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0. EDITORIAL #26

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TOOLS

ENERGY TECHNOLOGIES & DIGITAL AWARENESS

Understanding the Energy Transition by Analyzing the IT Revolution

An Infrastructural Reading to Direct Design Approaches Toward Energy Sustainability

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Abstract
The paper compares the IT revolution and the energy transition, analyzing the former's infrastructural evolution and drawing parallels with the latter. It aims to strategically reinterpret design projects in the context of energy sustainability.
The comparison between the electrical energy transfer system and the data transfer system offers insights and operational suggestions potentially transferable from one field to another. Thus, the analysis aims to analyze the limitations and potentials of the logical architecture models of the computer network, which have already been addressed and solved in the past, to reread the macro-strategies of current energy policies, based on the one hand on a technocratic vision that works on sources and infrastructure (that we can define as client server) and on the other hand on cooperation between actors and society (that we can define as peer to peer). Focusing mainly on this second approach, the paper investigates projects introducing an experimental model – communitarian, collaborative, horizontal, near –, using the IT metaphor as a critical-interpretive analysis capable of opening new reading and development scenarios. The essay intends to systematize the most recent experiments, sometimes still prototypical, conducted between design and art and pilot projects initiated in some European laboratory cities to identify possible strategies and contaminations in light of their energy infrastructure and thus outline a framework of operational strategies for the discipline of design.

1. The Infrastructural Issue of the Energetic Transition

In the different meanings identified by the 17 Sustainable Development Goals of the UN 2030 Agenda, the Energetic Transition is an open challenge that several productive sectors are only beginning to address. In particular, it is one of the central themes of the European Green Deal (European Commission, 2019). It seems urgent in light of the current energy crisis and the depletion of raw materials and finds ample space in the debate within the project disciplines.
One of the biggest challenges to achieving the Energetic transition is facing the issues connected to the energy transmission grid (Solomon et al., 2023).

The energy transmission grid faces several challenges that hinder its efficiency and effectiveness. The U.S. Department of Energy (DOE) has identified interconnection challenges on the transmission grid, which need to be addressed to improve the integration of clean energy sources (DOE, 2023). The current grid infrastructure cannot adequately support the integration of new clean energy sources and the increasing electricity demand. This is further exacerbated by the growing amount of renewable energy sources, which challenge the grid's stability and reliability (FUERGY, 2023). One of the significant issues facing the power grid is the transmission losses that occur during electricity distribution.

These losses impact the grid's efficiency and increase costs and energy wastage. Additionally, the outdated infrastructure of the transmission system is a significant problem as it is not equipped to handle the energy systems of the future

(Bushnell, 2013). This outdated infrastructure poses a threat to the expansion of renewable energy sources, in fact, a mass adoption of them impacts the electricity infrastructure. Bottlenecks or grid congestions may occur when the existing transmission and/or distribution lines, or transformers, are unable to accommodate all required load during periods of high demand – such as simultaneous charging of thousands of EV – or during emergency load conditions, such as when an adjacent line is taken out of service (Gielen et al., 2019).

Most existing power systems infrastructures feature large-scale generating plants, with demand traditionally considered uncontrollable and inflexible. However, with the increasing integration of distributed energy resources, traditional energy consumers will become prosumers who can both generate and consume energy. The generation of DERs is unpredictable and intermittent, and prosumers who have surplus energy can either store it with energy storage devices or supply it to others in an energy deficit. This energy trading among prosumers is called Peer-to-Peer energy trading (Zhang et al., 2017)

Other concerns regard the instability of electricity supply and, in particular, the reduction of the reserve margin during peak demand periods and the interconnection of national grids at the European level: at present, the European energy infrastructure consists of some 27 loosely connected grids, whereas the interconnection between the different areas of the internal market would play a key role in improving the reliability and resilience of the entire system, even in fragile contexts (TERNA, 2023).

Thus, modernization is crucial for ensuring the grid's reliability and resilience in the face of increasing demands and evolving energy systems. In conclusion, the problems of the energy transmission grid are multifaceted and require comprehensive solutions to ensure the grid's sustainability and efficiency. These solutions must address interconnection challenges and transmission losses and, more importantly, accommodate a new, more distributed energy flow throughout the grid.

2. The Paradigm of the IT Revolution, from Client to Server to Peer-to-Peer

Analyzing the issues and challenges connected to the energy transmission grid allows a comparison with another type of grid, the World Wide Web, whose evolution over the years has encountered similar problems, which in some cases have found solutions potentially transferable from one field to another. Specifically, in the context of the aforementioned shift from centralized energy supply models to peer-to-peer energy sharing caused by the development of new renewable energy sources, the revolution generated by the change from *client-to-server* (C2S) to *peer-to-peer* (P2P) network models in the IT field appears to be of interest.

From a network standpoint, the primary difference between these two terms is that, in a peer-to-peer network, every node can ask for assistance and deliver services. In a client-server network, the client nodes demand services, and the server node answers with assistance (Fig.1).

Historically, peer-to-peer file sharing exploded into the public consciousness with the release of Napster in 1999, which sparked a revolution in computer-mediated communication.

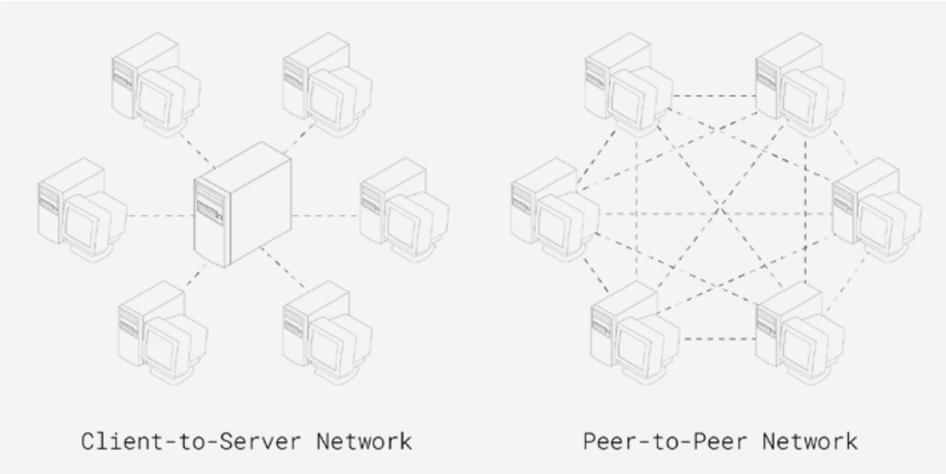

Figure 1. Diagram of Client -to-Server networks compared to Peer-to-Peer networks (credits Massimiliano Cason Villa).

Within a few years, peer-to-peer communication replaced client-server communication as the dominant communication paradigm of the Internet. Peer-to-peer has also redefined the role of home users, empowering them to produce and distribute content free from control by third parties (Huges et al., 2008; Liu et al., 2010).

The main characteristic of P2P networks is that they are decentralized, distributed systems that enable to share and integrate their resources, data, and services, free users from the traditional dependence on central servers, and will allow them to easily share resources (e.g., music, movies, games, and other software). Furthermore, existing P2P file-sharing networks can be divided into three categories according to the degree of network centralization: centralized P2P networks, decentralized P2P networks, and hybrid P2P networks. (Vu et al., 2009)

> Although P2P is often seen as an opposite model to the centralized client-server paradigm, it is essential to state that the first-generation P2P systems (e.g., Napster) started with the concept of centralization. However, in contrast to traditional client-server systems, the servers in centralized P2P networks only keep the meta-information about shared content (e.g., addresses or ID of peer nodes where the shared content is available) rather than storing content on its own. (Sifferd, 2002)

Fully decentralized peer-to-peer networks, which do not rely on any central server, later became widely used to address the problems of centralised P2P networks such as scalability, single point- of-failure and legal issues.

Finally, to avoid the problems observed in the centralized and decentralized P2P networks discussed above, hybrid P2P networks later emerged to provide trade-off solutions with a hierarchical architecture.

From an infrastructural standpoint, peer-to-peer grids feature a wide range of benefits. They distribute the responsibility of providing services from centralized servers to each peer node in the network, with the result of eliminating the bottleneck of centralized servers, optimizing the exploitation of the available bandwidth, processor, and storage across the entire network, and improving the availability of resources as if one peer node is overloaded or experiences a hardware failure, other peer nodes in the network can still handle requests.

2.1. Extending the IT Paradigm to Energy, Parallels, Insights and Possible Solutions

Suppose the paradigm of peer-to-peer versus client-to-server networks is extended to the energy transmission grid. In that case, some of the benefits of peer-to-peer networks can be looked at as useful insights and even possible solutions, particularly towards fostering the integration of new renewable energy sources.

As it was discussed above, in Italy the infrastructure necessary for the distribution of electricity is based on a high-voltage transmission network that allows the energy produced in power plants to be brought to local substations, where it is then converted to low voltage for distribution to individual consumers. Within the metaphor of the IT revolution, this model can be compared to client-to-server networks, where all resources (energy) are supplied by a single server (power plants), this comes at the cost of several issues, such as bandwidth limitations in period of high demand, that are directly translatable to the power transmission grid issues that this work wants to address.

Extending the metaphor to a peer-to-peer network, a new type of power infrastructure can be envisioned, one where all nodes in the grid are connected, and they both consume and produce energy from various sources. Just like on the Net, energy requests can be answered by more than one source, lowering bandwidth usage and the possibility of failures. The European Union is experimenting with such a model, but it is difficult to achieve for multiple reasons. On the one hand, because of the aforementioned infrastructural shortcomings

of the grid. On the other hand, the current regulation for the production and consumption of energy in the European Union prevents users on the grid from freely exchanging energy and currently needs to be updated to allow more decentralized networks (European Commission, 2021c).
Moreover, for these models to be feasible, the technical, economic, social, and behavioral challenges need to be considered. From a behavioral standpoint, sociologist Michel Bauwens describes peer-to-peer models as bottom-up models whereby agents in a distributed network can freely engage in common pursuits without external coercion (2017).
This description portrays peer-to-peer as a primarily social dynamic based on voluntary participation in the creation of common goods that are made universally available.
From a Socio-economic perspective, the peer-to-peer model can be compared to the *Collaborative commons* model, which is the first economic system that stands as an alternative to capitalism and socialism to make the global economy more democratic and ecological (Rifkin, 2014, p. 3).
To further describe this perspective, the American economist and sociologist Jeremy Rifkin also recalls the shift caused by peer-to-peer sharing networks to foreshadow how the companies with the greatest chance of success will be those able to restructure themselves according to a non-vertical, but horizontal management: “I am optimistic because I remember that the very powerful music and media majors collapsed because of millions of Lilliputians like Napster, and because I see that in the energy sector, the large vertically integrated companies are unable to scale the small markets created by green energy” (Romeo, 2014).

In a context where both technical and socio-behavioral challenges must be tackled, the discipline of design can mediate knowledge and needs (Bistagnino, 2008), taking knowledge from one area and transferring it to another to envision trajectories and strategies for innovation.
As such, the insights suggested by the analysis of the IT revolution and the advent of peer-to-peer models become a lens to reread the macro-strategies of current energy policies, based on the one hand on a technocratic vision that works on sources and infrastructure – that we can define as client-to-server—and on the other hand on cooperation between actors and society – that we can define as peer-to-*peer*.
The analysis will focus on the second approach, investigating projects that introduce an experimental model - communitarian, collaborative, horizontal, *near* - that is innovative compared to the established ones.

3. Peer-to-Peer Models to Face the Energetic Transition, Experiments for *Near* Infrastructures

At present, fully decentralized and off-grid peer-to-peer energy communities are mainly found in developing countries. They are born in conditions of strong energy poverty to compensate for the lack of a proper centralized energy grid, and they are usually connected to a number of other socio-economic challenges.
In Italy, people do not directly and locally exchange the energy they produce, whereas experiments in central Europe are based on decentralized social energy networks, whereby the energy consumed is internally and autonomously produced by increasingly self-sufficient communities, although not fully decentralized and off-grid.

In the context of this essay, these cases can be interpreted as primordial ‘peer-to-peer’ explorations of energy,
Following the metaphor built by the essay, the cases will be categorized by following the typologies of peer-to-peer networks that have been presented. The aim is to categorize the current experimentations of peer-to-peer energy sharing models within their efficacy to address the issues of bandwidth shortage and connection of the existing energy supply grid.

The centralized P2P category will not be used. In fact – as it has already been stated – it was born to address issues connected with the laws and regulations on the distribution of content on the Net. In contrast, the decentralized and hybrid P2P networks categories are adapted to addressing the technical issues linked to the transmission of data and energy alike. Inside the decentralized peer-to-peer category, both some of the most ambitious and the most recent energy communities will be analyzed, with a focus on off-grid energy production technologies and their feasibility within the current regulations. In the Hybrid peer-to-peer category, some of the most recent politics and experiments for the creation of energetically sustainable neighborhoods will be analyzed, focusing on how the integrations between the autonomous energy production technologies and the Centralized energy grid play into the efficiency of these experiments.
Towards more democratic and inclusive scenarios, the cases analyzed envisage greater individual empowerment, collaborative formats of energy co-production and co-management, strategic public-private alliances, and neighborhood social participatory actions that enhance the neighborhood scale.

These experiments can provide some indications that can be replicated in other urban contexts.

3.1. Decentralized Peer-to-Peer models, Off-Grid Experiments and Energy Communities

Access to energy is a key element for socio-economic development and human well-being. However, millions of people around the world, especially in developing countries, still live without electricity or have to rely on traditional and unreliable energy sources.
In this context, models based on off-grid energy production and consumption, such as energy communities, are emerging as a promising solution to ensure sustainable and reliable access to energy in rural and remote areas.

Energy communities represent an innovative form of community organization in which community members actively participate in the production, distribution and consumption of renewable energy. These models can be considered fully decentralized peer-to-peer models and offer an alternative route to centralized, monopolistic energy systems, with the aim of creating energy-self-sufficient communities and managing local energy resources more efficiently.

One of the earliest examples is the Auroville community in the southern Indian state of Tamil Nadu (Kapoor, 2007). Founded in 1968 by Mirra Alfassa and French architect Roger Anger, Auroville aims to be a place of peace, harmony, and human unity. The community lives in harmony with nature and practices sustainability principles in all aspects of daily life.

The community has historically been actively engaged in renewable energy production and consumption, minimizing the use of fossil fuels and promoting sustainable technologies such as solar, wind, and biomass. The goal is to achieve energy self-sufficiency and minimize the environmental impact of human activities within the community.
The first solar panels were installed in Auroville in the early eighties. Currently, Auroville has more than 150 houses fully powered by photovoltaic panels and about 50 houses that use solar power in conjunction with a grid connection. Some communities run solely on solar energy. The total standalone photovoltaic energy capacity of Auroville is more than 15% of the total photovoltaic capacity in India.

In recent years, energy communities have also started to sprung up all over the most remote regions of Italy, with examples such as the CER of Roseto Valfortore in Apulia (Eroe, 2021), Magliano Alpi in Piedmont (Turco, 2021), and Villanovaforru in Sardinia (Liberti, 2022).
Among these, an analysis of the latter highlights the issues connected to a true implementation of off-grid communities in Italy.
Founded in 2022 by Mayor Maurizio Onnis, the CER of Villanovaforru bases its production on a photovoltaic system built on top of the roof of a school gym. The system has a power output of 54.5 kilowatts and is connected to forty private and commercial consumers.
In the context of this analysis, the issues with Villanovaforru's model are twofold. On the one hand, the model is not based on actual self-consumption. Still, in exchange, the legislation stip-

ulates that the energy produced is fed into the grid, and those who are part of the energy community receive an incentive commensurate with their consumption during the hours the plant is active. In short, the users pay the bill, and the energy community receives money from the energy services manager. Furthermore, the 2021 decree on energy communities (European Commission, 2021a, 2021b) imposed a maximum power output limit of 200 kilowatts and required that the users connected to the energy community depend on the same secondary substation, that is, the plant where the electricity passes from medium voltage to low voltage. To understand the influence of these limits on the model's scalability, one only has to consider that a small town like Villanovaforru has three secondary substations.

The cases analyzed show the shortcomings of fully decentralized peer-to-peer energy consumption models. Even though decentralized models would greatly benefit the issues connected with the power supply grid infrastructure by allowing exchanges between nodes in the grid, said models still face application and scalability issues due to the evolution of the existing norms and – as such – appear feasible only in contexts with a lack of control and regulations on the subject.

3.2. Hybrid Peer-to-Peer Models, European Policies and Energy Neighborhoods

In recent years, the transition towards a more sustainable and decentralized energy system has become increasingly important on the political and social agenda, both globally and at the European level.

In this context, the peer-to-peer energy consumption model has emerged as one of the most promising solutions to address the challenges of energy production, distribution, and consumption. Several experiments are being carried out at the neighborhood and community levels (Stremke, 2022).
These models can be described as Hybrid peer-to-peer as they combine a mix of production models based on the insertion of small production cores in the form of neighborhoods within the city. The energy produced is partly used internally and partly shared with the centralized city grid.

Among the most notable examples the Kronsberg district in Hannover can be mentioned (Fraker, 2013), which covers approximately 150 hectares and was created in a participatory form to create new housing for EXPO 2000; the project, which includes residences, services, schools and a center dedicated to culture and the arts, envisages housing diversification with three different types of buildings based on energy consumption: “NEH” buildings with consumption below 55 kWh/m2a, “PH” buildings with consumption below 15 kWh/m2a and “SH” buildings with zero consumption, capable of producing more energy than they consume.

Within the district, the *SolarCity* project is an emblematic case: it is a social housing complex (supported by various bodies, including the Göttingen Energy Agency) that has benefited from European, national, and local funding. The flats are heated thanks to 1,350 m2 of solar collectors, and the excess energy produced in summer is stored in highly insulated tanks for winter use. This system is very efficient but relies

on the district's centralized grid to cover the entire share of housing needs (Guarini, 2011, pp. 8-9).
Furthermore, the Schoonship neighborhood in Amsterdam can be cited. Schoonschip is a floating residential neighborhood in a side canal of the River IJ in the Buiksloterham area of Amsterdam North (Leclercq, 2023). The initiators' ambition was to develop the most sustainable neighborhood achievable. Energy plays a central role, as it is generated locally and exchanged with neighbors via a smart grid.

After 10 years of making and implementing plans, 46 households comprising over 100 residents live on the houseboats. These goals were then translated into an ambitious urban design plan, in which the various houseboats are connected by shared jetties. All the homes are connected to a smart grid so that energy is generated collectively, exchanged, and settled between themselves. The 46 house-holds have a single connection to the national energy grid.

From an infrastructural point of view, these cases are functional but not fully decentralized, as they partly rely on the city's grid to be energy efficient, showing that a mixed approach between centralized and decentralized energy production models could be an alternative to an application of feasible peer-to-peer scenarios, in which citizens collaborate to shape a *revolution* of current production and consumption models, based on practices of co-creation, co-production and co-management of resources and goods.

4. Conclusions

The experiments described here cannot be understood as optimal or resolving solutions nor be considered better models in absolute value. Still, they open up alternative and complementary scenarios to the centralized energy production/consumption system, unprepared to face the great contemporary energy challenges.
When read through the lens of the IT revolution, these experiments allow us to see how the criticalities associated with economic-productive structures have been codified for years, enhancing citizens' role in the energy transition.

These models will have to be monitored shortly to fully understand their potential and limitations, margins of effectiveness, and inherent risks: their suitability for use must be assessed concerning the specificities of the territorial context, considering, for example – concerning codified centralized systems – the level of initial economic investment and expenses when fully operational, the pervasiveness and capacity for more or less capillary diffusion even in peri- or extra-urban contexts, the adequacy in satisfying both medium-low and discontinuous energy demands and high energy demands, but episodic and unpredictable.
In this interpretative hypothesis, the "peer to peer" model might be better when there is a capillary spread of many demands, with medium to low and discontinuous energy demands (e.g. in residential districts). In contrast, the "client-server" model would be better with stable energy demand, with a very high flow (e.g., in industrial areas), i.e., in contexts with high concentrated energy demand.

The hypothesis to be pursued should therefore envisage a hybridisation of the two systems, with an overcoming of the approach typically derived from the industrial revolution (linear vision) towards a more contemporary scenario, proposed instead by the information technology revolution (reticular and systemic vision): the digital paradigm of the electronic age can thus help us outline more sustainable urban and energy innovation scenarios, complementary if not alternative to those prevailing - but also abused and sometimes oversimplified - typical of the contemporary debate on sustainability (circular vision).

It is up to us to imagine and then promote radical changes, affirming new development trajectories and new value systems that can overcome the current ones at the root of contemporary economic, energy, environmental, and climate crises.

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IV

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