Chapter 5
'Society Can't Move So Much As a Chair!'—Systems, Structures and Actors in Social Ecology

Daniel Hausknost, Veronika Gaube, Willi Haas, Barbara Smetschka, Juliana Lutz, Simron J. Singh and Martin Schmid

Abstract From the socioecological perspective, society is conceived as a symbolic system that is coupled with biophysical elements. The biophysical and the symbolic components of society are considered to be coevolving. The expansion of the fossil energy regime, for example, was the result of changes in the symbolic systems of proto-industrial societies. At the same time, these systems were themselves transformed by the material dynamics the new energy regime released. Social Ecology has adopted complex systems theory as a metatheoretical framework to integrate the analysis of both symbolic and biophysical systems and their coevolution. This emphasis on systems in socioecological theory is balanced, to some extent, by a focus on actors in empirical socioecological research. The concept of actors and their agency plays an important role in transdisciplinary research, in local studies and in Environmental History. How are these actor-centered areas of research connected to the systems-centered theoretical framework

D. Hausknost (✉) · V. Gaube · W. Haas · B. Smetschka · J. Lutz · M. Schmid
Institute of Social Ecology (SEC), Alpen-Adria University, Schottenfeldgasse 29, 1070 Vienna, Austria
e-mail: daniel.hausknost@aau.at

V. Gaube
e-mail: veronika.gaube@aau.at

W. Haas
e-mail: willi.haas@aau.at

B. Smetschka
e-mail: barbara.smetschka@aau.at

J. Lutz
e-mail: julia.lutz@aau.at

M. Schmid
e-mail: martin.schmid@aau.at

S.J. Singh
Faculty of Environment, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada
e-mail: simron.singh@uwaterloo.ca

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of Social Ecology? How is agency accommodated in systems, and to what extent can systems and their structures be influenced by actors? This chapter explores these questions both theoretically and in relation to concrete research examples. In doing so, it highlights some of the unresolved theoretical questions in Social Ecology and suggests possible ways they can be answered.

Keywords Complex systems theory · Agency · Structures · Coevolution · Structural coupling

5.1 Introduction

What defines Social Ecology as an interdisciplinary research program is its explicit focus on *society-nature interactions* (Fischer-Kowalski and Weisz 1999). This definition entails far-reaching ontological and epistemological commitments that frame the field of research and delineate its boundaries. First, to speak of society-nature interactions presupposes the existence of society and nature as distinct realms that are not reducible to each other. Thus, society cannot be conceived of as just another part of nature, nor can nature be understood as a mere social construction. This is what Fischer-Kowalski and Erb (2006) termed a 'realist' ontological framework.

If we regard nature and society as categorically distinct entities, the question arises of what kind of knowledge can be generated about their interaction. After all, natural scientists and social scientists have not always been on the best speaking terms. This 'great divide' between the epistemological realms of the Natural and Social Sciences may put the entire project of Social Ecology at risk unless it is effectively 'bridged' by a common metatheory that allows researchers from disciplines as far apart as Ecology and Sociology, Biology and Political Science or Engineering and Economics to construct a common 'object of knowledge', that is, to discuss society and nature in a common language. Because Social Ecology is an interdisciplinary endeavor by definition, it requires a practicable basis of cooperation between disciplines as different as those mentioned above. This basis is all the stronger the less content is 'lost in translation' from the Social to the Natural Sciences and vice versa. This was the rationale behind the decision in the 1990s by the Vienna group of social ecologists to adopt *general systems theory* (as elaborated by Humberto Maturana and Francisco Varela) as a metatheoretical framework under which the concepts of both nature and society could be operationalized and their interactions studied. Because both social and natural entities can be plausibly described in systems-theoretical terms, systems theory constitutes a promising common ground for interdisciplinary research on society-nature interactions and has therefore become the privileged epistemological vantage point in socioecological research.

However, socioecological research in practice transcends the systems-theoretical framework in several respects. 'Colonization' as a constitutive concept of the socioecological framework (see Chap. 2) has been defined as the '*intended* and

sustained transformation of natural processes, by means of organized social interventions, for the purpose of improving their utility for society' (Fischer-Kowalski and Weisz 1999, p. 234; emphasis added). The emphasis on intentionality in the concept signals a form of agency that might exceed the explanatory confines of systems theory. This is a theoretical issue that has not been conclusively resolved within the theoretical framework of Social Ecology and that deserves further attention (see, for example, the systems-theoretical treatment of the possibilities and limits of purposive intervention in social systems in Willke 1994). On a more practical level, however, socioecological research frequently ventures into fields that abound with 'stakeholders' and 'agents' and that involve participatory processes in transdisciplinary research. These research endeavors pose important questions about the limits of the systems-theoretical framework and about interpretations of society that transcend it. Does it make sense to speak of 'stakeholders', let alone 'actors', in a systems-theoretical framework? What are the conditions and limits of 'participation' in an autopoietic system? What scope is there, for example, for 'political agency' to strive for radical change in the functional subsystem of politics? Can the economic system be deliberately transformed by intentional intervention from outside, or will it only change when the conditions for autopoietic self-reproduction are no longer given? Although some of these questions might be identified as simple problems of scale in that what looks like 'autonomous' agency on a micro level can be interpreted as recursive processes of autopoiesis from the bird's-eye view of systems theory, others address more fundamental questions about the limits of the systems paradigm on the one hand and the limits of agency on the other. These questions are no doubt stimulated by a kind of normative *unease*: if the social realm were all autopoietic with no scope for purposive intervention, what would be the point of engaging in problem-oriented research, as in Social Ecology? Social Ecology is driven by an intellectual and ethical urge not only to expose and define problems in the interaction between society and nature, but also to point toward ways of reorganizing these interactions in a more sustainable and less destructive way. This underlying hope for the possibility of purposive change informs the study of society-nature interaction and is based on the plausible assumption that social systems might not be as rigid as, for example, the laws of gravity and might be capable of answering to purposive intervention or 'agency'.

In this chapter, we address this tension between the systems-theoretical framework of Social Ecology and its agency-related components in an attempt to clarify to what extent this tension is plausible and can be made productive within the existing theoretical framework and to what extent it indicates the need for further theoretical elaboration and perhaps revision. In the next section, we retrace the arguments leading to the construction of the theoretical framework underpinning Social Ecology. We identify the neuralgic points in the framework where systems, structures and agency meet or where ambivalence between them occurs and leads to theoretical tensions. In doing so, we hope to prepare the ground for a further elaboration of the theoretical framework, leading to a more stringent and consistent paradigm. In section three, we present and discuss empirical research areas

in Social Ecology that operate precisely at these neuralgic points and within the tensions among agency, structures and systems theory, including transdisciplinary studies, local studies, agent-based modeling (ABM) and Environmental History as well as Long-Term Socioecological Research (LTSER). These instances of empirical research help to contextualize and flesh out these theoretical tensions and might provide guidance for their resolution. Section four identifies some of the theoretical frontiers of Social Ecology that come into view when the role of agency, structures and systems in society-nature interactions is assessed both theoretically and empirically.

5.2 The Role of Systems Theory and Agency in Social Ecology

As Fischer-Kowalski and Erb note in Chap. 2 of this book, general systems theory as elaborated by Maturana and Varela (1975) and applied by Luhmann (1984) to social systems constitutes a cornerstone of the metatheoretical framework of Social Ecology. This framework has three major advantages. The first is the capacity of systems theory to serve as a 'bridge' between the Natural and Social Sciences in that it offers a rather formalized and uniform language to describe and explain phenomena in both realms. The second advantage is that systems theory can easily be operationalized in quantitative terms and is compatible with different modeling approaches—an advantage that is particularly striking in the realm of the Natural Sciences. The third advantage is that the concept of autopoiesis—that is, the process of recursive self-creation constitutive of operationally closed systems—allows for a conception of nature and culture as two operationally distinct entities that follow incommensurable logics of reproduction but are nevertheless structurally coupled in a way that could be termed 'coevolutionary'. Put differently, an autopoietic understanding of systems enables us to conceive of culture as a system of meaning that evolves according to its own rules of reproduction and therefore becomes operationally autonomous from nature while remaining deeply dependent on it through its biophysical metabolism with it. This, by implication, enables us to develop a more profound understanding of the environmental crisis of modern societies, whose metabolism with nature has exploded in quantitative terms and has started to create effects in nature that are now considered disruptive and problematic within the symbolic realm.

5.2.1 Society as a Hybrid

Although an autopoietic conception of systems is now commonplace in the Natural Sciences (especially in Biology and Ecology), it remains controversial to conceive of societies in these terms, especially outside the German-speaking

world. In conceptualizing society, Social Ecology has drawn on the systems theory of Niklas Luhmann (1984, 1986), which is arguably the most elaborate and powerful social theory building on the concept of autopoiesis. For Luhmann, social systems consist of recursive communication and are thus essentially immaterial. Even human beings (and their mental systems) are not part of society but belong to its environment. Although this very radical notion of society allows Luhmann to explain the emergence of complexity and of functionally differentiated subsystems, it poses a critical problem to Social Ecology in that it does not offer an account of how social systems can influence natural systems (Fischer-Kowalski and Erb 2006). If social systems are strictly symbolic, some kind of interface is required that translates meaning (symbols) into physical action. The favored solution in the Vienna School of Social Ecology, as represented in this volume (see Chap. 2), is that the human being, as a 'hybrid' between the symbolic and material realms, constitutes this necessary interface. Consequently, Social Ecology distinguishes between 'society' and 'culture' such that the term 'culture' is reserved for Luhmann's system of recursive communication, whereas 'society' denotes a hybrid of culture and material components (the human body and its various material artifacts, including animal livestock) whose (re)production is (partly) controlled by culture. 'It is via these biophysical components of society that culture interacts with nature', as Fischer-Kowalski and Haberl (2007, p. 11) note. This theoretical move is, above all, of a pragmatic nature in that it allows for two distinct systemic realms to be analytically discerned (the symbolic realm and the material realm) while reserving the term 'society' for a rather underdetermined interaction-zone where those distinct systemic realms overlap. Thus, the disciplinary boundaries between the material and the symbolic are preserved, and interdisciplinary cooperation and communication are enabled in the new epistemic field that is constituted in defining 'society' as a hybrid.

An important consequence of this conceptual dislocation is that societies can no longer be conceived of as operationally closed systems in autopoietic terms. They 'consist rather of a 'structural coupling' of a cultural system with material elements' (Fischer-Kowalski and Haberl 2007; see also Fischer-Kowalski and Weisz 1999). This means that society as the central concept of Social Ecology is itself not a system but a hybrid formation that is suspended between and generated from different systems (the human body and its metabolic needs, some biophysical elements of nature, the nervous system of humans as the node of the symbolic world and culture as the 'objectified' system of communication). This is a rather open and conspicuously imprecise notion of society, and it begs the methodological question of how society as a non-system is possible in a world that is otherwise composed of systems (natural and cultural)—or to put it another way, what constitutes society as a conceptual unit if not its systematicity? How is this 'structural coupling' of the natural and the cultural to be understood if it is not the coupling of systems (as in Luhmann) or the coupling of a system and its environment (as in Maturana) but rather the coupling of a system with external 'elements'? However, this notion also offers a promising perspective on society as a hybrid realm that entails both systemic forces and instances of agency and 'free will'. The human as

the interface between the symbolic world harboring the realm of meaning and the material world in which it lives and into which it physically interferes is the key to the socioecological understanding of society. It is never independent of those systemically ordered realms; meaning is not generated *ex nihilo* in a single nervous system but in the recursive operation of communications between several or myriad such systems. The human being is obviously dependent on the continuous reproduction of biological and ecological systems, but it can influence both realms intentionally in that it submits new communications to the cultural system (cf. Luhmann 1984, Chap. 4) and exerts physical work on the material world (Godelier 1986; Sieferle 1997). The human being translates symbolic meaning into work (for example, a worker who is told to lay a brick on a wall will usually know how to use their body to do exactly that), and it translates material realities back into the system of communication (a pilot reporting a storm to the tower or a farmer discussing soil conditions with their neighbor).

However, the human is not merely a mechanical interface or catalyst between two otherwise unconnected systems—it is also actively intervening into them and transforming them. It is embedded in and constituted by different systems, but it is also an agent modifying them both intentionally and inadvertently as side effects of its actions. Society is thus more than the sum of its elements in that it includes the (immaterial and material) systems that regulate the reproduction of these elements, but it remains operationally tied to the human being as the hybrid unit that carries out the operations that reproduce and modify these systems (operations of communication, work and, arguably, consumption). As we will see, however, this understanding of the human as the hybrid interface between culture and nature, or the symbolic and material realm, poses some methodological problems with regard to the material efficacy of 'society'. If the individual human being (and her machines as extended bodies) is the transmission belt between these realms, and if culture is the symbolic realm that drives these (human and artificial) bodies, what is the *differentia specifica* of society as an analytical unit? Is society conceptually required to influence biophysical objects, as Fischer-Kowalski and Haberl (2007, p. 10) suggest? In other words, does society require the agency 'to move so much as a chair' (ibid., p. 11), or does it suffice to assign this role to the human body? This question, esoteric as it may seem to non-theorists, will be defined as one of the most important theoretical frontiers of Social Ecology in the concluding section of this chapter as it has a decisive influence on understanding the relationship among systems, structures and agency in society-nature interactions. As such, it is a question relevant not only to theorists of Social Ecology but also to any interdisciplinary endeavor to understand society-nature interactions and the scope of purposive human intervention.

The social ontology thus presented (open questions notwithstanding) allows for a reconciliation of the otherwise disjunctive notions of systems, agents and structures in that society is made up of agents who are deeply embedded in (and constrained by) systems and their material and symbolic structures. To fully understand this conception of society, we need to address the role of these structures. The structure of a system, according to Maturana, refers to the relation of its

elements at a certain point in time (Maturana and Varela 1990, p. 54; Riegas 1990, p. 336). The structure of a system thus denotes its concrete state and composition and not the underlying operations of reproduction that generated it. Although the recursive operations of a system remain the same, they allow for the emergence of diverse and complex (material and immaterial) structures that make up the world human beings inhabit. Thus, what humans as agents are confronted with are the structures of society (and of nature) and not the constitutive operations of the system (they are in the background, as it were, constantly reproducing and iterating the structures that surround us as meaning and matter). Take money as an example. Money as a universal equivalent emerged in the symbolic realm as a structure that became very powerful in the modern age. The underlying operation of buying and selling reaches back several thousand years in history (Graeber 2011; Simmel 1900/2011), but the historical convergence of certain societal structures (money, fossil energy, technology and science, for example) has ultimately led to the rapid development of new structures based on trade and commerce in what is called capitalism today. Hence, money has turned into an all-important symbolic structure of our world, although the binary operation on which it is based (buy/sell) has not changed. A single operation can thus have a large variety of effects in that it generates historically contingent structures that at the same time confine and enable the operation. Importantly, the effects of money are not confined to the symbolic realm but extend to the material world almost without limits in that money links its symbolic value to work and its material products and thus facilitates a social metabolism that has changed the face of the planet within just a few hundred years.

5.2.2 The Role of Structures

Symbolic structures, according to Luhmann, are 'expectations' and 'expectations of expectations'. This simply means that communication has to be recursive (and thus binding) to constitute meaning. Any utterance must connect to a preexisting structure of meaning or it will fail as communication and be perceived merely as 'noise' or nonsense. For a communication to be intelligible—and thus accepted, understood and perhaps responded to by the other(s)—the communicator must subject its own mind to a rigid selection process that is itself partly internalized 'conscious thought' and partly determined by the 'objective' (that is, independent of the single mind) structures of meaning within which the mind operates. Money is again a good example. The entire structure of meaning that money constitutes relies on the expectation that my ten-Euro bill will be accepted by anyone else for its universal exchange value. When I buy my lunch, the entire transaction is based on the expectation that the waiter at the restaurant will accept my bill and expects me to accept his price. My communication with the waiter will take the structure for granted: we might discuss the price of the dish but not the validity of money as such. It is very difficult to ignore this structure in modern societies or to 'do

without' it. The universal exchange that money enables became the constitutive operation of a powerful subsystem (the economy) that moves billions of tons of matter around the globe and transforms the planet via physical work while being based on a simple symbolic operation.

Our world abounds with structures of meaning to which agents must adhere to be successful or even to survive, be they criminal laws, the rules of scientific peer review, the formal and informal rules of the labor market or the various structures of social distinction to which everyone in a society is subjected (Bourdieu 1984). However, the world also abounds with material structures, many of which are the result of physical work that is again the effect of symbolic structures. These material structures include physical infrastructures, such as roads, motorways and cities and their architecture, and the fields, pastures and pit mines that are the result of our ways of transforming the surface of the earth. The electric power plants that supply our computers are structures, as are our computers and the fiber cables connecting them to the Internet. They are concrete arrangements that emerged out of symbolic structures (think of the scientific knowledge and engineering skill required to build them!) and material structures understood as congealed physical work (including the matter it transformed). The term 'arrangement' is thus used within the socioecological strand of Environmental History and denotes precisely these congealed practices that mold matter into structures (see Chap. 6) and enable the continuation (and intensification) of practices.

In summary, Social Ecology works with a social ontology that involves the interplay of systems, structures and agents as constituent moments of society. Systems (both material and symbolic) are always temporalized in structures, and these structures confine the scope of agency within society. Agents are embedded in and 'thrown into' (to use a term of Heidegger 1927/2006) the structures that constitute their reality. Their agency takes place within and sometimes against these structures and includes intentional interventions as well as 'blind' routines. Structures emerge as the result of iterative operations in a system and as the result of conscious interventions that may dislocate or disrupt them. Structures are inert and durable as well as 'plastic' and variable (Maturana and Varela 1990, p. 182). There is scope for agency but not for change *ex nihilo*. The operations of a system remain immutable because they are constitutive of the system itself, but the structures of the system can be changed or the system (in extreme cases) eliminated. For example, it might be impossible to eliminate the buy/sell mechanism that is the constitutive operation of the economic system (without eliminating the economic system itself), but it might be possible to redefine its role within society by intervening in political and institutional structures. Such an intervention, however, would require specific 'conditions of possibility' within the preexisting structures of meaning. Ultimately, it would be nonsensical and impossible to eliminate 'communication' as the constitutive operation of the symbolic realm, but it is possible (to some extent) to intervene in the structures of meaning that result from communication and that offer scope for the construction of very different types of society.

Social Ecology deals with all three moments of society (its systems, structures and actors), but it has a methodological bias for the systemic level. This bias might be due to the fact that research on social metabolism commits scholars methodologically to systemic thinking, as in material and energy flow analysis (MEFA) and in several modeling approaches. The epistemological focus is on understanding what is going on in a system and not primarily on how to influence it. The concrete (and historically emerged) structures of social metabolism are analyzed, but there has been relatively little research on the role and scope of agency in changing these structures. The only prominent field of research in Social Ecology that explicitly addresses actors is 'colonization', a concept that relates to intentional and sustained activities of transforming nature for human purposes. However, although the systems-theoretical underpinnings of Social Ecology are quite elaborate, the role of actors is not yet well-defined. In the next section, we will assess and discuss several research fields within Social Ecology that explicitly or implicitly address actors (or 'agents') in an effort to arrive at a more coherent and systematic understanding of agency in Social Ecology. This understanding will be discussed toward the end of this chapter.

5.3 Systems and Actors as Cross-Cutting Issues in Social Ecology: Examples of Strands of Research

Social Ecology seeks sustainable solutions to societal problems. Based on the analysis of society-nature interactions, this search for solutions requires a fundamental restructuring of the way socioeconomic systems are organized (Haberl et al. 2011) and entails changes in both production and consumption while addressing societal activities such as nutrition, transport and mobility, housing and energy supply. If social metabolism, as one key concept of Social Ecology, means 'the whole of the materials and energy flows going through the industrial [and subsistence socioeconomic] system[s]' (Fischer-Kowalski and Hüttler 1999), then it is essential to recognize that a variety of actors in society make choices in production and consumption, and these choices determine environmental impacts.

To achieve fundamental changes and, ultimately, a qualitatively new state in a society, key system parameters need to be transformed, and actors' decisions and behaviors need to be adapted. Such an endeavor is quite challenging and requires a sound understanding of past and current transition dynamics to base interventions in ongoing change processes on such knowledge. In support of change, several methods, such as policy formulation, decision-making and monitoring to improve societal self-observation, can enhance a social system's potential for sustainable development. The methodological spectrum of Social Ecology includes, among others, systemic actor-oriented and organizational analyses and the use of historical sources as well as models and scenarios.

5.3.1 Transdisciplinarity

One methodological approach to fostering sustainability by including the perspective of actors is to arrange the production of knowledge in transdisciplinary settings. Thus, scientists and stakeholders collaborate in formulating problems so that they fit practical needs and scientific standards in integrating their different knowledge bases and producing results that are useful for the solution of problems and the advancement of science. This coproduction of knowledge serves to obtain better system, target and transformation knowledge and to find answers to '… three kinds of research questions: (a) questions about the genesis and possible development of a problem field, and about interpretations of the problems in the life-world; (b) questions related to determining and explaining practice-oriented goals; and (c) questions that concern the development of pragmatic means (technologies, institutions, laws, norms etc.) as well as the possibility of transforming existing conditions' (Pohl and Hirsch Hadorn 2007, p. 36), as our Swiss colleagues describe the principles of transdisciplinary sustainability research.

A wide range of methods are available that enable a variety of combinations. For example, scenario workshops can build on participatory modeling work using the decisions on key factors and values in the model as a baseline for envisioning different scenarios and as feedback on relations between factors and results. Another path for coproducing knowledge on transformative action is to develop decision support tools in and for participative research settings. Social multi-criteria evaluation (SMCE, Munda 2008) is a method to identify options for agency and political measures in stakeholder workshops. Assigning values and preferences and ranking alternatives is meant to be a joint endeavor that yields better knowledge for stakeholders and scientists alike (see also Method Précis on Transdisciplinary Research).

Transdisciplinary methods can empower those who make decisions on a daily basis. Everyday decisions of actors can, for example, be discussed using the heuristic of the sustainability triangle, which visualizes the interrelated ecological, economic and social factors of sustainability. Abandoning the perspective of sectoral/separated sustainability questions, the triangle takes on a systemic view of sustainability and elucidates the positive feedback loops among the increase in social well-being, wealth and resource use in industrialized economies and the specific dependencies among these factors. This allows for the discussion of possible interruptions of this spiral/helix. Actors can reflect upon the consequences of their actions and develop ideas on how to interrupt the vicious circle of unsustainable dynamics in a creative way. The sustainability triangle serves as a theoretical framework for asking whether and how actors, social systems, institutions and networks affect and are affected by resource use and by socioeconomic structures and dynamics and whether they foster or constrain a transition toward sustainability. With this knowledge, possible and potential interventions can be investigated. This framework enables such agents to develop alternative actions and political measures. It empowers actors with the possibilities of description and analysis, and it

gives them a tool for envisioning and developing steps toward more sustainable pathways. There are several empirical examples of using the triangle conceptually and as a communication tool, some of which are described in Chaps. 26 and 29.

In transdisciplinary research, concepts and approaches that allow for constructive communication with and between actors are required, whether for modeling or other analytic purposes. For example, time and its use is both an analytical tool for investigating sustainability and a prevalent conception used in everyday discussions. Time-use data can be helpful in analyzing inequality and social dynamics. If we use time-use data as an indicator of changes in quality of life, we can introduce them via the triangle in the discussion and analysis of the development toward more sustainable solutions. An empirical example is given in Chap. 26 and the Method Précis on Functional Time-Use Analysis.

5.3.2 Formalized Models

The development of formalized models is becoming increasingly important in Social Ecology. The aim of these models is to help understand interrelations, to reconstruct past states of the system using incomplete datasets, to create forecasts or scenarios about future developments and to structure communication processes in a formative manner. The interactions of society and nature are based on human decision-making. Recent developments in computational science, however, have allowed for the application of numerical models for the systematic analysis and simulation of human decision-making and its direct and indirect effects. Modeling can be applied as a means for testing hypotheses about interrelations in complex human-environment systems (Van der Leeuw 2004), where reductionist approaches (e.g., limited to the analysis of social or biophysical parameters alone) are insufficient.

Model development has been found to provide a transdisciplinary platform that allows actors and experts to communicate on an equal footing throughout the research process. Participation of this kind is described as key to enabling social actors or social systems to learn from or be stimulated by the research process (Gaube et al. 2009; Hare and Pahl-Wostl 2002), and it represents a core methodology of Sustainability Science (Kates et al. 2001) and integrated Land Science (Turner et al. 2007). Participatory and transdisciplinary methods allow for mutual learning and for collaborative structuring of themes and aims, making sense for both practitioners and researchers. For example, participatory modeling as applied by Social Ecology not only helps us understand complex interrelations by reconstructing past states of a system and creating scenarios about future developments but also helps us structure communication processes and develop future scenarios and strategies together with stakeholders, empowering those directly affected. An empirical example is given in Chap. 26.

In terms of actors, the usefulness of models is not limited to their application as tools supporting transdisciplinary settings. Agent-based models (ABMs) are

particularly useful for representing and understanding human decision-making. The strength of ABMs is their ability to simulate aggregate outcomes resulting from decisions made by many individual actors. The general application of ABMs has proven their utility in analyzing the dynamics of socioecological systems in which the decisions of actors influence biophysical dynamics, such as socioeconomic metabolism and land use, and vice versa. Using ABMs for the reconstruction of past decision-making and its impact on biophysical stocks and flows requires the reconstruction of the behavior of historical actors and depends upon consistent narratives (Van der Leeuw 2004). The challenge is to validate ABMs coupled with biophysical models by reconstructing past trajectories. Scale mismatch can occur when social and biophysical variables are combined (Fresco and Kroonenberg 1992). According to Gilbert (2007), different validation strategies are required by models that aim to formalize a theory (abstract model) or to describe a wide class of social phenomena (Boero and Squazzoni 2005). For an ABM, the two main components—agents and the examined environment—must be defined. For example, relevant agents for the food system in the long term are above all farms and consumers. Each farm and each consumer makes decisions concerning food production and diet dependent on a variety of framework conditions (e.g., availability of fossil fuels, chemical fertilizers, agricultural prizes and subsidies). In formalizing these decision-making processes and their linkages, an explicit actor-oriented understanding of society-nature interaction is required. Chapter 25 provides an empirical example of the use of ABMs to analyze urban residential decision-making.

5.3.3 Local Studies

In Social Ecology, society is conceived of as a cultural system that is structurally coupled with biophysical elements and that functions to reproduce a human population within a territory. This definition distinguishes ‘society’ from specific social systems (such as a firm or a friendship network), but it does not necessarily determine the location in a hierarchy of social units of a similar kind (for example, household, local community, state, federal state or the European Union). The scale is not such an important issue as long as it is understood that one (smaller) ‘society’ may be part of another (larger) ‘society’. However, investigating socioecological systems (or social systems within a territory) across scales provides relevant information on society-nature interactions and their cumulative effects for sustainability analysis. Investigating ‘local’ systems is of great interest to some Social Ecology scholars because it furthers their understanding of the dynamic interplay among systems, agents, structures and decision-making processes and the way this interplay is related to sustainability (Singh et al. 2010; Chap. 27 in this volume). As such, local studies analyzing the decisions of (local) actors provide valuable insights into these processes: the interplay of systems, structures and agents, why certain decisions are made, and how these factors affect landscapes, ecosystems and society-nature interactions.

Here, 'local' refers to the sub-regional scale (such as a village or town, an island, an estuary or a valley), and local social systems are defined as systems that show some degree of social (cultural) integration, self-governance and systemic services and whose boundaries are socially (and not just geographically) defined. Direct empirical observation and primary data collection take place within these local social systems. Undertaking local studies entails methodological challenges in terms of primary data collection. It requires innovative and logical thinking in the field to generate the necessary data. The level of engagement and contact with the local community is far more intense than in studies that rely on secondary data. Often, the researcher encounters challenging situations due to the close proximity to local actors and stakeholders and becomes engaged in power struggles in some way.

There is a long tradition of studying local communities within Anthropology, Rural Sociology, Development Studies and Human Geography. 'Local studies' take a local view of a global problem by downscaling and investigating the way global processes affect the local and vice versa (e.g., subsidies, nature production, markets) and how this affects rural landscapes and society-nature interactions. For example, introducing transportation infrastructure into a village may bring the market closer to the people, which might in turn fuel the production of cash crops, which would require more imports (e.g., fertilizer, machinery, fossils, seeds) and the need for more capital. Therefore, a growing dependence on exports is likely to intensify food production through the use of agriculture inputs, which in turn will affect land use and increase the need for more labor. Increased population will lead to more pressure on the same territory or encroachment into new areas, or it may lead to migration. Social Ecology has emphasized the investigation of local 'rural' systems located in the transition economies of the global south (e.g., Fischer-Kowalski et al. 2011; Grünbühel et al. 2003; Ringhofer 2010; Singh et al. 2001). However, there is increasing interest in investigating the local and the rural in industrialized countries (e.g., Petridis et al. 2013; Chap. 28 in this volume).

5.3.4 Environmental History and LTSER

Environmental History and 'Long-Term Socioecological Research' (LTSER, Singh et al. 2013) are two varieties of long-term and historical approaches that bridge the gap between the Natural and Social Sciences and the Humanities (compare Chap. 6). With its ability to integrate the Natural Sciences and the Humanities, that is, to integrate research on the impact of human interventions in ecosystems with research on the socioeconomic and cultural reasons for such interventions, Environmental History aims to significantly extend the temporal scope of Sustainability Science.

To gain firm conceptual ground for interdisciplinary Environmental History, it is important to reflect the tensions and contradictions between system- and actor-centered approaches. Theoretical concepts are both epistemological and serve as

tools for *interdisciplinary communication*. Thus, environmental historians must reflect, balance and bridge different approaches to be able to communicate with both the Natural Sciences and the Humanities. For most historians, systems theory is as strange and uncomfortable as Foucault's *discourse analysis* and Bourdieu's *praxeology* probably are for most system ecologists. The debate about nature's role in history has occupied many scholars in the field of Environmental History since its inception in the 1960s. One of the most pressing questions for some environmental historians is whether nature itself should be granted *agency* or should even be conceptualized as a historical *actor* (e.g., Steinberg 1991).

When Environmental History is based on a systems approach (similar to Social Ecology), it is particularly strong when it finds *explanations* for changes in patterns of society-nature interactions, for example, as a result of the transition from an agrarian to an industrial sociometabolic regime, and it is appropriate when it comes to quantifying changes in material and energy flows from and to 'nature' through social systems (e.g., Krausmann 2004; Sieferle et al. 2006). The system approach results in *explanations* for changes we observe from an etic perspective of an observer outside the system observed. Historians generally take an emic approach: they critically read and interpret their sources to *understand* why historical actors did what they did (Schmid 2006).

'However', wrote Theodore Schatzki, 'in challenging the long-standing Western theoretical practice of segregating society from nature, interactionist approaches [here, Schatzki notably refers to Viennese Social Ecology, authors' note] unwittingly uphold a key conceptual move that underlies such segregations: the separation of society from nature, the idea that theoretical work should begin from the presumption that society and nature are substantially, and not just analytically, distinct' (Schatzki 2003, p. 87). From a Humanities perspective, the distinction between nature and culture in Social Ecology can indeed become problematic. When one works with an analytical distinction, the risk of an ontological misconception is always at hand. 'There is no clear line between us and nature', wrote Richard White in his book on the Columbia River (White 1995, p. 109). Environmental History abounds in evidence that this observation is very much to the point. After environmental historians had explained—and, from time to time, defended—an interactionist approach among historians for years, some of them thought it was time to explore another *hybrid* concept. The result was the concept of 'socio-natural sites' (SNSs, Winiwarter and Schmid 2008; Winiwarter et al. 2013).

To bridge system- and actor-centered approaches, SNSs distinguish between human *practices* and material *arrangements* (instead of 'nature' and 'society'). Practices and arrangements are both understood as socio-natural hybrids. Arrangements are both the material precipitates and prerequisites of practices, and either can transform the other—if one changes, the other changes as well. The SNS is defined as the *nexus* of practices and arrangements. The concept is constructivist in the sense that it is a theory of second-order observation; by observing past observers through historical sources, it is the environmental historian who constitutes an SNS. Practices and arrangements are bound to each other, and the

nexus between the two is *spatially* explicit, so it can be charted on a map. This is an important difference from the socioecological framework of nature-culture-interactions, where systems interact functionally (and not spatially) with each other.

5.4 Synthesis: The Interplay Among Actors, Structures and Systems and the Quest for Sustainability

Before we draw some preliminary conclusions and sketch some of the gaps in our understanding of the interplay among actors, structures and systems in Social Ecology, let us take stock of what we have learned so far in this essay.

First, we defined a social ontology according to which actors are constantly embedded in social systems and their symbolic and material structures. Social systems are based on self-referential symbolic operations and are therefore 'operationally closed', that is, essentially autonomous (but not autarkic) in their evolution. The result of the constant execution of these operations and of the interplay between different subsystems (which constitute each other's environments) is the emergence of concrete structures of meaning as well as material structures that result from the 'translation' of meaning into physical work (the plan of an architect is a symbolic structure resulting from a long evolution of meaning, but the building of the structure is its translation into physical labor and includes the transformation of large amounts of matter and energy). These structures in turn influence, regulate and sometimes even determine the generation of new meaning and the behavior of actors. They determine the 'possibilities' and 'impossibilities' of the social, so to speak. Certain forms of architecture, to continue the example, favor certain forms of communication and might even disable others. Laws 'enable' certain forms of behavior and 'disable' others, as do traditions or belief systems. Markets regulate possibilities in terms of prices, demands and supplies. Actors are immersed in all these structures, but they have learned (and are trained) to 'read' and understand the possibilities they have and to move within the structures of their world. In other words, actors are adapted to the systems and structures that constitute their world, and their 'actions' are usually adapted to the possibilities these structures provide. Acting against these possibilities, that is, acting to consciously change structures to generate other possibilities or to foreclose existing ones, is a relatively rare behavior in humans as the vast majority of human actions take the form of habitualized behavior, routines and internalized patterns of choice selection (Reckwitz 2003; Warde and Southerton 2012). However, the capacity in humans to act *against* the grain of structures does exist and is well documented (Tilly and Tarrow 2007). What it requires is (a) the ability to take the position of an 'observer' of the system, or, in systems-theoretical terms (Luhmann 1997), the ability to position oneself in the surrounding structures and to distinguish between these structures and the operations that constitute them, and (b) the ability to make a conscious attempt to intervene in them.

Both capacities, observation and intervention, must be distinguished analytically. Although the former is necessary for the latter to occur, the conditions of success for any attempt of structural intervention depends on many other factors that need to be discussed in detail. The mere potentiality of intervention by no means offers an indication of its chances of success. Both observation and intervention are represented in the methodological spectrum of Social Ecology. Material and energy flow accounting (MEFA), long-term socioecological research (LTSER) and land-use change research are fields of study that involve the observation of societal subsystems and their material dynamics without directly addressing the chances of actors intervening in these processes. They represent the systems perspective in Social Ecology, as it were. The more actor-focused research fields presented above, by contrast, address the question of intervention and its 'conditions of possibility' more directly. However, they, too, have a strong commitment to observation. For example, both local studies and Environmental History analyze the various ways in which actors are immersed in structures and arrangements and the extent to which willful agency is prescribed by them. In some cases, these studies reveal historical efforts to change structures or help to determine strategies for intervention at the local level. The same can be said for agent-based modeling (ABM) as a method that can be applied for both ends: it can help reveal the structural preferences of actors, that is, it can elucidate the underlying structures that shape the actions of a relevant population or group. If used in a participatory way, where first-order observations are fed back to the participating actors or where their own observations constitute the basis of the research framework, then ABM can indeed reveal opportunities for intervention and provide guidance in building appropriate strategies. The same is true for most transdisciplinary approaches within Social Ecology. Here, the idea is to strengthen the capacity of actors for societal self-observation and for identifying their own position within relevant structures and system dynamics to generate intervention strategies for specific problems. In transdisciplinary projects, a problem perceived by actors often presents the starting point for the research collaboration, which then proceeds to analyze the systemic and structural features underpinning the problem to produce the knowledge necessary to solve the problem by intervening in some of the structures identified.

Hence, actor-oriented approaches in Social Ecology rely on methods of societal self-observation to identify opportunities for intervention in the structures of social systems. However, these strands of research have so far mostly focused either on local scales (islands, cities, valleys, neighborhoods) or on concrete organizations such as hospitals and firms. A more general and substantial investigation of the conditions that allow purposive intervention in the hybrid structures that constitute the socioecological reality on our planet is lacking. For example, a structural analysis of entire political systems with regard to these conditions has not been conducted from a socioecological perspective (but see Fischer-Kowalski 2011 for a conception of framework conditions for sociometabolic transitions). The structural dependence of political institutions in modern democracies on the fossil energy regime (and its material metabolism) within which they emerged has only been

presumed, not systematically investigated. Here, the famous 'systemic imperatives', or *Sachzwänge,* in democratic (as well as authoritarian) regimes need to be analytically linked to the material preconditions of regime stability. Conversely, the logics of political regime stability and legitimacy need to be better understood and their implications for the material reproduction of society studied. If it can be shown that the symbolic structures that constitute political systems depend on certain material structures for their stable reproduction, then the implications for climate change mitigation and a purposive sustainability transition would be massive: it would mean that for a successful intervention in the sociometabolic structures of modern societies, new and specific symbolic structures (institutions) are required and that the existing structures are not 'fit' to enable such societal intervention. Social Ecology could contribute crucial insights to the intricate relationships between the material and symbolic conditions of political and social system stability and thus help devise effective strategies for large-scale interventions in modern societies. This would require a methodological alignment of large-scale system observations in both the biophysical and symbolic realms in that the conditions of possibility for societal intervention are investigated not only on local scales and in individual organizational units but also on the national, supranational and global scales.

To do so, the structural relationship between actors as (potentially) willful units and the systems within which they operate and that constrain them need to be further investigated. In particular, the effectiveness of systemic-structural constraints and of the different modes of agency that try to break them needs to be better understood and properly theorized. First efforts in this direction have been undertaken in Hausknost (2014) and Hausknost and Haas (2013), where the 'transformative potential' of different modes of political agency are conceptually distinguished and assessed. The underlying observation is that political systems have developed strategies to relegate internal pressures for change into modes of agency that least destabilize the structure of the system. Consequently, pressures for radical change (such as pressures to decarbonize the economy or to move away from unsustainable modes of production) are relegated to modes of change that are systemically compatible but rather ineffective. At the same time, such modes of agency that would be most effective in transforming the sociometabolic regime but would destabilize existing symbolic structures are being suppressed by the system. This perspective allows for a conceptual integration of the system-actor divide in that it analyzes the ways in which symbolic systems tend to stabilize their structures by relegating purposive agency into modes of change that are least threatening to their internal integrity. To enhance the effectiveness of political agency, actors would need to focus on ways to overcome the system's power to suppress certain modes of agency instead of relying on the ineffective modes of agency the system offers. This analysis provides an actor-oriented perspective that does not deny the systemic constraints of agency but instead puts these very constraints at the center of its agenda. The crucial question then becomes what options for purposive agency there are (in the respective systems analyzed) to influence or reduce the systemic constraints that hold back purposive societal interventions.

To move this research agenda forward and to integrate it with the existing actor-oriented approaches in Social Ecology, the theoretical assumptions underpinning the socioecological conception of society as a hybrid between a symbolic system and material components need to be refined and revisited. One of the issues driving socioecological theory production has been the problem of the 'impotence' of the systems-theoretical conception of society with regard to the material world, or, as Fischer-Kowalski and Haberl (2007, p. 10) put it, 'How can a purely symbolic system make a difference in terms of influencing biophysical objects?' The programmatic demand implicit in this question is that 'society must not be so exclusively self-referential that it cannot move so much as a chair' (ibid., p. 11). The solution Social Ecology offers, as noted above, is to conceive of society as the *structural coupling* of a cultural system (recursive communication) with material elements (see also Chap. 2). This definition, however, denies society the status of a system as 'a unit that is able to reproduce a difference between itself and its environment' (Fischer-Kowalski and Weisz 1999, p. 244) because the material components (human bodies and their artifacts, including livestock, infrastructures and tools) do not belong to the system of communication nor do they constitute a separate system of their own. They belong to either ecological systems (human and livestock bodies) or the inanimate material world (buildings, roads, machines, computers, etc.). What ties them to the symbolic system of culture, however, is that they are all animated or created and reproduced by symbolic programs. The human body is the most immediate interface between the symbolic and the material realm. The artifacts that were created through the human body (and with the help of other artifacts that ultimately—in a historical perspective—were created by human bodies) are material representations of symbolic structures and thus carry the symbolic realm within them (the most conspicuous example perhaps being the computer as a 'hybrid' of material hardware and symbolic software that reproduces and multiplies communication at an ever-increasing rate; Miebach 2011).

Although this conception of society is intuitively compelling, it involves a major methodological challenge in that the term 'structural coupling' in complex systems theory has so far been reserved for systems alone and is difficult (or perhaps impossible) to apply to the relation of systems on the one hand and selected 'elements' on the other. In Luhmann (1997, p. 114), society as a symbolic system is structurally coupled *exclusively* to the cognitive systems of the individuals who constitute the population. These cognitive systems and the social system are cogenerative in that the existence of one is the precondition of the other's autopoiesis (Lippuner 2011, p. 312). Social systems depend on the performance of cognitive systems, which generate new communications and actualize the latent existence of society. The cognitive systems, conversely, depend on society as a system of meaning that enables them to communicate in the first place. The two systems are structurally coupled because each uses the other as a means of selection (and thus complexity reduction) in the common medium of language. Thus, society is coupled *exclusively* to individual cognitive systems, and, as Luhmann adamantly stresses, there is no direct coupling of society to any physical, chemical or biological entity (Luhmann 1997, p. 114). The cognitive systems, in turn, are

coupled to the neurological systems of human bodies via the medium of perception (Lippuner 2011, p. 318). Thus, any material influence on society has to go through individual perception (and thus neurological systems) and then through individual consciousness (and thus cognitive systems) to be filtered into society (and thus systems of communication) (ibid., p. 331).

Hence, Luhmann seems to offer an answer to the question of the material efficacy of society. He would perhaps argue that it is never 'society' itself that moves a chair but a human body, which is structurally coupled to a cognitive system, which is structurally coupled to society. Hence, society 'acts' through the human body by way of a three-stage structural coupling: communication—consciousness—perception—body (Lippuner 2011, p. 331). Luhmann, in that sense, would endorse the socioecological concept of the human as a 'hybrid', but he would insist that 'society' can only 'act' in the material world through the individual and that the narrow zone of communication that can be consciously influenced by individual cognitive systems is the only channel through which society can 'help itself' (Luhmann 2002, p. 124). He would probably agree that every freight vessel crossing the ocean and moving thousands of tons of commodities is ultimately steered by human bodies that are directed by cognitive systems that are coupled to the system of communication that constitutes their world of meaning. Without the latter, however, there would be no ship, no commodities, no navigation and no trade. For this complex causal chain to work, the structural coupling of the systems involved must be very rigid and tight, and the scope for conscious intervention in the complex system of meaning that constitutes society must be all the more limited the more functionally differentiated and globally dispersed this tightly knit web of meaning is.

This dual perspective of society as a symbolic macro-structure and the individual as both the material 'agent' and the possible source of conscious intervention (which, of course, is only successful if it is 'selected' by society in that only the individual consciousness can 'think' and only society can 'communicate'; Luhmann 1997, p. 105) has not yet been theoretically pursued to the necessary depth in Social Ecology. An important fact is that there is no communication between individual minds that is not already 'social', and there is no 'communication' between the individual and society (because all communication is always already *in* society). *Nevertheless*, all meaning is generated in individual minds. Understanding this fact might yield interesting new perspectives in transdisciplinary and empirical approaches that try to identify opportunities for purposive intervention in society (cf. Fuchs 2003). After all, the structural coupling of individual minds with society presupposes that all new meaning is somehow generated in individual mind systems and that society might have an influence on the selection of meaning by devising institutions that create an enhanced openness to novelty and provide new selection mechanisms that differ from those 'naturally' provided by the functional differentiation of industrial societies. Are there ways in which society can 'help itself' by increasing the chances of selection of such communications that result in effective sociometabolic interventions? What, for example, might be appropriate institutions that allow for a greater openness of societal

structures to integrate new patterns of meaning, new prescriptions and new attributions? Luhmann himself was skeptical in this regard (Luhmann 1986) because, in his view, the very independence of society from any 'direct' material influence has been the very precondition of its successful autopoiesis. Social Ecology has not pursued these questions far enough to come to any substantial conclusions. Instead, it decided at an early stage to separate the 'cultural' from the 'social' (see above) in that the former is merely symbolic and the latter involves the 'structural coupling' of the symbolic sphere with material 'elements'. It thus left the core question—how is the symbolic realm transmitted into the material realm and vice versa?—undertheorized and stopped at a promising but underdeveloped notion of hybridity that only says that there must be *some* kind of transmission ('structural coupling').

This question of the transmission mechanisms between the symbolic and the material and of the role 'conscious' meaning generation can play in influencing it is a major theoretical frontier of Social Ecology that needs to be further explored. The paradigm as such is compelling, but the very logic of social 'hybridity' must be filled with a deeper theoretical explanation. This can be done by either following Luhmann much further than the theorists of Social Ecology have done so far (as indicated above) or by following alternative paths of Social Theory that have proven successful in conceptualizing hybridity (for example, the Actor Network Theory of Latour (1993, 2004); see also Miebach 2011) and that might be in a better position to explain the 'material agency' of technology and other artifacts that are congealed symbolic structures that codetermine the generation of new meaning and the selection of possible actions.

Should Social Ecology insist that society (and not individual bodies coupled to it) must have the potency to 'move a chair', then it might indeed have to drop systems theory altogether and look for other social theories that provide a more encompassing notion of agency. Social Ecology's more recent interest in 'hybrid structures', that is, 'structures moulded both physically and culturally, in which the rules of the two realms are somehow superimposed upon one another' (Fischer-Kowalski and Steinberger 2011, p. 643), suggests an openness toward technosociological notions such as 'material agency' and actor networks. The compatibility of such notions with the systems-theoretical metatheory of Social Ecology needs to be examined in more detail, however. An integration of different sociotheoretical approaches under the umbrella of Social Ecology might be viable (as the theoretical developments in Environmental History suggest—see above). However, the price that will have to be paid in the long run might be increased theoretical complexity and thus the danger of undermining the basis for interdisciplinary communication and cooperation in Social Ecology. We are confident, however, that this frontier can be explored and 'conquered' by elaborating theoretical solutions to these problems that are at the same time complex enough to live up to the complexity of the problem and simple enough to enhance the interdisciplinary cooperation that is the main strength of socioecological research. In any case, Social Ecology is facing the exciting challenge of refining and further developing its theoretical paradigm to accommodate a more nuanced understanding of the ways in which systems, structures and actors interact in a world that is made up of symbolic meaning and physical matter.

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