Toward a polycentric low-carbon transition: the roles of community-based energy initiatives in enhancing the resilience of energy systems

Thomas Bauwens

Abstract

An understanding of the resilience of energy systems is critical in order to tackle forthcoming challenges. This chapter proposes that the polycentric governance perspective, developed by Vincent and Elinor Ostrom, may be highly relevant in formulating policies to enhance the resilience of future energy systems. Polycentric governance systems involve the coexistence of many self-organized centers of decision making at multiple levels that are formally independent of each other, but operate under an overarching set of rules. Given this polycentric approach, this chapter studies the roles of community-based energy initiatives and, in particular, of renewable energy cooperatives, in enhancing the institutional resilience of energy systems. In this perspective, the chapter identifies three major socio-institutional obstacles, which undermine this resilience capacity: the collective action problem arising from the diffusion of sustainable energy technologies and practices, the lack of public trust in established energy actors and the existence of strong vested interests in favor of the status quo. Then, it shows why the development of community-based energy initiatives and renewable energy cooperatives may offer effective responses to these obstacles, relying on many empirical illustrations. More specifically, it is argued that community-based energy initiatives present institutional features encouraging the activation of social norms and a high trust capital, therefore enabling them to offer effective solutions to avoid free riding and enhance trust in energy institutions and organizations. The creation of federated polycentric structures may also offer a partial response to the existence of vested interests in favor of the status quo. Finally, some recommendations for policymakers are derived from this analysis.

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Polycentric governance approaches for a low-carbon transition:

the roles of community-based energy initiatives in enhancing the resilience of future energy systems

Thomas Bauwens

1. Introduction

Energy systems are constituted of technological, social and ecological components and processes that interact with each other in a complex fashion. Acknowledging this complexity is crucial to coping with the challenges that energy systems currently present. The analyses of the political economist Elinor Ostrom and her collaborators may be very insightful in this endeavor. Although Ostrom's approach comes within the scope of rational choice theories, she was conscious of the implications of complexity theory and incorporated some of its concepts, such as nonlinearity, self-organization and feedback loops in to her own work (Morçöl 2014). Based on her contributions, energy systems can be conceptualized as complex "social-ecological systems" (SESs), i.e., systems of interdependent bio-physical and non-human biological units interacting with social and institutional components.[1] SES scholars have been particularly interested in the determinants that reinforce or hinder the "resilience" of such systems. Resilience of an SES refers, essentially, to its capacity to retain the same system characteristics despite changes in the behavior of its component parts or the surrounding environment (Carlson and Doyle 2002, Walker et al. 2004).

An understanding of the resilience of energy systems is critical in order to tackle forthcoming challenges. In particular, climate change and the depletion of fossil energy sources require massive transformations of our models of energy production and consumption. In response, the necessity of a transition to low-carbon sources is increasingly acknowledged. This transition will most likely imply the displacement of fossil fuels by various renewable, intermittent and distributed energy technologies along with energy demand reduction, and will be highly disruptive for established energy actors. The ability of future energy systems to implement this transition process will depend, therefore, on their resilience, understood as their capacity to deploy these renewable energy (RE) technologies fast enough so as to maintain their essential functions, such as the provision of energy services. However, several socio-institutional barriers can severely undermine this resilience. In this chapter, three barriers are discussed: the collective-action problem, arising in the diffusion of more

[1] Institutional components are constituted by the formal and informal rules shaping and structuring the interactions between people within collective settings (families, local communities, markets, business organizations, etc.) (Ostrom, 2005).

sustainable energy technologies and practices; the lack of trust from the public in established energy actors; and the existence of strong vested interests within the energy industry in favor of the status quo. Regarding the first obstacle, averting climate change is an action of global and public interest, because everyone benefits from a reduction of greenhouse gas emissions even if not contributing to it. This problem can therefore be configured in terms of a collective-action problem (Sandler 2004). According to the conventional theory of collective action, rational actors pursuing their own interest will indeed not participate in collective efforts because they have incentives to free-ride on the constructive behavior of others (Olson 1965; Hardin 1968).

It is proposed in this chapter that the polycentric governance perspective, developed by Vincent and Elinor Ostrom, may be highly relevant in formulating policies to enhance the resilience of future energy systems. Polycentric systems involve the coexistence of many self-organized centers of decision-making at multiple levels that are formally independent of each other, but operate under an overarching set of rules (Ostrom et al. 1961). Given this polycentric framework, this chapter focuses on the roles of community-based energy (CBE) initiatives and, in particular, of RE cooperatives, in enhancing the institutional resilience of energy systems. CBE initiatives are formal or informal citizen-led initiatives which propose collaborative solutions on a local basis to facilitate the development of sustainable energy technologies (Walker and Devine-Wright 2008; Bauwens et al. 2016). As a specific form of CBE initiative, the cooperative model enables citizens to collectively own and manage RE systems at the local level (Huybrechts and Mertens 2014). CBE initiatives are therefore inspired by a self-organization principle, which is at the core of polycentric systems.

This is organized as follows: the first section presents Elinor Ostrom's approach to complexity and the main building blocks of her work, including the Social-Ecological System framework. The second section explores the concept of resilience of SESs and specifically emphasizes the need for institutional adaptability and polycentrism. The third section applies these theoretical lenses to energy systems. As a first step, the section shows how energy systems can be considered as social-ecological systems and describes some essential features of the historical model of present energy systems, i.e. a model based on centralized extraction and conversion of fossil energies. Secondly, after discussing the need for a transition to low-carbon sources, this section describes three major barriers to this transition. The fourth section describes why the development of CBE initiatives and RE cooperatives may offer effective responses to these obstacles, and, finally, the last section provides some main conclusions and recommendations for policy-makers.

Elinor Ostrom and complex thinking

There are many different notions and measures of complexity (Mitchell 2009). One way to define the complexity of a system is to characterize it in terms of its degree of hierarchy or level of organization (Simon 1962; McShea 2001). This approach sees complex systems as composed of multiple nested subsystems. Each subsystem possesses unique emergent properties, which depend on its own constitutive elements, but appear only when these elements are integrated. In this sense, each subsystem constitutes a whole, but is also, at the same time, a part of a larger structure. This nested, hierarchical structure is common to physical, biological and social complex systems (von Bertalanffy 1969). As an example in the biological context, the human body is composed of cells which are organized into tissues, which themselves constitute organs, which are parts of physiological systems. In the social context, individuals are part of families, which organize into villages or tribes, which organize into larger groupings, etc.

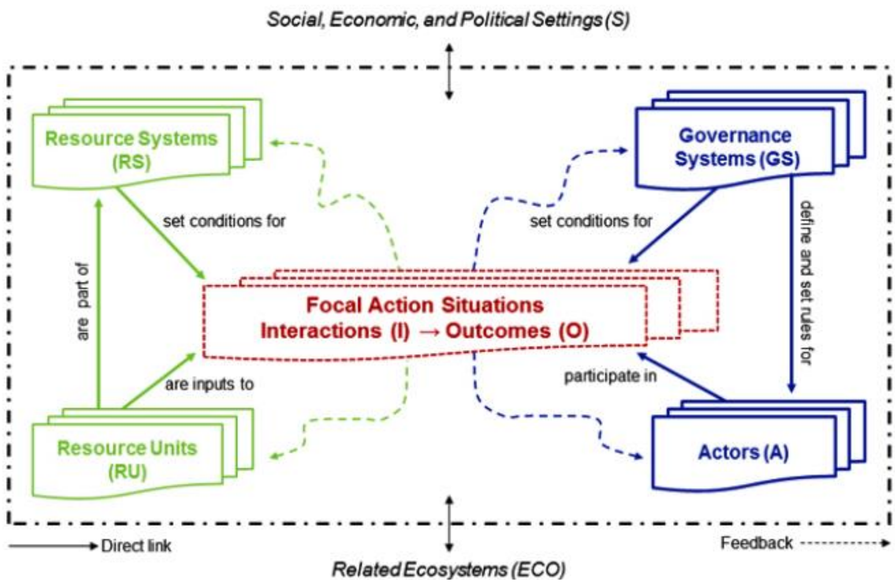
Elinor Ostrom's conception of complexity finds its roots in this hierarchical vision. Ostrom focused primarily on institutions, which are the rules, the norms, the dos and don'ts that structure all kinds of social interactions. She built on the concept of "holon" to describe and analyze the multilevel nature of complex institutional systems (Ostrom 2005). A holon refers to what, being a whole in one situation, is simultaneously itself just a part of another larger system (Koestler 1973). In this hierarchical approach to complexity, these part-whole units are the fundamental constituents of any complex system. This holon property also holds for institutional systems: rules affecting one situation are themselves parts of a larger system of rules designed by individuals interacting at a higher level of decision-making. Ostrom and her collaborators used this idea to develop the "Institutional Analysis and Development" (IAD) framework to help structured thinking about the elements that influence decision-making in social situations and, in particular, collective action situations and social dilemmas[2]. This framework offers a nested set of variables which can be used to investigate human interactions and outcomes in a wide variety of settings. It has notably been used as a basis for developing a theory of common-pool resource management and for studying decentralized natural resource policies (Yandle and Dewees 2003; Clement 2010).

The IAD framework has been especially useful for studying social dilemmas at a micro-scale, but pays little attention to the broader social, institutional and physical environment, including demographic and market pressures. For this reason, a common criticism addressed to the IAD

[2] A social dilemma is a situation in which an individual profits from selfishness unless everyone chooses the selfish alternative, in which case the whole group loses (see https://en.wikipedia.org/wiki/Social_dilemma for further information).

framework is that actors have often been presented as "independent of the larger historical and social context in which [they] operate" (Clement 2010: 131; see also Agrawal 2001). In order to include the influence of broader contextual variables, Ostrom and her colleagues designed the "Social-Ecological System" (SES) framework (Ostrom 2009; McGinnis and Ostrom 2014). A SES encompasses "interaction between, on one hand, a society's cultural and institutional arrangements, and, on the other hand, its physical environment" (Aligica and Tarko 2014: 55). Indeed, human beings transform the physical environment into usable resources (food, raw materials and energy). In addition, SESs reflect the hierarchical approach to complexity described above, as they are composed of multiple subsystems, whiles being embedded in multiple larger systems (Anderies et al. 2004). The elementary unit of this framework is constituted by an "action situation", in which multiple actors interact with each other under the influence of different contextual variables. These interactions produce outcomes, which are linked to contextual variables through feedback paths (Figure 1).

Figure 1. Graphical representation of the Social-Ecological Framework.



Source: McGinnis and Ostrom (2014).

Contextual variables relate to four core interacting subsystems: Resource Systems, Resource Units, Governance Systems and Actors. Resource Systems designate the biological/technological systems from which Resource Units are extracted. These Resource Units can then be consumed, used as inputs in a production process or exchanged for other goods and services. Governance Systems include "the prevailing sets of processes or institutions through which the rules shaping the behavior of the [actors] are set and revised" (McGinnis 2011: 181). Actors are individuals or collective entities who participate in relevant action situations and are defined by some shared attribute(s). Social, Economic, and Political Settings and Related Ecosystems represent respectively the broader social and ecological contexts that may influence the focal SES exogenously.

Ostrom's approach to resilience of complex social-ecological systems

Most discussions about resilience currently unfold within the SES framework just presented. Social-ecological resilience encompasses three properties (Carpenter et al. 2001): (a) the amount of disturbance a system can absorb while remaining "within the same domain of attraction (that is, retain the same controls on structure and function)"[3]; (b) the ability of the system to self-organize (versus lack of organization, or organization forced by external factors); and (c) the ability for learning and adaptation of the system. The first property, the "absorption capacity", is an equilibrium approach to resilience. Under this perspective, a resilient SES is a system that returns to the pre-existing situation, conceived as a state of equilibrium, if disrupted (Holling et al. 1995). In the non-equilibrium vision of resilience, embedded in the third property, SESs are acknowledged to "organize around continuous change" (Janssen et al. 2007: 309). Under this perspective, the focus is not so much on a return to an initial equilibrium state, but rather on the idea of adaptability to shocks and stresses and on the extent to which institutions foster such adaptability. Closely linked to this definition of resilience are the notions of adaptive capacity (Gunderson 2000) and transformability (Walker et al. 2004). It may be worth noticing that, unlike sustainability, resilience can be desirable or undesirable. For instance, system states that reduce social well-being, such as polluted water supplies or dictatorships, can be highly resilient. In contrast, "sustainability is an overarching goal that includes assumptions or preferences about which system states are desirable" (Carpenter et al. 2001: 766).

Janssen et al. (2007) showed that interactions between biophysical and social elements of an SES are bidirectional: pressures on ecological systems can affect the social-economic configuration and, conversely, threats to social-economic institutions can impact the biophysical environment. Social-institutional components and, in particular, institutional adaptability are thus crucial to analyzing resilience of an SES. "An institutional arrangement that inhibits innovation or does not secure it at a fast enough rate is an institutional arrangement that undermines resilience" (Aligica and Tarko 2014: 57). On the top of this capacity of institutions to adapt and change, Ostrom stressed the importance of self-organized initiatives by local actors in ensuring resilience of SESs. Indeed, under certain conditions, coordination and rules do not require external drivers or hierarchically superior

[3] See Carpenter et al. (2001 :766).

forces to happen and can emerge from actors' interactions. Relying on Shepsle's (1989) definition of a robust institution, she sought to define the set of general principles that enable the maintenance of self-organization over time. These principles have been demonstrated empirically (Ostrom 1990) and theoretically (Wilson et al. 2013) to promote resilient SESs. These design principles are: (1) clearly defined and generally understood boundaries and institutional roles; (2) effective monitoring against free-riding; (3) graduated sanctions against offenders; (4) proportionality between costs and benefits; (5) conflict resolution mechanisms generating outcomes perceived as fair; (6) minimal recognition of rights to organize[4]; (7) effective collective choice arrangements such as consensus, which avoid decisions imposed by some members at the expense of others; and (8) subsidiarity and nested or "polycentric" structures.

This last principle, which refers to the concept of "polycentricity", is, according to Aligica and Tarko (2014), the most distinctive feature of the Ostromian approach to resilience. Polycentricity describes the coexistence of many self-organized and autonomous centers of decision making, all operating under an overarching set of shared rules (Ostrom et al. 1961). Polycentric systems involve the existence of local resource governance units nested in larger, general-purpose units located at higher levels of decision-making (often governments, but not necessarily), according to a principle of "Russian nesting dolls". As stated above, self-organization is an essential guiding principle of polycentric systems. Accordingly, a key assumption of polycentric approaches is that governance arrangements are more effective when citizens have the juridical and material capabilities to self-organize multiple governing bodies at diverse scales (Andersson and Ostrom 2008).

Polycentric governance presents several practical advantages over highly centralized systems. First, it enhances the institutional resilience of an SES. By creating redundancy of local centers of decision making, it fosters the conditions for the experimentation and creativity needed to explore novel and potentially superior combinations of rule systems, i.e. for adaptability of rules. This redundancy also mitigates the effects of a governance failure by limiting such effects to one locality, compared to the substantial costs induced by a failure of a centralized unit that covers a large area. Second, polycentric systems may exhibit informational benefits compared to highly centralized systems by encouraging the use of local knowledge to devise rules that are better adapted to each local situation than any general set of rules. Highly complex systems of rules involve many interconnected factors that have to be taken into account, so that "no one, including a scientifically trained, professional staff, can do a complete analysis" (Ostrom 2000: 12). In these conditions, it is often better to rely

[4] In Wilson et al.'s (2013: 522) words, "groups must have the authority to conduct their own affairs. Externally imposed rules are unlikely to be adapted to local circumstances and violate principle 3".

on the knowledge that local resource users have accumulated, since they are likely to devise rules that are better adapted to their local needs than "one-size-fits-all" rules created at a very centralized level (Irwin 1995, Wynne 1996). A third, related benefit of polycentrism is that it enables feedback on the performance of rules to be captured in a disaggregated way (Ostrom 1999). Fourth, local resource users know each other. They are thus more likely to select trustworthy partners and exclude untrustworthy ones, enhancing the conditions for cooperation and reciprocity between participants (Powers and Thompson 1994; Andersson and Ostrom 2008). Fifth, polycentrism lowers enforcement costs by strengthening local perceptions of the legitimacy of rules, and also by making it easier to fashion rules that can affordably be monitored. Indeed, if local actors are involved in the design of rules and the monitoring of compliance with these rules, they will be apt to craft rules that make infractions highly obvious so that monitoring costs are lower. Further, by creating rules that are seen as legitimate, local actors encourage higher conformance.

While polycentricity is opposed to highly centralized governance, the existence of an overarching set of shared rules implies that it should not be equated to full decentralization either. If the governance regime lacks coordination among self-organized initiatives, it will not operate as a system, but rather as a network of fragmented and unstructured actors who may dissipate their efforts in unproductive directions. This may lead to contradicting actions and poor efficiency (Black 2008).[5] This is why, asides from bottom-up and self-organized initiatives, top-down institutions are crucial in the creation and maintenance of any polycentric governance system to coordinate the activities of the multiple participants, the resolution of conflicts between lower-level units and the exchange of information about what has worked well, and may be transferable, from one local setting to others. Mansbridge (2014) identifies at least four roles for these higher-level governance units: (1) the threat of imposing a solution if local parties cannot come to a negotiated agreement; (2) the provision of a relatively neutral source of information; (3) the provision of "institutional facilities" to facilitate negotiations; and (4) the monitoring of compliance and sanctioning defection from compliance in the implementation phase after the negotiators have reached agreement.

One example of large-scale successful polycentric structure is the scientific community, as explained by Tarko (2015). This community lacks any central management or a formalized

[5] In this perspective, some authors have pointed out various limitations linked with fully decentralized governance systems, among which are: the high cost of self-organization (Meinzen-Dick 2007); the risk of local tyrannies, i.e. the lack of democratic governance or the domination of self-organized systems by local leaders who change rules for their own advantage (Platteau and Gaspart 2003; Platteau 2004); the problem of stagnation, i.e. actors' reluctance to produce new rules and institutions to innovate due to the complexity of the resource system involved; and the risk of conflict among user groups (Alston et al. 1999).

legislative or rule-enforcement body and multiple research centers coexist, each with its own somewhat different research agenda and preferred methods of investigation. Yet, the success of the scientific community and the progress of science is the result of an overarching set of shared informal rules which limits free-riding and enables the whole system to work. In environmental contexts, the polycentric perspective has been applied to analyze water (Marshall et al. 2013; Pahl-Wostl and Knieper 2014) and forest resource management (Nagendra and Ostrom 2012). References to the polycentric perspective have been made to a limited degree in previous work on governance of energy systems (Sovacool 2011; Goldthau 2014; Koster and Anderies 2013) but without significant or systematic development.

Resilience of energy systems and low-carbon transition

Energy systems as social-ecological systems

Recent studies argue for framing energy systems as SESs (Hodbod and Adger 2014; Bauwens et al. 2016). Production, distribution and consumption activities within energy systems involve interactions between, on the one hand, ecological processes and technological artefacts and, on the other, social practices and systems of institutional rules. As such, they can be analyzed through the lenses of the SES framework introduced above. Energy systems consist of "resources that are converted through various means to provide energy services" (Löschel et al. 2009: 391), energy services being defined as the benefits that energy carriers produce for human well-being (e.g., mobility for an automobile, heat for a stove, mechanical energy for air circulation). Energy resources can be renewable and nonrenewable, as well as primary or secondary. Renewable resources include solar radiation and all of its biospheric transformations Renewable resources include solar radiation and all of its biospheric transformations (e.g. wind, moving water or biomass), and geothermal heat. Their main common characteristic is that they are naturally regenerated over a short period of time. Nonrenewable resources, on the other hand, cannot renew themselves within timeframes that are meaningful to humans. They include fossil fuels, coals, hydrocarbons and radioactive minerals. As for the second distinction, primary energy means the energy "embodied" in natural resources and not yet converted into other forms of energy. Secondary energy includes the forms of energy generated by conversion of primary resources, e.g., petroleum products, manufactured solid fuels and gases, or electricity. Crossing these two criteria yields four types of resources (Table 1).

Table 1. Different types of energy resources and fuels

	Renewable	Nonrenewable
Primary	Solar radiation, plant mass, wind, moving water	Coals, crude oil, natural gases, uranium, other minerals
Secondary	Biodiesel, ethanol, processed wood-pellets, electricity	Coke, coal gas, refined crude oils, nuclear fuel rods, electricity

Source: Sovacool and Dworkin (2014).

It follows that energy systems can be subdivided into two major types of Resource Systems: bio-physical Resource Systems, which are natural, and technological Resource Systems, which are human-made. Bio-physical Resource Systems refer to the systems from which primary energy resources are extracted and, in the case of renewable resources, through which the levels of the focal resource are regenerated by natural dynamic processes. Nonrenewable resources "are defined in terms of reserves or energy stocks, which can be depleted over time", whereas "renewable energy resources are defined in terms of energy flows (e.g., energy production per year)" (Löschel et al. 2009: 396). For this reason, the distinction between Resource Systems and Resource Units is blurred in the case of renewable resources. Resource Units of bio-physical Resource Systems are, for instance, the tons of oil or gas withdrawn from reservoirs, the photons radiated by the sun or the liters of water flowing from water sources. Bio-physical Resource System variables encompass the type and abundance of resources, their renewable or nonrenewable nature, their location, etc.

Technological Resource Systems, on the other hand, are defined here as the set of humanly constructed facilities and infrastructures that enable the conversion, transport, distribution and consumption of primary or secondary energy. They can be decomposed into multiple constituents: the generation assets, the "delivery mechanisms" and the "prime movers". Prime movers are "the technology that converts primary and secondary fuels into useful and usable energy services" (Sovacool and Dworkin 2014: 38), such as human muscles, steam engines, jet turbines or household electric appliances. Delivery mechanisms are the delivery infrastructures used to connect primary resources to prime movers, including pipelines, tankers, and electric transmission and distribution lines. The Resource Units of technological Resource Systems are the flows of primary or secondary energy circulating in these infrastructures. Technological Resource System variables cover the type of primary resource used, the characteristics of generation assets (their size, their load factor[6], their

[6] The load factor is the percentage of time an asset is operated at full load.

distance from the grid, whether they are intermittent or not), delivery mechanisms and prime movers.

In addition to these bio-physical and technological characteristics, energy systems are shaped to a considerable extent by Governance Systems and Actors variables. For instance, Moe (2010) remarkably shows that the differences observed in the energy structure of countries cannot solely be explained by their different energy resource endowments. The occurrence and the pace of transitions from one energy source to another, for instance, are also largely determined by the level of political power and influence of established energy actors. In addition, energy systems are shaped to a large extent by households, grassroots actors and civil society (Smith 2012; Stern 2014). By supporting, accepting or opposing changes in larger energy systems, individuals acting as citizens can influence public policies or private organizations' decisions and can contribute to shaping the transformation of energy systems. These reactions sometimes organize into social movements, e.g., public reactions to nuclear power, shale gas extraction infrastructures or onshore wind farms.

The historical model of the energy supply industry

It is worth highlighting two aspects of the way energy supply systems have been historically shaped: the dominance of fossil fuels as the main primary energy source and the development of a centralized model of energy supply. Regarding the first aspect, our dependence on fossil fuels is striking. Out of the 157,482 terawatt-hours (TWh) of primary energy generated in 2013 by humankind, fossil fuels provided about 81.4% of this total, while nuclear energy provided 4.8%, and renewable sources provided the remaining 13.8% (10.2% by biomass and waste, 2.4% from hydropower and less than 1.2% from other RE sources) (IEA 2015). Regarding the second aspect, the rise of fossil fuels coincided with the construction of very centralized technological Resource and Governance Systems which have prevailed until today. At the technological level, the dominant model of energy infrastructure is characterized by large centralized power stations generally located close to sources of fossil fuels and remote from load centers, which supply huge grids run by regional or national monopolies. The energy sector has emerged as a vertically and horizontally integrated system with important technical interdependencies. At the governance level, the energy industry was historically institutionalized along with this technological configuration, according to a highly hierarchical and centralized organization under the control of the State. It was vertically integrated, which means that firms operating in the different functions of the energy value chain, i.e. production, network activities and sales, were strongly interconnected through ownership rights, contracts and regulation (Künneke 2008). This was somewhat modified with market liberalization. In practice, however, although the liberalization process significantly changed e.g.

the European landscape of the power industry, institutions are still strongly marked by this historical configuration. For instance, according to DTI/Ofgem (2006), the market and regulatory models adopted in the UK at privatization reflected the predominantly centralized model of transmission and distribution. As a result of these technological and institutional evolutions, industrial economies have, to a large extent, become "locked" into fossil-fuel based, centralized energy systems through a path-dependent process driven by technological and institutional feedbacks and mutual reinforcements—so-called "increasing returns to adoption" in economists' jargon (Unruh 2000). Once a country is "locked in," it faces persistent market and policy failures that reduce the chances for alternative technologies to join the market (Arthur 1994; David 1985).

Furthermore, in this model, actors from the demand-side, i.e. energy consumers, are minimally engaged in energy generation (Eyre 2013). Energy users do not need to know where energy is coming from, how it is produced and transported. Centralized generation "has led to the design and deployment of a range of energy technologies, services and procedures, from meters to bills to regulatory institutions to power stations, that foster minimal public engagement" (Devine-Wright 2007: 68). From a supply-side perspective, it has led "designers, developers and installers of new energy technologies [to] aim to minimize public engagement since this would be assumed to increase the risk of resistance, delay, planning refusal and inefficient or incorrect use of technologies".

The dominance of fossil fuels poses major threats to the ecological and social sustainability of energy systems. Climate change at a global scale and local air pollution associated with greenhouse gas emissions are probably amongst the most alarming ones. Other challenges include energy security in a context of finite fossil sources and price volatility, the geopolitics of energy, universal access to energy services and energy poverty. While there is little consensus about when fossil resources will exhaust, the expected global demand expansion ensures an accelerated decline of current reserves. Furthermore, the world's known remaining oil reserves are concentrated in unstable regions of the world, especially the Middle East. Similarly, the other main conventional energy fuels—coal, natural gas and uranium—are distributed very unevenly. This highly concentrated distribution of oil has caused the transfer of immense wealth from oil-importing countries to oil producers (Sovacool 2012). The concentration of fossil fuels also generates price volatility and interruptions in supply (Sovacool et al. 2014).

These challenges require massive transformations of energy systems and call for a transition toward low-carbon energy systems. In turn, the ability of energy systems to implement this transition process depends on their resilience, understood in this context as their capacity to deploy low-carbon technologies so as to maintain their essential functions.

Institutional obstacles to a low-carbon transition

There are many constraints to a low-carbon transition, but most existing studies focus on the technical and economic feasibility of alternative energy systems in meeting energy demands at the same time as meeting a carbon reduction target (e.g., Ekins et al. 2013). The remainder of this chapter concentrates however on constraints of a socio-institutional nature. These mostly derive from a lack of support from society, organizations or government agencies or a lack of appropriate institutions to govern change. These challenges are thus more directly related to Governance Systems and Actors variables rather than to Resource Systems and Units. The focus is drawn on three specific challenges that are particularly threatening for institutional resilience of energy systems: the collective-action problem arising from the diffusion of sustainable energy technologies and practices, the lack of public trust in established energy actors and the existence of strong vested interests in favor of the status quo.

Regarding the collective-action problem, following Samuelson (1954), economic goods are frequently classified into two categories: private goods and public goods. A good is purely private when the producer bears all the costs of production and a single consumer enjoys all the benefits of consumption. A pure public good, in contrast, is characterized by non-rivalry and non-excludability. Non-rivalry means that an individual's consumption of the good does not limit the capacity of others to consume the same good. Non-excludability implies that it is difficult to exclude individuals who have not paid for the good from its consumption. The collective-action problem is intimately related to the attribute of non-excludability. More precisely, a person who cannot be excluded from the benefits of a public good will have no incentive to bear a part of the costs of its production and will thus have a strong incentive to behave as a "free-rider" (Olson 1965). Collective-action problems constitute a threat to the resilience of any SES, because they lead to overharvesting of common resources or to the underprovision of public goods and, eventually, to the collapse of the system.

In the context of energy systems, averting climate change is a global and public interest. Past energy transitions (e.g., from traditional biomass to coal and from coal to oil) have been driven by a large minority of consumers who were willing to pay considerably more for privately accruing services associated with new energy sources or technologies (Fouquet 2010). In contrast, the environmental benefits of the current low-carbon transition are shared by all individuals and thus clearly present characteristics of a public good. It is likely that too few consumers will be willing to pay more for the environmental improvements, although their number is growing (Longo et al. 2008). For instance, free-riding has indeed been identified as one of the major barriers to the diffusion of RE technologies. While attitudinal surveys demonstrate high levels of public support for green power products (Batley et al. 2001; Nomura and Akai 2004), the green marketing literature consistently reports a large gap between the number of residential customers willing to pay a premium for them and actual participation rates in green pricing programs (Byrnes et al. 1999; Wiser 1998). The collective-action problem has then also been identified as a barrier to sustainable electricity consumption within households (Ohler and Billger 2014).

A second socio-institutional obstacle lies in the lack of trust in traditional energy actors. Trust in institutions can be defined as "believing that a person(s) or organization(s) can be relied upon to accomplish objectives because they are competent and possess values and intentions that are consistent with all or part of the public" (Greenberg 2014: 152).[7] Trust is important for institutional adaptability and resilience because it enhances cooperation and enables shared cognition. That is to say, people feel they can rely on the statements of others without having to go back to first premises to check their validity (Cvetkovich 1999). This is why trust also enables actors to cope with new situations more quickly. In addition, trust appears to be a crucial element as far as energy systems are concerned, mainly because public concerns about risk have intensified in recent years (Slovic 1993). Nuclear power plants and waste management facilities, natural gas plants, fracking, oil refineries, giant hydropower dams and many other issues are examples of areas of public concern as regards energy. Trust is also an important ingredient in the transition to a low-carbon society, because the implementation of decentralized RE installations and smart-metering technologies need to be steered by individuals and organizations that are highly trusted and rooted in local communities (Eyre 2013). Trust in actors that are responsible for the development of a technology is critical when it comes to social acceptability of this technology, especially when people know little about it (Jobert et al. 2007; Walker et al. 2010; Huijts et al. 2012). In the wind power context, Eltham et al. (2008) have documented, through the study of public opinions of a local population living near a wind farm, how suspicion of the developers' motives by the public, distrust of the developers and disbelief in the planning system may preclude the success of wind farm projects. Moreover, evidence shows a general lack of trust by the public in traditional energy actors as far as the development of alternative energy is concerned (Mumford and Gray 2010;

[7] It is worth distinguishing institutional trust, which refers to trust in organizations and institutions managing energy projects, such as public authorities, developers, power utilities and other actors, from interpersonal trust, which describes trust among the members of a community and is closely connected to the notion of social capital (Walker et al. 2010).

Greenberg et al. 2012). This lack of trust in conventional energy actors is likely related to the centralized institutional configuration of energy systems described above. Institutions involved in energy (e.g., governments and multinational companies) form part of the expert systems of global politics, commodity markets and large scale engineering which are not easily accessible to ordinary citizens (Mumford and Gray 2010). The centralized model of energy supply also increases the spatial, social and political distances between actors and, therefore, undermines trust.

A third important hindrance to low-carbon transition is the existence of strong vested interests. Profound shifts in the energy system toward a low-carbon society create "winners" and "losers" and "those that stand to gain or lose out will be at the heart of change debates" (Kuzemko et al. 2016: 101). Generally, incumbent energy actors, including those in the fossil fuels and nuclear industries, and electric utility companies, have a vested interest in preserving the current system. For instance, traditional power utilities are directly damaged by the increase in the proportion of decentralized renewable technologies—especially photovoltaics—forming part of the total installed electricity capacity (Groot 2014). Furthermore, incumbent actors generally have enormous political influence and are able to coordinate their substantial resources to resist any change that threatens their interests. Actually, established actors do not always seek to resist change intentionally, but as they fight for their own interests (regulations, subsidies, favorable institutional arrangements, etc.), they often do this to the detriment of alternative energy. Vested interests are a threat to the resilience of energy systems because they lead to institutional rigidity. As Olson (1982) shows, an economic sector which becomes economically prosperous also typically acquires political influence and seeks to secure institutional arrangements that are beneficial to itself, but not for society at large. If a society is controlled by vested interests, it loses its ability to adapt and shift the status quo (Moe 2010). Based on a comparison between Japan, China, the United States, Germany, Denmark and Norway, Moe (2015) shows that whether or not renewable energy has been a success is determined by the extent to which countries have been successful in controlling these vested interests and prevented them from unduly influencing energy institutions. In turn, the ability of incumbent actors to be politically influential depends on the historical economic and political importance of the industries they represent (Kuzemko et al. 2016).

The next section explains how community-based energy initiatives in general and energy cooperatives in particular may contribute to overcome these barriers to low-carbon transition and thus enhance the institutional adaptability and resilience of energy systems.

Community-based energy initiatives and institutional resilience

Community-based energy (CBE) initiatives are typically characterized by a high degree of citizen agency and involvement in the ownership, management and benefits of projects (Walker and Devine-Wright 2008) and, as such, strongly echo the principle of local self-organized decision-making units characterizing polycentric systems. The cooperative model is arguably one of the strongest forms of CBE initiative in Europe. It is not by chance that this model is the only one that is represented at the European level by a federation.[8] RE cooperatives are also often strongly embedded in the international cooperative movement, an international network of cooperatives and advocacy organizations that aim to promote and spread the cooperative principles of solidarity and democratic governance (Birchall 1997). Furthermore, while access to finance during the at-risk stage is acknowledged as a barrier to the development of community energy projects (Nolden 2013), cooperatives are particularly suitable to ensure the financial viability of small-scale projects, through fundraising among community individuals, compared to other models depending on grants or loan schemes.

The cooperative model enables citizens to collectively own and manage RE projects at the local level (Bauwens et al. 2016; Huybrechts and Mertens 2014). Through this model, citizens produce, invest in and, in some cases, consume RE. The following cooperative principles, adopted by the International Co-operative Alliance (ICA) in 1995 (ICA 1995), are generally common to all types of cooperatives around the world: voluntary and open membership, democratic member control (e.g., the "one person-one vote" rule), economic participation by members, autonomy and independence, education, training and information, cooperation among cooperatives, and concern for community. These principles clearly do not uniquely define cooperative structures and in Western Europe there is considerable variety in the legal forms of democratic enterprises (Borzaga and Defourny 2001)[9], but in general these forms share features that embrace the above cooperative principles (Spear 2004). From an economic standpoint, cooperatives present a model of ownership different from conventional business organizations (Hansmann 1996). They are generally owned by their members/users rather than investors, unlike capitalist corporations. Part of the surplus goes to indivisible reserves, which are unavailable for distribution to members, even if a cooperative were to be dissolved. These reserves represent the collective assets of the organization. Another part of the surplus can in principle be divided pro rata among the members according to the volume of transactions (not members' shares) they have conducted with the organization. When the net

[8] See http://www.rescoop.eu.

[9] See Fici (2013) for a comparative analysis of the legal identity assigned to cooperatives in several European jurisdictions.

income is partially allocated as a return on capital shares, such profit distribution is subject to a cap, which suggests that maximization of return on capital may not be a key objective. Finally, as previously mentioned, cooperatives use a democratic governance structure, which involves equal individual voting rights ("one person, one vote") and the absence of barriers to entry for new members. This is another major trait of the cooperative identity, as in other company types the default governance rule is "one share, one vote".

Why would CBE initiatives, and cooperatives in particular, help solve the collective-action problem that arises in the diffusion of sustainable technologies and practices? To understand this, it is crucial to acknowledge the importance of local actions in mitigating climate change. Many analysts call for an institutional solution at the global level, because global threats such as climate change are believed to require "global solutions", negotiated at the international level (Nordhaus 1994; Stern 2007; Wiener 2007). Solutions to the climate crisis certainly demand efforts at the international level, where most efforts are now being concentrated. Yet, in line with the polycentric governance approach, a global policy is not the only strategy needed and positive actions are required at multiple, smaller scales to start the process of climate change mitigation and secure the efforts made at the global level (Bulkeley and Betsill 2005; Bulkeley and Kern 2006; Ostrom 2010, 2012). Indeed, collective-action problems faced by large groups, such as the problem represented by climate change mitigation, are often decomposable into social dilemmas at a smaller scale, some of which are typically surmountable given the existence of social norms and, especially, of pre-existing trust networks (Ostrom 2010). Accordingly, several studies have argued that community-based energy initiatives facilitate collective action for climate change mitigation by fostering individual behavioral change toward more sustainable energy practices (Middlemiss 2008, 2011; Heiskanen et al. 2010; Seyfang 2010). CBE initiatives are said to influence their members' energy-related behavior, notably by activating social norms.[10] From an institutional perspective, a "community" is a social institution characterized by high entry and exit costs and non-anonymous interactions among members (Bowles and Gintis 1998, 2002). In addition, interactions among community members are more frequent and extensive than interactions with 'outsiders'. These structural characteristics of interactions contrast with those of other institutions, such as markets, at least in their idealized forms. Market interactions are characterized by ephemerality of contact, anonymity among interacting actors and ease of entry and exit. In contrast to markets, by facilitating direct personal interactions, communities effectively encourage the formation of norms, such as

[10] Social norms are "customary rules of behavior that coordinate our interactions with others. Once a particular way of doing things becomes established as a rule, it continues in force because we prefer to conform to the rule given the expectation that others are going to conform" (Young 2008: 647).

interpersonal trust, group identification, solidarity, reciprocity, reputation, personal pride, vengeance, etc.

Norms have proven to be powerful and cost-efficient mechanisms to encourage energy conservation (Allcott 2011; Nolan et al. 2008).[11] Gadenne et al. (2011) showed that environmental concern, combined with social norms and community influence, can positively contribute to environmental behaviors. Ek and Söderholm (2008) also found that social or moral norms can affect the purchase of green electricity. In addition, different qualitative studies suggest that some communities encourage low-carbon lifestyles by stressing the associated social rewards for climate-beneficial actions (Middlemiss 2008) or by turning the social dilemma they represent into assurance games where members can be assured that others will participate (Heiskanen et al. 2010). Furthermore, CBE initiatives may lower information costs related to energy-efficiency technologies and conservation behaviors and therefore contribute in overcoming some of the informational and behavioral barriers to energy efficiency constituting the so-called "energy efficiency gap" (Gillingham and Palmer 2014).[12] Indeed, CBE projects raise their members' awareness about sustainable energy practices through communication channels and information provision. Again, norms are likely to play a role in this respect as the trustworthiness of the sources of information can positively affect the effectiveness of a message (Stern et al. 1986; Laskey and Syler 2013). Finally, several studies emphasized the effects of trust networks and peer behaviors on the adoption of sustainable micro-generation technologies, such as photovoltaic panels (e.g., Bollinger and Gillingham 2012). CBE initiatives are able to inform and influence consumer decision-making because of the trust networks they hold through longstanding linkages with key individuals in local communities (Noll et al. 2014).

Clearly, economic incentives play a role as well in overcoming the collective-action problem. Indeed, by allowing citizens to become the residual claimants on the financial surplus generated by RE assets and on the decision-making power, CBE initiatives contribute to trigger investments in and public support of sustainable technologies at the community level. Thus, CBE initiatives combine both social norms and standard economic incentives to foster contributions to the global public good of averting climate change. The respective weight given to norm-driven behaviors and economic incentives is not necessarily the same in all CBE initiatives and depends on several

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[11] Social psychologists distinguish between two types of norms: injunctive norms and descriptive norms. The former involve perceptions of which behaviors are typically approved or disapproved of by other people and provide points of comparison, e.g., concerning others' energy consumption, while the latter involve perceptions of other people's typical behaviors (Schultz et al. 2007).

[12] The energy efficiency gap describes the existence of unexploited 'profitable' investment options in energy saving technologies and practices.

factors, including how "market" and "community" institutional dimensions are prioritized within CBE initiatives, spatial characteristics of membership and the stage of development that CBE initiatives have reached (Bauwens 2016).

The case of Connexus energy illustrates particularly well the roles of CBE initiatives in enhancing social norms and, ultimately, encouraging sustainable energy-related behaviors. Connexus Energy is the largest cooperatively-owned supplier in Minnesota (it supplies electricity to about 125,000 households). In partnership with the energy efficiency company Opower, it has launched one of the longest behavioral intervention programs for energy efficiency in the United States. Home Energy Reports were sent to the 80,000 participating households and contained two components: an Action Steps Module providing household-specific energy conservation tips and a normative comparison of the household's energy use to that of similar neighbors. During the three years since the start of the program, households of Connexus have collectively reduced their consumption by about 30,000 MWh and avoided CO_2 emissions equivalent to 350 air flights in the US (Laskey and Syler 2013). Another empirical example is provided by the web platform EnergieID[13], based in Flanders (northern Belgium). It enables energy users to follow their energy consumption and compare it with that of other similar households, thereby activating social norms. The website was put online in 2011 and offered free monitoring tools for individuals. In 2014, EnergieID was formalized as a cooperative, with the view of creating a common platform in which users can share their data with different service providers in a secured and anonymous way. EnergieID collaborates with partners such as municipalities, other cooperatives and service providers. For instance, the Flemish cooperatives BeauVent and Ecopower encouraged their members to use the platform and a more formal partnership was established in 2012 with the creation of groups called "BeauVent" and "Ecopower" on the website. The members who register in these groups are invited to report their electricity consumption each month. After one year, BeauVent and Ecopower analyze these consumption figures and provide members with a personalized report about their consumption and how they can reduce it further. They incentivize people to report their consumption by offering a prize (generally a device related to energy efficiency, such as a consumption monitor, a LED light, etc.) at the end of the period.

Regarding trust in institutions involved in energy, which can also be described as a specific kind of social norm, the literature on CBE initiatives shows that these initiatives are typically characterized by a high degree of trust (Walker et al. 2010). Similarly, it has been shown that cooperatives are generally perceived as trustworthy, given their constraint on the profits distribution and their

[13] http://www.energieid.be

democratic governance (Hansmann 1996; Ole Borgen 2001). In addition, citizen ownership contributes to the trust capital of CBE initiatives and cooperatives as it provides the guarantee to non-controlling stakeholders that the firm is managed by people who share their interest (Spear 2000). This is consistent with the findings that horizontal networks, where people have equivalent status and power, engender trust because they facilitate exchanges of information and face-to-face communication, whereas hierarchies tend to inhibit information flows due to asymmetric power relationships (Kasperson et al. 1999). Finally, the local anchorage of CBE initiatives and cooperatives reduce the social distance between stakeholders, further consolidating trust. As a result of this high trust capital, there is evidence that community-based or cooperative ownership enhances social acceptability of controversial RE facilities, such as onshore wind power (Bauwens 2015; Maruyama et al. 2007). Comparative research has shown that a high degree of citizen involvement in wind energy projects is positively correlated with high deployment rates (Bauwens et al. 2016; Toke et al. 2008). If citizens are the residual claimants on the organization's surplus and decision-making power, they are likely to feel more fairly treated and would be more willing to accept or support the outcome.

Finally, the ways CBE initiatives and cooperatives could contribute to overcoming the challenge of vested interests are less obvious, because this challenge is generally of a systemic nature that cannot be solved at the operational level, whereas most of the time the main mission of CBE initiatives and cooperatives is to implement sustainable energy projects on the ground. The notion of polycentric systems is crucial here. The Governance Systems variables affecting energy systems are the outcome of interactions between political, industrial and civil society actors located at higher levels of decision-making and thus local CBE initiatives taken individually are not likely to influence these decisions. However, as Ostrom (2005) notes, local communities often spontaneously form larger associations in order to deal with larger issues. The creation of federated structures is a way of enhancing the bargaining power of small players such as CBE initiatives in the face of incumbent energy actors. Indeed, the latter are smaller in number, have relatively homogeneous interests and are able to coordinate their substantial resources to resist any change that threatens their interests. In contrast, CBE initiatives are dispersed, generally focus on very local issues and have limited resources and political power. Several studies have acknowledged the difficulties experienced by grassroots initiatives in surviving in increasingly hostile environments, not to mention the obstacles to scaling up their impact and challenging mainstream actors (Bauwens et al. 2016; Seyfang et al. 2013). Coordinated actions may thus be seen as an attempt to reach a more balanced distribution of political power in energy markets, which is still very biased in favor of large-scale players. While decentralization of governance in energy systems is sometimes conceived as a panacea, the emergence of coordinated actions among cooperative initiatives calls for a more polycentric approach, according to which "various scales need to be taken into account when designing regulatory answers and setting up governance arrangements" (Goldthau 2014: 136). In this perspective, although decentralized energy systems obviously exhibit a strong local component, federated structures highlight the importance of the ability of local initiatives to transcend their local experience in order to form networks at higher levels and articulate their interests to national and international strategies.

An Example of Federation of RE Cooperatives: REScoop.eu

The creation of a federation of RE cooperatives at the European level, like REScoop.eu[14], can typically be interpreted as a way to integrate the local level with the national and international ones. This federation was established in 2011 by a consortium of 12 cooperatives and 2 national federations, with the objective of supporting the development of RE cooperatives. By 2016 active membership had risen to more than 1,200 cooperatives. The mission of REScoop.eu encompasses three main activities. First of all, REScoop.eu seeks to gather and centralize information and knowledge from individual initiatives. It has, for example, identified and contacted more than 2,400 existing RE cooperatives across Europe and created a database containing basic information about 693 of such organizations. On the basis of this inventory, REScoop.eu has been able to produce a number of documents including best practice case studies, guides and handbooks targeting new initiatives. The second key activity conducted by REScoop.eu is the exchange of information within the network. This exchange takes place both through a web-based platform and through personal interactions. Twenty-five "mentors", i.e. representatives of well-established RE cooperatives, were also identified in the network in order to actively support emerging initiatives across Europe. Finally, REScoop.eu also conducts communication and advocacy activities toward external audiences, such as policy-makers, citizen groups, corporations, NGOs and the media. Accordingly, the missions of REScoop.eu encompass most of the missions of intermediary actors identified by Geels and Deuten (2006) and extended by Hargreaves et al. (2013). In addition, this network has formally set membership standards, which include the ICA principles mentioned above and additional ecological, social and ethical common principles in the charter of REScoop.eu. Therefore, the network has defined the set of basic rules shared by all initiatives belonging to the network. These rules are not blueprints, however, and do not preclude local initiatives from developing their own additional rules. Although the European federation is still in infancy, it does share some of the essential characteristics of a polycentric system. Firstly, local cooperatives form

[14] See http://www.rescoop.eu.

a multiplicity of local autonomous decision centers that are able to put their different methods into practice and to make operational decisions independently from each other. Secondly, despite this autonomy in the implementation of local actions on the ground, the European federation has also defined some guiding principles under the form of a charter, which provides a framework of overarching basic rules, including the cooperative principles, which are supposed to be shared by all members. Currently, however, it does not have clear monitoring mechanisms against free-riding.

Conclusion and recommendations for policy-makers

Acknowledging the complex interdependencies between the various components of energy systems is essential for designing effective responses to the urgent challenges posed by the on-going energy transition. Elinor Ostrom's contribution to the literature on social-ecological systems fits well with complexity theories and, in particular, with hierarchical perspectives on complex systems. This chapter argued that present and future energy demand and supply systems can be adequately conceptualized as SESs and that Ostrom's polycentric approach holds great promise for analyses of their institutional resilience.

Institutional resilience of energy systems and their capacity to adapt to changing conditions are crucial factors in tackling present and future energy and climate change challenges. However, different obstacles undermine this resilience capacity. The present chapter focused on three of these hindrances: the collective-action problem in the diffusion of more sustainable energy technologies and practices, the lack of trust in conventional energy actors and the existence of strong vested interests within the energy industry. It showed that community-based energy initiatives, as parts of larger polycentric systems, may greatly help overcome these barriers and, thereby, enhance the institutional resilience of energy systems. More specifically, it was argued that CBE initiatives and RE cooperatives present institutional features encouraging the activation of social norms and a high trust capital, therefore enabling them to offer effective solutions to avoid free-riding and enhance trust in energy institutions and organizations. The creation of federated polycentric structures may also offer a partial response to the existence of vested interests in favor of the status quo.

While social and environmental contexts within which policy interventions take place become more and more complex and uncertain, a polycentric approach appears to offer a flexible and adaptive framework for the governance of the low-carbon transition. In this approach, a crucial role for policy-makers is to create favorable conditions for the self-organization of local communities. They must also ensure the coordination of the whole system of initiatives and guarantee the enforcement of the overarching set of rules common to all by sanctioning defection from compliance. As Mansbridge (2014) noted, they should also provide a relatively neutral source of information, manage potential conflicts and facilitate negotiations between lower-level governance units. All in all, the vision of the state's role in the polycentric governance perspective is that of a "supportive" state. It should cope with complex problems of modern life, such as energy-related challenges, by relying on the massive amount of social capital contained in local communities and let local self-organized initiatives flourish, thereby enforcing individuals' and communities' feeling of autonomy and self-determination.

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