21. Social metabolism

Dario Padovan, Osman Arrobbio and Alessandro Sciullo

INTRODUCTION

In this chapter we introduce the concept of metabolism as a theoretical tool to understand the current relation between society and nature. The exchange of matter and energy between living systems and their ecological environment is an inescapable mechanism needed for the reproduction of the former. This applies to social systems, but at the same time this metabolic perspective allows us to perceive the concrete ways in which the contradictions of capital accumulation are generating ecological crises and catastrophes. Moreover, metabolism entails dynamics of local and global inequalities. As suggested by Bensaid (2002, p. 302), 'the critique of political economy discovers a turbulent topology, divided up into basins, springs, wells, flows; an articulated space, imbricated and interlocking, whose fault-lines and fractures organize the metabolism of unequal exchange'. The dynamics of social metabolism that entail conflicts and protests at different scales ask for a more radical conceptual tool to deal with these dynamics. In this vein, we suggest using the Foucauldian notion of apparatus on which we might inscribe the local and global tensions regarding the metabolic regulation of energy and water, the two most important 'political liquids' of this era (Caffentzis 2005).

The chapter is organized as follows: in the next section we introduce a general definition of social metabolism underlining how its dynamics and changes are crucial for understanding and assessing the sustainability of the social system and of the social practices it entails. The third section briefly illustrates some socio-metabolic approaches used to carry on investigations. The fourth section provides some insights regarding the sociological dilemmas that underline the social metabolism theory, focusing mainly on different disputes that inhabited the field. In the fifth section we suggest developing, together with some other authors, a sociology of flows coupled with the Foucauldian concept of apparatus. The final section shows that energy and hydro-social metabolism are marked by increasing political controversies and conflicts.

METABOLISM AND SOCIO-ECOLOGICAL REPRODUCTION

For their reproduction and maintenance, societies draw matter and energy from nature, which they transform, distribute, consume and reject. This process is named societal metabolism. Despite all the work on societal metabolism and its environmental impacts, little has been revealed about the regulation of its two main dynamics: production and consumption. Analysis of regulation implies the identification of agents involved in practices of production and consumption (reproduction). This is evidently a functionalist approach, but it is useful as a preliminary exercise to identify main social sectors of societal reproduction and their rulers or drivers. The way in which different agents perform particular activities and the telos they pursue gives rise to different metabolic regimes.

Metabolic regimes have two functions: on the one hand, they fulfil social needs for transforming resources into usable and consumable forms; on the other, they provide grounds for the process of wealth accumulation. Therefore, societal metabolism is not a distinctly delimited, socially disembedded sphere of physical relations, which tends towards general stability. Instead, social metabolism is a complex process that tends to accumulate capital (natural, human, technical and monetary) while it provides socially useful objects, artefacts and services. These functions are apparently not in contrast but are complementary. However, metabolic processes that are too fast and too linear, that is, not circular, might overrun socio-ecological stability, generating a crisis, as, for instance, the rift between consumption and resource availability.

In this chapter we link metabolism and social practices. The practices taken into consideration are those of basic social reproduction, such as eating, cooking, housing, heating, cleaning, moving and caring (Chapter 34 in this volume). Societal metabolism comprises bundles of everyday-life activities aimed at the stable and recursive reproduction of the social material life of human beings. These bundles are the basic units of metabolism, the triggering activities that start metabolism, while also being outcomes of metabolism itself. For instance, social practices by which people eat are either the activators of food collective metabolism or the consequence of socio-metabolic processes that make them possible. All human activity involves the harvesting, transformation, consumption and conservation of matter and energy (Rosa and Machlis 1983; Foster 1999, 2000). From a material viewpoint, practices always consume matter and energy as input and produce something material as output. Thus, we employ the concept of 'practice' in order to focus on the ongoing material social reproduction. The material base of social life is constituted by human practices. Also, practices entail relations – between human agents and with technical artefacts, natural resources and services. These relations vary in different historical circumstances and constitute the specific conditions of social reproduction: human agency must operate within those specific conditions. The mode of combining social metabolism and abstract and concrete practices – mainly labour – brings about the predominant 'form of life'.

Societal metabolism and its connected practices are not only a matter of biophysical accounting; they are also driven by cultural and symbolic horizons. This is why practices of consumption for decades have been studied from a symbolic, cultural, linguistic and identity-making perspective. However, metabolism is driven by the necessity of collective reproduction, which gives reproduction back its original, material meaning. The recent interest in 'metabolism' as a category is owing to its capability to capture this and to account for the resources that systems consume for their reproduction. Systems are consuming too many resources, which is leading to a turn in social ontology, now aiming to cope with the finite biophysical limits. In our view, the 'practice turn' (see, for example, Knorr Cetina et al. 2001; Schatzki 2010; Shove et al. 2012) is one of these ontological approaches, which tries to deal with the material basis of social reproduction. Thus, the 'metabolic turn' (Ayres 1994; Fischer-Kowalski 1998; Foster 1999) is a new ontology in the field of studying physical systems, such as cities, firms and buildings. This implies a reincorporation of the social into the biophysical realm (Padovan 2014).

Metabolism is not only a metaphor, but also a theoretical category useful for understanding, explaining and accounting for the relations of systems to their environments. Societal metabolism is an input/output mechanism, with the aim of maintaining the turnover connected to the conversion of matter and energy into useful things. This is an intrinsic feature in the

reproduction of any organism (Padovan 2003, 2014), yet it is also a category that is useful for investigating, pinpointing and assessing the regulatory processes that govern this complex interchange between organisms and their environment.

At the heart of a metabolic regime are two relations: the first is that between technical progress and nature appropriation (Chapter 22 in this volume), where technical efficiency depends partly on the institutional arrangements and partly on the resistance of natural actants, such as soil, animals, plants, climate and geological stratification, to increase productivity (Moore 2012). The second is the relation between the accumulation dynamic and the mode of social reproduction (Burkett 1999; Foster 1999, 2000). People increasingly depend on the market for their reproduction. This insertion of the reproduction of the labour force in the accumulation scheme dramatically modifies its properties. Flexible combinations of economic and extra-economic practices help to secure, although only temporarily and in specific economic spaces, societal metabolism stability. Yet, if the role of market forces becomes increasingly crucial for societal reproduction, complementary but declining functions of other agents, such as social assemblages, non-humans actants and community activities, might undermine its stability.

The specific processes by which society's metabolism is synchronized with or desynchronized from its environment are determined by a variety of historically organized constellations of practices. The rise of the metabolic rift is a consequence of a historical mode of regulation imposed on metabolic throughput (Clark and York 2005; Clausen and Clark 2005; Clark and Foster 2010). The current societal metabolism is ontologically orientated to an unstable condition owing to its growth and accumulation. The systematic innovation of socio-technical regimes often implies the expansion of consumption, the creation of new needs and the discovery of new uses and exchange values. The consequence is that societies organize their resource throughput by changing parameters of natural processes to gain better access to nature's resource supply (Schandl et al. 2002), and this can bring about very dramatic consequences at the socio-ecological level.

Our attention might turn to the structural coupling and coevolution of infrastructural forms, social practices and discursive apparatuses in the overall reproduction-regulation of societal metabolism, whereas these assemblages are the ground on which societal reproduction processes arise, eventually bringing the system towards dissipation and inequality. Metabolism entails different interconnected activities carried on by different organized agents (Dickens 2004). It corresponds with the whole process of reproduction of the system itself and of its parts, irrespective of the system to which it refers (for example, city, household or firm). This process might be deconstructed into different fields of practice, entailing different agents and sociotechnical systems along all the goods provision chain: appropriation, production and transformation, distribution, consumption and, finally, disposal. All these interrelated activities are subjected to different organizational regimes, rules, knowledge and capabilities (Chapter 18 in this volume). Consequently, they need flexible analytical tools to be reassembled in a new understanding. Practice approaches might help in this effort. Practices can be of all types. There are practices implied in the reproduction of largest social systems, as well as practices aimed to reproduce everyday life; practices aimed at the production of means of production, and practices designed to produce stuffs and goods for households, as well as practices for disposing waste. Practices are the basic units of social affairs.

MODELS OF SOCIETAL METABOLISM

Among the metabolic approaches we find Industrial Metabolism, Urban Metabolism, the multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM) approach, household metabolism and metabolic rift. All have their specific methods for analysis of the exchange between social and natural systems.

Industrial metabolism studies the throughput of raw materials and energy sources in productive systems, arguing that societies must actively regulate this process and develop efficient machinery to diminish the rate of material consumption (Ayres 1994). The analysis of the metabolism of a socio-economic system is a truly interdisciplinary enterprise that uses concepts and methodologies from several social and natural sciences (Fischer-Kowalski 1998, 2003; Fischer-Kowalski and Hüttler 1999). The tool used by industrial or socio-economic researchers is material and energy flow accounting (MEFA). The MEFA framework analyses important aspects of society–nature interaction by tracing socio-economic materials and energy flows, and by assessing changes in relevant patterns and processes in ecosystems related to these flows – that is, the colonization of terrestrial ecosystems (Haberl et al. 2004).

The MuSIASEM approach makes it possible to perform a check on the feasibility and desirability of patterns of metabolism of socio-economic systems by providing a characterization at different levels and scales of: (1) the performance of socio-economic activities (for households, enterprises, economic sectors, national economies and the world economy) and (2) ecological constraints (micro and macro). This is achieved by looking at the interference that the metabolism of matter and energy flows controlled by human activity induces on the expected pattern of metabolism associated with the self-organization of natural ecosystems (Giampietro et al. 2009). While MEFA uses a stock-flow approach as its basic analytical distinction to account for the system's different elements, MuSIASEM uses the fund-flow framework, where the fund is transformative while stocks are not.

Urban metabolism is a multi-disciplinary and integrated platform that examines material and energy flows in cities as complex systems shaped by various social, economic and environmental forces. The biophysical approach to studying and quantifying urban material and energy flows and stocks is the predominant task of urban metabolism today (Gandy 2004). It generally focuses on quantifying the flows of materials or energy in an urban system, in order to identify environmental problems and to design more efficient urban planning policies (Brunner 2008; Barles 2010; Rapoport 2011). However, cities are not only physical entities. They are also symbolic, social, cultural machines. A growing cohort of scholars is expanding the conceptions of urban metabolism as not only consisting of material and energy cycles, but also of highly politicized physical and social processes. These scholars move away from a society–nature dualism and choose to see the city as a process of metabolically transformed nature, a dynamic intersection between social and bio-physical dimensions to urban space, even a socio-natural hybrid or a cyborg of machine and organism (Heynen et al. 2006, Swyngedouw 2006).

The household metabolism is an approach that enables an evaluation of the environmental impact of a community/country, based on the linkages between household consumption and the processes of producing and managing goods. It measures the households' final consumption, including all energy that is consumed directly and indirectly in the processes of production of final goods (Moll et al. 2005). Household metabolism makes it possible to identify different types of aggregation and categorization of consumption (Benders et al. 2006). In addition, the

metabolic model for family units allows us to identify the structure of the everyday practices of consumption, by which the physiology of the socio-economic system itself can be reconstructed (Padovan et al. 2015). All these approaches address the physical account of metabolic processes, but they rarely study the practices of agents that shape the metabolism dynamics.

Finally, there is the metabolic rift suggested by Foster and Burkett derived from the works of Marx (Chapter 4 in this volume). Here the emphasis is on the rift that capitalism inserts in the metabolic process between society and nature. The rift recalled by Marx is the disproportionateness that the process of production and consumption under capitalism generates in the relation of exchange between social and natural reproduction. As stated by Foster (2000, p. 141):

> It was in Capital that Marx's materialist conception of nature became fully integrated with his materialist conception of history. In his developed political economy, as presented in Capital, Marx employed the concept of 'metabolism' (*Stoffwechsel*) to define the labor as 'a process between man and nature, a process by which man, through his own actions, mediates, regulates and controls the metabolism between himself and nature.' Yet an 'irreparable rift' had emerged in this metabolism as a result of capitalist relations of production and the antagonistic separation of town and countryside. Hence, under the society of associated producers it would be necessary to 'govern the human metabolism with nature in a rational way', completely beyond the capabilities of bourgeois society.

METABOLISM AS A SOCIOLOGICAL PROBLEM

The concept of social metabolism is becoming one of the most robust instruments by which to understand the current complex scenarios related to the society/nature complex. For instance, the social metabolism with Nature or the interchange between Man and Nature, as it is currently objectified, shows its fetishized form historically specific to capitalism, in the same way that the invisible hand is the fetishized form of freedom of interchange between men (Cunha 2018). However, it also has a wider meaning, implying some theoretical and ontological problems that emerge from the dualistic nature of the concept.

In the field of social and human sciences, socio-ecological metabolism has been a matter of different disputes. As noted by Foster, the centrality of the concept of metabolism in Marx's thought has been recognized for a long time, though its full significance has rarely been grasped until recently. For example, in the 1920s, Lukács emphasized the 'metabolic interaction with nature' through labour as key to Marx's dialectic of nature and society. He did not, however, go any further. He asserted that 'the metabolic interchange with nature' was 'socially mediated' through labour and matter. Such a metabolic 'exchange of matter' between nature and society, Lukács wrote, 'cannot possibly be achieved – even on the most primitive level – without possessing a certain degree of objectively correct knowledge about the processes of nature (which exist prior to people and function independently of them).' It was precisely the development of this metabolic 'exchange of matter' by means of production that formed, in Lukács's interpretation of Marx's dialectic, 'the material basis of modern science' (Foster 2013, p. 3).

Schmidt (1971) devoted a large part of his book on the concept of nature in Marx to provide a detailed interpretation of the use of the concept of metabolism and to reflect on the social, historical and ecological implications of the concept, which he synthesized in a key premise: 'Marx conceived labor as a process of progressive humanization of nature, an act which is

coincident with the gradual naturalization of humans' (Schmidt 1971, p. 76). Nature is thus thought by Marx to be the material substrate of work, the primary source of all instruments and subjects of labour. All act of giving form to a natural substance must obey the peculiar laws of matter. Finally, for him 'in Marx nature is not merely a social category. It cannot be totally dissolved into the historical processes of its appropriation in respect of form, content, extent and objectivity. If nature is a social category, the inverted statement that society is a category of nature is equally valid' (Schmidt 1971, p. 70).

In the wake of the discovery and systematization of Marx's work, there is a rediscovery of the ecological potentiality of the metabolic perspective, so much so that Marx's *Capital* can be viewed as a theory of metabolism. The metabolism with nature and the internal societal metabolism, which implies the circulation and consumption of commodities, are seen in this perspective as the motor of capitalist accumulation, and capital as the agent that was able to bend these metabolic exchanges to the logic of value (Saito 2017). Viewing metabolism as a tool to investigate social dynamics at different levels and scales somehow challenges all the post-humanist thought that it is strongly influencing the debate about the transformation of planetary biogeochemistry.

Metabolism as a concept has been contended by Moore, who noted that there has been virtually no critical interrogation of social metabolism as the metabolic exchange between two entities: 'nature' and 'society'. The 'separation' of nature and society has been taken for granted. For him this might be a problem because reality is much messier, and the relations of humans and the rest of nature more intimate than the dualistic model suggests. This dualism, which is Cartesian in nature, has the tendency to draw strong lines between what is human and what is 'natural'. We might call this an epistemic rift that generates a series of violent abstractions implicated in the creation and reproduction of two separate epistemic domains: 'Nature' and 'Society'. This epistemic rift, notes Moore again, attests the broad material divorce of the direct producers from the means of production (Moore 2014).

Whereas Moore argues for a dissolution of the analytical boundary between the social and the natural, thus conceding legitimacy to the post-humanist trends championed by Haraway and Latour, for Hornborg this is not only completely at odds with a coherent and well grasped materialism, but also dismantles any chance of politically challenging the destructive forces ravaging our planet (Hornborg 2017). According to Hornborg, Moore's claims would signify a post-humanist co-optation of the critique of capitalism, which in his consequences might serve no other interests than those of neoliberalism. Briefly, metabolism allows us to understand differences and interchanges of society and nature, and it notes that nature is never completely subsumed by capitalist society. That is, as noted by Schmidt (1971), nature is irreducible to a social category, it cannot be completely captured by the historical process of its appropriation, and thus the total unification of nature and capitalism seems not adequate to Marx's perspective and premise.

Under the capitalist conditions of existence, the irreducibility of the natural to the social implies an ontological and insuperable dualism. The reason for the persistence of this dualism can be explained by reflecting upon the concept of consumptive production, which for Marx is the basis of human metabolism. As noted by Marx, the production of the living form is immediately equal to the consumption of elements extracted from the environment. According to Marx (1993, pp. 90–1):

> Consumption is also immediately production, just as in nature the consumption of the elements and chemical substances is the production of the plant. It is clear that in taking in food, for example, which is a form of consumption, the human being produces his own body. But this is also true of every kind of consumption which in one way or another produces human beings in some particular aspect.

However, as noted by Haug (2018), the consumptive production is in the capitalist society functionally disjointed in the two realms of production and consumption mediated by the labour producing value. The separation between production and consumption is the condition for the exchange of commodities for the self-valorization of the capital itself. Here, the immediate unity in which production coincides with consumption leaves its immediate duality intact. It also means that when the biological metabolism, which presupposes the unity of production and consumption, is subsumed under the social sphere, it is separated and even opposed between the two realms of activity – production and consumption – thus reproducing the immanent dualism of capitalism. Production and consumption are ontologically, functionally and spatially differentiated: on one side there are the provisioning systems of material and immaterial goods (Fanning et al. 2020) that depend on the technical development of the production (Haug 2018); on the other, there are bundles of social practices that make individuals able to appropriate and consume these goods (Padovan 2015). In summary, the capitalist society is a world of unsolvable dualisms and contradictions, and the socio-ecological metabolism is part of these dualisms.

SOCIOLOGY OF FLOWS, DEVICES AND APPARATUSES

Even if it recognizes the dualistic nature of capitalist society, the metabolism approach tries to overcome it by challenging the idea that there is an unbridgeable gap between producers and consumers. Even though we think we know where consumption starts and ends, from the viewpoint of natural resources each activity included in social reproduction (production, distribution, exchange and consumption) consumes energy, matter, ecosystems services and labour. Everybody consumes, thus everybody is a consumer, even producers (Princen et al. 2002). That the routine enactment of many different activities entails the consumption of energy and matter including the body's energy, is now being shared by several scholars (Warde 2005; Røpke 2009).

Metabolism is at its simplest level a matter of inputs and outputs. That is, socio-ecological metabolism is a matter of flows. Investigating systems' metabolism can offer multiple indications and indicators on what a system is doing and how it is changing. From the viewpoint of social science, an interesting approach to study metabolic dynamics of different systems is a sociology of flows as suggested by Mol and Spaargaren (2005), based on Castells's and Urry's seminal works (Castells 1996; Urry 2003). This vision can be merged with the notion of apparatus that might help the development of a sociology of flows strengthening the perspective on regulation and security. An apparatus[1] focuses on strategic practices aimed to cope with problems of security: spaces and technologies of security, treatments of the uncertainty, and forms of normalization of human conduct (Foucault 2007). An apparatus is far more orientated towards distinct goals implying a flexible management of flows than Urry's (2003) vision, for which flows have no goal or end and tend to generate, via iteration, complexity, instability and uncertainty.

According to Foucault (1980, p. 194), 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'. 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 series of devices arranged in a way so that they influence the scope, an arrangement that exerts a normative effect on its environment since it introduces specific dispositions. He then 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 in this chapter, to energy, water, mobility and informational grids (Padovan and Arrobbio 2017).

For example, a more or less smart energy grid is not simply a complex of technical devices. It is something more: an apparatus. It is made of a series of devices connected in a complex way that engenders a strong detection and regulation of energy flows and of social behaviour associated with them. Norms are thus developed and inscribed in the example of energy grids into a play of power, aimed to overcome resistances, or to change inertial habits, or again to orientate 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. The same applies to other provisioning systems, such as food, mobility and, finally, water. All these are a combination of devices hold together by an apparatus.

Moreover, if we pay due attention to the essential distinction between flows (quantities of materials qualitatively transformed in the process) and funds (agents transforming a given set of inflows into a given set of stocks and outflows) in the material production process as suggested by Georgescu-Roegen (1971), metabolism is shaped by the ways in which flows are transformed (the structure of the funds or who is involved in the transformation, such as workers or households), and by the proportion between inflows, stocks and outflows. However, the relation between flows and funds is still a matter of regulation, that is, of the way in which apparatuses regulate the dynamics of flows and funds. To obtain a safe circulation of people, money, commodities, water, energy, and so on, and to secure stocks depending on flows but also generating them, an apparatus must regulate flows. In doing that, it generates a circulating and securing power that, in turn, often generates resistance, tensions, ruptures and protests. The analysis of conflicts, manipulation and efforts to access or appropriate flows, as well as resistance to escape the regulation of flows, is a matter of investigation for a sociology of flows. Apparatuses are concerned both with ordering and disordering, regulation and deregulation, normalization and deviation. Instead of ordering and capturing with omniscient foresight, apparatuses get muddled and mix things up, producing subjectivities which escape and need to be reinserted into a different 'multiplicity', forcing a constant reconsideration of the 'new' (Deleuze 1992, pp. 162–3).

Each flow implies devices and an apparatus connecting them to control and regulate the flow itself. Moreover, that human agents always belong to apparatuses and act within them, means that apparatuses exercise a specific power on them but also that agents can change them and the flows managed by them, accepting, resisting or fighting against them (Agamben 2009). New apparatuses often generate a complex and contradictory behaviour in the agents involved in them. Agents hope that something will improve, but they immediately experience

disorder, misunderstanding, regret or disappointment. In its functioning, each apparatus shows, as explored by Deleuze (1992), lines of breakage and fracture. Sometimes these are situated at the level of powers, other times at the level of knowledge, while at yet other times more at the level of practical action. Generally, the lines of subjectivation – that the modern subject is sculpted by the apparatuses in which it is involved – indicate fissures and fractures, and change depends on these fissures and fractures that appear in the apparatus. The creation of the apparatus is shaped by these breaks. This is why each apparatus deserves its own diagnostic, its own archaeology. Moreover, an apparatus creates a propensity for particular types of events, a trend that some things 'happen'. The application of this concept to an energy or water grid opens the possibility of its change. Can an apparatus become flat, democratic, equal or differentiated in its functions and provisions? Might an apparatus, such as a thermal grid, be designed and managed in order to raise insensible but enduring changes in the agents' performance, or to be flexible enough to change by virtue of agents' performance?

ENERGY AND WATER METABOLISM, AND THE ASYMMETRY OF SOCIAL POWER

Social metabolism seems a good point of departure for studying energy and water controversies around the world. Energy flows enter and escape from any system. Water is the flow necessary for any system reproduction. Both energy and water are stored in different carriers and forms (virtual water): they move in the form of direct and indirect (embedded) energy and water, as for example, matter, food and biomass.

Social and environmental injustice connected with energy and water arises because grids are complex apparatuses of connection of different agents, equipped with different power of influence and intervention on flows (Chapter 17 in this volume). It is self-evident that energy and water providers and final users are very asymmetrical in the influence on their management. In their working, grids bring and convey energy, water and social power in the form of rules and norms, bringing up the problematic of how their processes change their own configurations. This asks for an analysis of how energy and water flows through complex systems, how they engender and support already existing positive and negative feedback loops among production, distribution and consumption, and how technical devices, knowledge and enunciations build up regimes and apparatuses. Social forms, as living systems, depend upon flows of water and energy maintaining their systemic viability but also these flows are exchanged as commodities that might generate tensions and conflicts among producers, distributors and final users (Padovan 2015, Padovan et al. 2015).

Energy and water networks are analogous to social networks, since they are made of the same substance: a variable and disparate assemblage of natural, technical and social elements, a continuous process fostering differences and repetitions. As in social networks, in which power flows (re)produce asymmetries and differences (but also negate them), in these technical networks water flows reproduce asymmetries and dissimilarities. The analogy may go further, as long as we pinpoint dynamics of water and energy circulation, security and control: how is the grid governed? Who benefits in terms of provision and consumption? Is the grid an apparatus that assures a win–win mechanism? To answer these questions, we should not to look at water and energy grids as a vertical apparatus going from the centre to the periphery,

but understand it by looking at its extremities, at its outer limits where it becomes capillary (Foucault 2003).

Specifically, three fields of research can be enriched by a metabolic outlook on water and energy. One is the study of potable water grids. They are the most advanced and desirable method of delivering water to households. Originally, in temperate climate Western countries this was the way to provide water for all. It was a measure of social justice (Bocquet 2004). The growing technical and financial needs of water grids and the ideological tendency to privilege private style management for utilities (Bakker 2003) have changed the meaning and function of the grid. Different levels of service and access to energy and water among different populations and individuals are the vehicle of social hierarchies and injustice (Hellberg 2017).

The second field concerns the dramatic increase in interest in the energy communities, that is, the use of this primary good for increasing the autonomy of local groups vis-à-vis the control generated by national public bodies or multinational companies (Gregg et al. 2020; Sciullo et al. 2020). The transition towards sustainable energy not only entails a shift from centralized systems of energy provision towards mixed forms, but also a change in the organizational structure, which comes with new actors who partly replace incumbents in the market. Decentralized, community-based ownership of energy equipment, sources and distribution systems (that is, an energy community) is a prominent example of energy generation and distribution under the control of local owners and used by community members. The energy transition implies a radical shift in energy metabolism and the regime or apparatus that governs as we described previously.

The third field of critical research is the large social organization and management of energy, its crucial contribution to the expanding capitalist society and its crucial contribution to climate change. We can note how neoclassical economic theory has failed to adequately take into account the relationship of human beings to the metabolism of energy and matter in the biosphere. We can note also that energy is going to be theorized into social theory, and that social sciences are developing the due interest for the operations and functions of energy as one of the pillars of social reproduction and capital accumulation.

CONCLUSIONS

Our goal has been to suggest a metabolic approach to investigate the socio-material relations that manage water and energy flows in our society. Water and energy regulation is invested in real and effective practices, where it relates directly to its object, target and field of application. Instead of simply asking who rules or manages the water and energy grids, we should try to discover how multiple bodies, forces, objects, desires and thoughts are gradually and materially constituted as subjects in the making of them. This may correspond to a call for a renewed sociology of flows since, for instance, we have seen that conventional grids leave agents in a state of blindness regarding the functioning of the water and energy systems. However, the deployment of smart grids implies a process of subjectivation, whereby agents are invested in a twofold dynamic of freedom and individual responsibility. Together with water and energy, grids also convey data, prescriptions, rules and codes aimed at disciplining and regulating user practices, from connection to payment. Agents can bend the grid toward their own goals or refuse all the regulating power underpinning it. Forms of adaptation, rejection and manipulation mark the grid, becoming sources of controversies and conflicts between different final

users, as different tenants experience different intensities and performances of the grid, or are located in areas where the grid malfunctions. Finally, the transition process towards more democratic and decentralized ways of management is often, if not always, seen as a simple addition of different technical operations. From our viewpoint, these operations are inappropriate as socially naïve, as they assume that the 'right' results descend in a linear way from the application of the 'right' techniques. We suggest that analysts and developers should think in terms of apparatus, assemblage, bundle of practices and arrangements qualified by circularity and co-evolution.

NOTE

1. The word 'apparatus' is the English translation of the French word *dispositif*, in Italian *dispositivo*. Device refers to a technical *dispositif* and it has nothing to do with the philosophical meaning of apparatus as we use here.

REFERENCES

Agamben, G. (2009), *What is an Apparatus?* Stanford, CA: Stanford University Press.
Ayres, R.U. (1994), Industrial metabolism: theory and policy, in R.U. Ayres and U.E. Simonis (eds), *Industrial Metabolism: Restructuring for Sustainable Development*, Tokyo: United Nations University Press, pp. 3–20.
Bakker, J.K. (2003), A political ecology of water privatization, *Studies in Political Economy*, **70** (1), 35–58.
Barles, S. (2010), Society, energy, and materials: the contribution of urban metabolism studies to sustainable urban development issues, *Journal of Environmental Planning and Management*, **53** (4), 439–55.
Benders, R.M.J., Kok, R., Moll, H.C., Wiersma, G. and Noorman, K.J. (2006), New approaches for household energy conservation. In search of personal household energy budgets and energy reduction options, *Energy Policy*, **34** (18), 3612–22.
Bensaid, D. (2002), *Marx of our Times*, London and New York: Verso.
Bocquet, D. (2004), A public company as a challenger to a private monopoly: providing water to the Eternal City, 1865–1964, *Business and Economic History On-Line*, **2**, 1–13
Brunner, P.H. (2008), Reshaping urban metabolism, *Journal of Industrial Ecology*, **11** (2), 11–13.
Burkett, P. (1999), *Marx and Nature*, New York: St John's Press.
Caffentzis, G. (2005), The petroleum commons: local, Islamic and global, *Alternatives: Turkish Journal of International Relations*, **4** (1–2), 108–23.
Castells, M. (1996), *The Rise of the Network Society*, Malden, MA: Blackwell.
Clark, B. and Foster, J.B. (2010), The dialectic of social and ecological metabolism: Marx, Mészáros, and the absolute limits of capital, *Socialism and Democracy*, **24** (2), 124–38.
Clark, B. and York, R. (2005), Carbon metabolism: global capitalism, climate change, and the biospheric rift, *Theory and Society*, **34** (4), 391–428.
Clausen, R. and Clark, B. (2005), The metabolic rift and marine ecology, *Organization and Environment*, **18** (4), 422–44.
Cunha, D. (2018), The Anthropocene as fetishism, in B.R. Bellamy and J. Diamanti (eds), *Materialism and the Critique of Energy*, Chicago, IL: MCM, pp. 51–72.
Deleuze, G. (1992), What is a dispositif? in T.J. Armstrong (ed.), *Michel Foucault Philosopher*, New York. Routledge, pp. 159–68.
Dickens, P. (2004), *Society and Nature*, Cambridge: Polity Press.
Fanning, A.L., O'Neill, W.D. and Büchs, M. (2020), Provisioning systems for a good life within planetary boundaries, *Global Environmental Change*, **64**, 1–11.

Fischer-Kowalski, M. (1998), Society's metabolism. The intellectual history of material flow analysis, part I, 1860–1970, *Journal of Industrial Ecology*, **2** (1), 61–78.
Fischer-Kowalski, M. (2003), On the history of industrial metabolism, in D. Bourg and S. Erkman (eds), *Perspectives on Industrial Ecology*, Sheffield: Greenleaf.
Fischer-Kowalski, M. and Hüttler, W. (1999), Society's metabolism: the state of the art. The intellectual history of material flow analysis, part II: 1970–1998, *Journal of Industrial Ecology*, **2** (4), 107–37.
Foster, J.B. (1999), Marx's theory of metabolic rift: classical foundations for environmental sociology, *American Journal of Sociology*, **105** (2), 366–405.
Foster, J.B. (2000), *Marx's Ecology*, New York: Monthly Review Press.
Foster, J.B. (2013), Marx and the rift in the universal metabolism of nature, *Monthly Review*, **65** (7), 1–19.
Foucault, M. (1980), *Power/Knowledge: Selected Interviews and Other Writings, 1972–1977*, New York. Pantheon Books.
Foucault, M. (2003), *Society Must Be Defended. Lectures at the Collège de France, 1975–76*, New York: Picador.
Foucault, M. (2007), *Security, Territory, Population, Lectures at the Collège de France, 1977–78*, London: Palgrave Macmillan.
Gandy, M. (2004), Rethinking urban metabolism: water, space and the modern city, *City*, **8** (3), 363–79.
Georgescu-Roegen, N. (1971), *The Entropy Law and the Economic Process*, Cambridge, MA and London: Harvard University Press.
Giampietro, M., Mayumi, K. and Ramos-Martin, J. (2009), Multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM): theoretical concepts and basic rationale, *Energy*, **34** (3), 313–22.
Gregg, J.S., Nyborg, S., Hansen, M., Schwanitz, V.J., Wierling, A., Zeiss, J.P., et al. (2020), Collective action and social innovation in the energy sector: a mobilization model perspective, *Energies*, **13** (3), 651.
Haberl, H., Fischer-Kowalski, M., Krausmann, E., Weisz, H. and Winiwarter, V. (2004), Progress towards sustainability? What the conceptual framework of material and energy flow accounting (MEFA) can offer, *Land Use Policy*, **21** (3), 199–213.
Haug, T. (2018), The capitalist metabolism: an unachieved subsumption of life under the value-form, *Journal for Cultural Research*, **22** (2), 191–203.
Hellberg, S. (2017), Water for survival, water for pleasure – a biopolitical perspective on the social sustainability of the basic water agenda, *Water Alternatives*, **10** (1), 65–80.
Heynen, N.C., Kaika, M. and Swyngedouw, E. (eds) (2006), *In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism*, Abingdon: Routledge.
Hornborg, A. (2017), Dithering while the planet burns: anthropologists' approaches to the Anthropocene, *Reviews in Anthropology*, **46** (2–3), 61–77.
Knorr Cetina, K., Schatzki, T.R. and von Savigny, E. (eds) (2001), *The Practice Turn in Contemporary Theory*, London and New York: Routledge.
Marx, K. (1993), *Grundrisse. Foundations of the Critique of Political Economy*, London: Penguin Books.
Mol, A.P.J. and Spaargaren, G. (2005), From additions and withdrawals to environmental flows: reframing debates in the environmental social sciences, *Organization & Environment*, **18** (1), 91–107.
Moll, H.C., Noorman, K.J., Kok, R., Engstrom, R., Throne-Holst, H., Clark, C., et al. (2005), Pursuing more sustainable consumption by analyzing household metabolism in European countries and cities, *Journal of Industrial Ecology*, **9** (1–2), 259–75.
Moore, W.J. (2012), Cheap food and bad money, *Review*, **33** (2–3), 125–61.
Moore, W.J. (2014), Toward a singular metabolism. Epistemic rifts and environment-making in the capitalist world-ecology, *New Geographies*, **6** (November), 10–19.
Padovan, D. (2003), The concept of social metabolism in classical sociology, *Revista Theomai/Theomai Journal*, **2**, 26–40.
Padovan, D. (2014), Metabolic exchanges and practices of regulation. The assemblage of environment and society in early social sciences, *Ecological Informatics*, **26**, 6–17.

Padovan, D. (2015), Assembling societal metabolism and social practices: the dynamics of sustainable and unsustainable reproduction, in P. Strandbakken and J. Gronow (eds), *The Consumer in Society. A Tribute to Eivind Sto*, Oslo: Abstrakt Forlag AS, pp. 335–62.
Padovan, D. and Arrobbio, O. (2017), Making energy grids smart. The transition of sociotechnical apparatuses towards a new ontology, in N. Labanca (ed.), *Complex Systems and Social Practices in Energy Transitions. Framing Energy Sustainability in the Time of Renewables*, London: Springer, pp. 259–82.
Padovan, D., Martini, F. and Cerutti, A.K. (2015), Social practices of ordinary consumption: an introduction to household metabolism', *Journal of Socialomics*, **4** (2), 1–11.
Princen, T., Maniates, M. and Conca, K. (eds) (2002), *Confronting Consumption*, Cambridge, MA: MIT Press.
Rapoport, E. (2011), Interdisciplinary perspectives on urban metabolism. A review of the literature, working paper, Environmental Institute, University College London.
Røpke, I. (2009), Theories of practice. New inspiration for ecological economic studies on consumption, *Ecological Economics*, **68** (10), 2490–7.
Rosa, E.A. and Machlis, G.E. (1983), Energetic theories of society. An evaluative review. *Sociological Inquiry*, **53** (2–3), 152–78.
Saito, K. (2017), *Karl Marx's Ecosocialism. Capitalism, Nature, and the Unfinished Critique of Political Economy*, New York: Monthly Review Press.
Schandl, H., Grünbühel, C.M., Haberl, H. and Weisz, H. (eds) (2002), *Handbook of Physical Accounting Measuring Biophysical Dimensions of Socio-economic Activities*, Vienna: Federal Ministry of Agriculture and Forestry, Environment and Water Management.
Schatzki, T.R. (2010), Materiality and social life, *Nature and Culture*, **5** (2), 123–49.
Schmidt, A. (1971), *The Concept of Nature in Marx*, London: New Left Books.
Sciullo, A., Wierling, A., Arrobbio, O., Delvaux, S., Gilcrease, G.W., Gregg, J.S., et al. (2020), Collective action initiatives in the energy transition, in A. Diemer, E. Nedelciu, M. Schellens, M. Morales and M. Oostdijk (eds), *Paradigms, Models, Scenarios and Practices for Strong Sustainability*, Clermont Ferrand: Oeconomia Editions.
Shove, E., Pantzar, M. and Watson, M. (2012), *The Dynamics of Social Practice*, London: Sage.
Swyngedouw, E. (2006), Circulations and metabolisms: (hybrid) natures and (cyborg) cities. *Science as Culture*, **15** (2), 105–21.
Urry, J. (2003), *Global Complexity*, Cambridge: Polity.
Warde, A. (2005), Consumption and theories of practice, *Journal of Consumer Culture*, **5**, (2), 131–53.