materially constituted as subjects in the making of the thermal grid, or to grasp the material agency that uses energy. For instance, we realized that conventional grid leaves agents in a state of blindness regarding the heating system functioning. On the other hand, the deployment of smart grids implies a process of subjectivation whereas agents are invested by a twofold dynamic of freedom and individual responsibility. While water flows through pipelines, the grid conveys also data, prescriptions, rules, advises for users, disciplining and regulating their practices. The study of the multiple peripheral bodies, the bodies that are constituted as subjects by power effects in the frame of thermal grid, enlightens the way in which it acts and is enacted by different users. In our investigation, we noticed also that agents can bend, in some cases, the grid towards their own goals, or can refuse at all the regulating power conveyed by it. Forms of adaptation, rejection, manipulation, constellate the grid along its entire length, becoming often sources of controversies and conflicts mainly in buildings where different tenants experience different intensities and performances of the grid, or in different areas where grid shows some malfunction. Energy/power handling is not a homogeneous phenomenon; it is marked by different levels of intensity and power. Energy/power is something that circulates, or rather is something that functions only when it is part of a chain. It is never localized here or there, it is never in the hands of someone, and it is never appropriated in the way that a commodity can be appropriated. Power functions. Power is exercised through networks, and individuals do not simply and passively receive the energy circulating in those networks; they are in a position to both submit to and exercise this power. They are never the inert or consenting targets of power; they are always its relays. In other words, power passes not only through the pipelines but also through the users. It is not passively applied to them, but it asks for a process of subjectivation.

Thermal (but also electric) grids are complex systems of connection of different agents equipped with different agency and different power of influence and intervention on consumption and environmental impact. It is in some way self-evident the fact that big energy providers and final users are very a-symmetrical in the influence on energy management. At the theoretical level, we can see two big categories of agents: natural and corporate. Natural persons are obviously those people that do not have any legal definition, the final users of the energy. They can only make contracts and agreements with providers and managers. The other category is the one of corporate actors that range from extractors, refiners of oil and gas, sellers and intermediaries placed at the core of the big energy market, national and local providers, energy managers of other corporate actors such as cities and firms. All of them are corporate actors in the sense that they act as fictional persons, law rules their actions, and finally they get an internal structure composed of positions rather than persons, a structure in which persons are merely occupants of positions (Coleman 1974, 1982).

We can define corporate actors as those organized actors, which participate directly in (policy-oriented) decision-making, which are formal organizations, have a real constitution and a real membership, purport to represent the interests of their membership, but often have been challenged for misrepresenting these interests by both internal and external critics. Their decisions result in the establishment, maintenance and transformation of rule regimes (Flam 1990). The main consequence of the corporate actors' agency is an asymmetry of the relations in the energy grid. The relationship between the two actors (natural personas and corporate actors) is asymmetric in the types of parties they involve, but are asymmetric —often extremely so—in two other respects as well: in the relative sizes of the two parties, and in the numbers of alternative transaction partners on each side of the relation. One main consequence of the asymmetry is that a corporate actor nearly always controls most of the conditions surrounding the relation. The result is that two parties beginning with nominally equal rights in a relation, but coming to it with vastly different resources, end with very different actual rights in the relation. This asymmetry of rights taking place in the evolution of a system of relations is one of the main reasons that make people distrust regarding generally processes of socio-technical innovation at the point to refuse them. Distrust, disappointment, discontent are conditions that shape people when they realize the asymmetries of power in which they are involved. This is the case of such top/down strategies of smart grid deployment, whereas actions of involvement are not contemplated or are merely claimed.

Conclusions: Transitional Apparatuses as New Frame for Policymakers

Because of path-dependency mechanisms deployed by the development of fossil fuel conventional energy grids, the transition towards smart energy grids must start from them. A counterapparatus, far more suitable and acceptable for current purposes of energy transition of those existing nowadays, can be built only on already existing infrastructures. There is not alternative to begin from this constraining stage of thermal grid evolution. Consequently, we need to know how conventional grids work and where their potential for change is. As technological zones they are rather rigid, linear, inelastic and thus useful only to a certain extent. In the case of district heating the situation is even worse in the sense that the rigidity and path dependency of co-generation apparatuses is very strong: likely it will be very tough to emancipate this energy provision from its fossil fuel primary source. Moreover, the socio-technical vision of grids transition is considerably naïf: the list of stuff that "should be done" is not enough to ensure a successful transition.

The notion of apparatus or dispositive seems to us more useful to adopt strategies of transition. This notion is similar to concepts such as assemblage (DeLanda 2006) and arrangement (Schatzki 2011, 2015), which outline a relational system for dissimilar elements and practices. Apparatuses, assemblages, and arrangements are concepts that often overlap, and that at the empirical level can operate symbiotically to explain the forging and emerging of practices such as energy production, distribution, usage, and dissipation. All in all, that of apparatus seems to us a more intense, dynamic, and agential concept than the other ones. The co-evolution of varying lines and strata of practices, techniques, discourses, and singularities establishes it. An apparatus is more concerned with its security and functional certainty than an always virtual and a never fully actualized assemblage. Moreover, it is purpose-oriented in the sense that an apparatus organizes people, artefacts, enunciations, and things according to functions, statuses and relations of agents involved in it (see Schatzki 2015 when it describes Deleuze "regimes of power"). Finally, it denotes large systems of real life, such as energy systems with a time-space relevant dimension, which are incessantly changing. Regarding energy grids, it is undoubtable that they are greatly concerned with their security and continuity in time and space, being them an indispensable support for the societal reproduction. They aim towards clear purposes, are spatially deployed and, finally, they are under an incessant process of change depending on the practices performed within them. This tension for change is what distinguishes an apparatus from other kind of socio-technical configurations such as arrangements or assemblages.

Apparatuses are made of lines, which show continuous variations. The features of nonlinear change, emergent properties, spontaneous self-organization, fractal becoming, and so on are perceived to represent not the abnormal conditions of existence of physical, chemical, biological and even socio-historical processes but rather their 'normal' conditions of existence (Ansell-Pearson 1997). The fact that human agents always belong to apparatuses and act within them, interacting with their lines of functioning, means that apparatuses exercise a certain power on them but also that these agents can change them by performing their own practices or fighting against them, as said by Agamben (2009). In other words, apparatuses are agents of change aimed to secure in this way their own continuity and the immortality of the society where they act (Garfinkel 1988). Each apparatus shows lines of breakage and fracture. Sometimes these are situated at the level of powers; at other times at the level of knowledges; other times more at the level of structures of practical action. More generally, it should be said that the lines of subjectivation indicate fissures and fractures. Change depends on the content of the apparatus, and each apparatus deserves its own diagnostic, its own archaeology. Moreover, an apparatus creates a propensity for certain types of events, a trend that some things "happen". The application of this concept to an energy grid opens up the possibility of its change towards the smartness. Can an apparatus become smart, or flat or democratic or equal or differentiated in its functions and provisions? Might an apparatus such as an energy thermal grid be designed and managed in order to generate insensible but enduring changes in the agents' performance? Or to be flexible enough to change in virtue of agents' performance?

An apparatus can change whereas it gives visibility to variable creativity arising out of itself. What counts is the newness of the regime in which a new perspective arises (Deleuze 1992). The newness of an apparatus in relation to what is going before is what one could call "actuality". The new is the current that we are fostering. Each apparatus is thus defined in terms of its newness content and its creativity content, this marking at the same time its ability to transform itself, or indeed to break down in favour of a future apparatus, unless it concentrates its strength along its hard, more rigid, or more solid lines. Apparatuses are composed of lines of visibility and enunciation, lines of force, lines of subjectivation, lines of splitting, breakage, fracture, all of which criss-cross and mingle together, some lines reproducing or giving rise to others, by means of variations or even changes in the way they are grouped. Important consequences arise whereas these lines are more or less rigid and unyielding when they try to orchestrate new configurations and bundles of practices along the grid. An apparatus has in some way the capacity to capture, orient, determine, intercept, model, control, or secure the gestures, behaviours, opinions, or discourses of living agents. An energy grid is an apparatus aimed to capture bodies making them subjects, in the sense of subjectification. As said by Agamben (2009), a subject is that which results from the relation and, so to speak, from the relentless fight between living beings and apparatuses.

Our scrutiny of conventional thermal grids suggests recommendations to policy makers and technical designers to be taken in mind when they decide to build up smart grids.

- Conventional thermal grids offer—because they already are a web of reciprocal actions and of functional interdependencies—the ground on which smartness can be built upon. It means that constraints and opportunities are already established, and they have to be in some way forced up to reach desirable goals of smartness.
- The transition process towards the smartness is often, if not always, seen as a simple addition of different technical operations. From our point of view, these operations are too naïf, socially inappropriate, and driven by a mechanic and linear causality. We suggest thinking in terms of apparatus, or in terms of circularity and co-evolution.
- Different and contrasting aspects mark the deployment of feedback devices. On one side smart energy devices can gradually become 'backgrounded' within routines and practices, increasing the agent's information about the amount of energy they consume. On the other side, beyond a certain level these devices do not encourage householders or customers to reduce their levels of consumption.

They realize the limits to their energy saving potential and become frustrated by the absence of wider policy and market support.

- Smart grids are aimed to shave peaks. This goal can be reached by orchestrating new patterns of differences and repetitions in the heating practices performed by actors.
- A thermal grid bears at the same time energy, power, heat, information, rules, codes, data, and so on. The fact that human practices and technical systems do not act in synchrony is often a matter of communication, interpretation and reciprocal interpenetration.
- The intensity deployed in a thermal grid is fated to disappear in favour of extensity. However, it does not mean that difference inside the grid cancels out. The extension process produces new orders of differences and individualization that inhabit the depth of the reality. A smart thermal grid with all its devices pulls for new singularities and attracts new differences and asymmetries.
- The deployment of change depends on the struggle between agents and apparatuses. It means that in the fostering of smart thermal grids a process of singularization occurs, which implies a harmonization of interests and practices among the different agents of the grid.
- The process of smartness lies into technological areas where metrological, infrastructural and qualification aspects have to be met synchronically, in order to give start to a new becoming involving all socio-technical aspects and the way they communicate and foster feedback.
- The system and its history and dynamics—which is the combination of the intensity that drives the system and the extensity that it exhibits—produces at the end novel patterns depending on its own entropy. In this vision of non-equilibrium thermodynamics, socio-technical systems evolve in an unpredictable way.
- In this perspective, we can say that physical, technological and social agents of the grids are caught into a process of individualization and singularization that opens up new energy arrangements, new intensity/extensity configurations and new forms of socio-technical organization.
- Having described grids as apparatuses we can also say that they are aimed to endorse disciplined actors in order to secure energy provision. However, the way in which people are pushed to behave in way to make energy use more efficient is also unpredictable.

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