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Challenges for Social-Ecological Transformations: Contributions from Social and Political Ecology

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Abstract: Transformation has become a major topic of sustainability research. This opens up new perspectives, but at the same time, runs the danger to convert into a new critical orthodoxy which narrows down analytical perspectives. Most research is committed towards a political-strategic approach towards transformation. This focus, however, clashes with ongoing transformation processes towards un-sustainability. The paper presents cornerstones of an integrative approach to social-ecological transformations (SET), which builds upon empirical work and conceptual considerations from Social Ecology and Political Ecology. We argue that a critical understanding of the challenges for societal transformations can be advanced by focusing on the interdependencies between societies and the natural environment. This starting point provides a more realistic understanding of the societal and biophysical constraints of sustainability transformations by emphasising the crisis-driven and contested character of the appropriation of nature and the power relations involved. Moreover, it pursues a transdisciplinary mode of research, decisive for adequately understanding any strategy for transformations towards sustainability. Such a conceptual approach of SET is supposed to better integrate the analytical, normative and political-strategic dimension of transformation research. We use the examples of global land use patterns, neo-extractivism in Latin America and the global water crisis to clarify our approach.

Keywords: social-ecological transformation; societal relations to nature; social ecology; political ecology; land use; resource-extractivism; water crisis; transdisciplinarity

1. Introduction

Transformation has become a major topic of sustainability research. The terminology indicates a shift both in the focus of research and in the understanding of the real scale of the challenges contemporary societies are facing. The consequences of this shift for policy-making are far reaching. In the last decades, incremental environmental governance was considered the cornerstone of a pragmatic policy approach. This approach, however, is increasingly criticised as being insufficient for coping with problems like climate change, biodiversity loss, resource depletion, food security or social inequalities. Consequently, the quest for a “societal transformations towards sustainability” [1–13] or even for a “Great Transformation” [14] emerged as a guiding theme.

This shift, on the one hand, opens up new perspectives. On the other hand, it runs the risk of narrowing down the scope of research and the corridor of possible action, leading to what has been termed “a new critical orthodoxy” [15]. The latter is characterised by a tension between the call for a

comprehensive societal transformation and a strong trust in existing institutions like state, market, science, technology, and (Western) knowledge [15].

Without any doubt, transformations towards sustainability necessarily involve political-strategic aspects, including the capability to intervene into ongoing socio-political, economic, institutional and technological transformation processes, as well as providing transformative knowledge in various different political-administrative settings. However, there is a tendency towards more political-strategic projections at the expense of rigorous analytical approaches, capable of bridge transformation requirements and transformation strategies. What is needed, therefore, is a more solid understanding of those dominant societal dynamics that hinder a transformation towards sustainability. This presupposes considering a variety of interacting and conflicting transformation processes. Whereas some of these intentionally aim at sustainability (for example, the German “Energiewende”), others pursue different targets (for example, geopolitical strategies to secure resource access). Moreover, some of these transformations are the outcome of policies and structural societal conditions and thus unintended (and perhaps difficult or impossible to influence) by those actors that focus on deliberate, intended transformations towards sustainability [5,16], but perhaps influenced by the interests of powerful societal actors. Thus, conflicting and to some degree antagonistic societal processes and the power relations involved have to be considered. Only by explicitly addressing a plurality of conflicting transformation processes, a better analytic understanding can be achieved, which offers a more realistic approach for strategic interventions [12].

Besides the analytical and political-strategic dimensions, a third, rather normative dimension of the transformation debate remains unclear: What is a desirable, fair and feasible future for global societies? Sustainability transformations need adequate political strategies, but can only be successful if grounded in a robust analytical approach and a legitimate normative perspective. Drawing on the three-dimensional sustainability discourse [17], we argue in this paper that a better integration of analytical perspectives on ongoing transformations of societal relations to nature and of normative considerations of what may constitute a desirable goal of global transformations towards sustainability is needed to improve the political-strategic aspirations of transformation research.

Several conceptual and methodological challenges prevent an integrated, i.e., analytical, normative and political-strategic understanding of social-ecological transformations (SET). In this paper, we outline a conceptual approach that aims at meeting these challenges, based on Social Ecology (SE) and Political Ecology (PE) (we are aware, that the use of the term Social-Ecological Transformation is not limited to SE and PE and we do not proclaim to have an ownership. Moreover, in such an article, it is not possible to present in detail SE and PE that are—in themselves—ramified. We refer to our work at the Institute for Social-Ecological Research in Frankfurt [18,19], the Institute for Social Ecology in Vienna [20,21] and the Department of Political Science at the University of Vienna [22,23], see also [24]. We are also aware that several other “transition” concepts exist in various scientific communities which, despite some similarities, differ in important respects from our concept of transformation. In ecology, for example, the concept of “ecological transition” or “regime shifts” denotes “substantial, long-lasting reorganizations of complex systems, such as ecosystems” [25]. In cultural ecology, the concept of ecological transition was used to describe sociocultural trends towards population growth, increasing mechanisation and growing exploitation of natural resources [26]. The “transition management” approach [27,28] asks for the processes how social innovations in niches are upscaled to regimes and landscapes. Both SE and PE refer to the concept of societal relations to nature (SRN), in German *Gesellschaftliche Naturverhältnisse*. However, the English translation of the German term *Gesellschaftliche Naturverhältnisse* is an issue: several translations are possible and in the use like societal nature relations. However, if we refer in the following to conceptual considerations how this concept may improve sustainability research, we explicitly use the term societal relations to nature (SRN), being aware that there are (minor) differences in the exact meaning even within the institutions involved. See for an elaborated understanding of the concept in sustainability research: [17], for the history of the concept in the German tradition of critical theory: [29]). Both SE and PE emphasizes the

interactions between and co-constitution of environmental conditions and societal dynamics including inequalities and power relations. They consider the societal roots of the ecological crisis as part of a “multiple crisis” [30] or as “a crisis of societal relations to nature” [19]—a complex constellation, that is centred on dominant societal patterns of production and living (at a material as well as symbolic level), their ecological implications, and controversies about how to respond scientifically and politically. Both SE and PE stress the relevance of shaping SRN for every society and they offer several insights about how a crisis of SRN develops, e.g., regarding the societal metabolism of industrial societies that depend on fossil fuel (see below).

The aim of this paper is to demonstrate why such a point of departure can help to advance an integrated understanding of the challenges for societal transformations. For this purpose, we discuss three key assets of a combined SE and PE approach. First, by focusing on SRN, SE provides a more realistic way of understanding the societal and biophysical constraints of sustainably transformations at the interplay between several spatial and temporal scales (see Section 3). Second, PE emphasises the conflict-driven and contested character of the appropriation of nature and thus the power and domination-shaped character of SRN. With that, PE counters the often unreflected understanding of governance and political steering within the transformation debate by analysing actor constellations, the structural conditions of policy making and power relations (see Section 4). Third, both SE and PE pursue a transdisciplinary mode of research (TD; concerning SEC, in particular local studies but also Health Studies are important areas of TD research, see: [31–33]; ISOE follows TD as a rule, and the TD approach is based on own research on transdisciplinary concepts and methods, see [34,35], see also Section 5 of this paper for more details). TD is, at its core, about the co-production and integration of different forms of knowledge [25]. Such a mode of research is decisive for adequately understanding any strategy for transformations towards sustainability (see Section 5). Taking advantage of these assets, the conceptual approach of social-ecological transformations is supposed to help investigate problematic and non-sustainable structures and processes (analytical dimension), to contribute to transformations towards sustainability on the level of action and decision-making processes (political-strategic dimension) and analysing what are societally desirable and at the same time achievable conditions and ends (normative dimension).

In the following chapter, we discuss in more detail why a critical understanding of transformation is required. In Sections 3–5, we elaborate on the three assets of the combined SE and PE approach. In each of these sections, we try to demonstrate the relevance of their respective conceptual contributions by discussing particular examples from empirical research. Our aim here is merely to illustrate our arguments. We do not claim that the chosen examples can provide enough empirical evidence for actually proving the solidity of our approach—this is the object of further research. To conclude, we outline the contours of a critical and integrative approach to social-ecological transformations.

2. Transformations towards Sustainability—Strengths and Weaknesses of the Current Debate

Compared with the discussion about sustainable development that has evolved since the publication of the Brundtland-Report in 1987 and the Rio-Conference on Environment and Development in 1992, the current debate on transformations towards sustainability marks a progress [36]. The quickly growing relevance of the transformation concept is fuelled by the acknowledgement of a multiple crisis, including a crisis of SRN, which cannot be dealt with by environmental policy alone or by changes within other separated policy fields. In reverse, it questions the established institutional responses and its interplay [22,37,38]. However, as Nalau and Handmer argue, the discussion around transformative change is still emerging and it is not clear as to what transformation means, how it can be evaluated, and how the conceptions of transformation fit within the current understanding of dealing with policy problems in practice. [10] (p. 349). Despite the fuzziness of the concept, they conclude that transformation can be understood as a “fundamental shift that questions and challenges values and routine practices and changes prior perspectives employed to rationalise decisions and pathways” [5,10] (pp. 350, 668).

There is, however, much ambiguity and disagreement about the meaning and function of the concept. First of all, as the terms “sustainability transformation” or “transformations towards sustainability” (often equated with the aim of a “low-carbon society”) indicate, most research is committed to a normative or political-strategic approach to transformation. Analytical clarity is often superseded by visionary and strategic orientations as the quote from Nalau and Handmer suggests (for more details [12]). Undoubtedly, visionary and strategic claims are making the debate so important. Yet they might run the risk of downplaying the socio-economic, political, cultural, and subjective dimensions that are deeply inscribed into SRN. For instance, we currently observe the rise of authoritarian rule and authoritarian neoliberalism as well as of right-wing parties [39,40] as a response to the financial crisis of 2008. Our observation is, however, that these tendencies and their root causes are not properly addressed in the transformation debate. Such tendencies deepen the crisis of SRN as they go hand in hand with climate change scepticism, the promotion of unconventional fossil fuels, or increased mining activities even in ecologically sensitive areas. The motivation here often is to protect a certain mode of living against the ramifications of the crisis and against a profound social-ecological transformation. The societal causes of non-sustainable dynamics remain, however, in the debate often rather opaque (see below).

Second, further challenges within the transformation debate emerge around the question of how to address biophysical constraints of societal development. Concepts such as “planetary boundaries” [41] or the “Anthropocene” [42,43] aim to operationalize those constraints, but they have several limitations. Beside limits of scientific certainty about the precise extent of thresholds (such as biodiversity loss), the spatial and temporal scale as much as the interplay of scientific analysis and societal appraisements (including cultural perceptions) represent major challenges. Scientific analyses are decisive to determine potential thresholds of (global) environmental change and resource use. However, boundaries have to be defined within societal and political processes, as they are necessarily linked to normative values. In other words, the biophysical constraints of societal development can only be determined with a transdisciplinary approach (see below). Moreover, the interaction between human activities (e.g., concerning land use) and natural processes (e.g., the services ecosystems provide or the contribution of land use to global warming) are crucial to determine the constraints and the option space for further resource use (e.g., concerning the options for feeding the world or for bioenergy use; [44]). These interactions are different at global or local scales or in short-term or long-term perspectives—but all these spatial and temporal scales are important to define the biophysical constraints of a desirable sustainable future.

If, for example, the boundaries for dangerous consequences of climate change are only addressed at a global scale, their impact on particular regions are neglected as much as the inequalities of certain modes of production or living across and within countries worldwide (as expressed with the term imperial mode of living, [13]). Thus, natural science analyses on the biophysical thresholds must be connected to social science analyses, dealing with both the existing societal demand of resources and the options and implications for desired futures. If the critical interactions between societal and natural processes and structures herein are neglected, a preference for large-scale technical solutions (e.g., for geoengineering as part of the “Good Anthropocene”; [45]) and a rejection of deep-rooted social-ecological transformations might be the political consequence.

Third, there is much ambiguity within the debate concerning the subjects or drivers, objects, scope and pace of such a transformation. Whereas some scholars argue for more technical or social innovations, emerging from niches in an unplanned transition process [46], others argue for an important role of the state [10,14]. But to address the subjects or drivers of transformation more profoundly requires analysing existing interest structures and power relations, hegemonic constellations and the very structure of the state and its steering capacity at various scales.

When it comes to the “objects” of transformation, it is analytically and politically highly relevant to identify what needs to be transformed. At the descriptive level, the global systems considered as overused reference objects include the global climate system, fertile land, soil or the oceans as resource

sources or as the deposits of natural elements (prominently, [41,47]). Others point at “drivers” of change such as demographic trends, the globalisation of production, trade and financial markets, resource intensive modes of production and living, urbanisation, industrialisation in countries of the Global South, increasing resource use and prices, technological progress and digitalisation [14,48]. The multi-level perspective [28] focuses on stabilised lock-ins and path dependencies of existing socio-technological systems like energy, transport, housing or agro-food systems which are constituted by technologies, markets, policies, user practices and cultural meanings. This approach assumes that radical innovation emerges in niches and is pushed by dedicated actors. Innovation in niches might become relevant at the regime or even landscape level. By referring to the SRN concept, we argue that a more precise understanding of the objects of transformation is required in order to understand the “sustainability of unsustainability” and the rootedness of unsustainability in everyday practices [11,19,49,50]. It is neither an environmental crisis nor an interplay of multiple societal crises, but the interplay of both: a comprehensive crisis of the interactions between societal and biophysical processes (we will come back to this point in Section 4).

Moreover, there is a tension between a global and long-term transformation process and a plurality of transformation pathways at lower spatial, temporal and social scales marked by a variety of individual and societal actions conflicting to some degree with each other. Despite the globalist view on problems (i.e., planetary boundaries), the implicitly privileged scale of transformation seems to be the regional or national scale (in some cases the EU level). Even the Sustainable Development Goals or the Paris Agreement of the FCCC are to be implemented by nation states or national governments, respectively. This has to do with the existing political and economic conditions and reflects frustration with global governance approaches: beside the processes of the internationalisation of the state [51,52] and the emergence of global binding rules, the national political system is the one where binding decisions are taken and where the financial, legal and knowledge resources prevail. The economic system and the dominant economic groups are partly internationalised, but, at the same time, they stick to the national scale in the sense that the conditions of production, strategic resources, and compromises with workers and trade unions are still linked to the national scale. Recent crisis politics are a clear indicator for this claim. The “own” (national) business and growth remain crucial for politics.

A further tension is related to temporal scales. Most of the debate on transformations towards sustainability is concerned with the urgency of far reaching transformations in the face of accelerating climate change. From the perspective of the global climate system, there is strong evidence that a delay of actions will increase impact and costs and that the window of opportunity to avoid dangerous climate change is closing fast [53]. At the same time, the debate about the Anthropocene opens up the discussion to time scales beyond institutional capacities and human imagination [54]. Moreover, ongoing processes to mitigate climate change (e.g., the quest for technological “solutions” like nuclear power or bioenergy with carbon capture and sequestration, abbreviated BECCS, [55]) may represent a threat for sustainability not only for some further generations but for millions of years (e.g., concerning nuclear waste; [56]). Thus, short term requirements and long-term impacts are conflicting and must be balanced in policy making. However, existing economic and political institutions, focusing mainly on short-term returns in terms of money or political power, are incapable to address such long-term, interwoven and conflicting time scales. Thus, realistic transformation approaches need to balance visionary and future oriented strategies with an analysis of the constraints for future anticipation and long-term policy-making (including scientific uncertainties).

Towards a Critical Concept of Social-Ecological Transformation

To sum up, current research on transformations towards sustainability needs a better understanding of ongoing transformation processes and a better integration of long-term and short-term perspectives as well as on large-scale and regional or local-scale transformation approaches. What is largely missing in the current transformation debate are analyses that focus in more depth on the interactions between globalized societies and the natural environment, analysing resource use

patterns and its social implications in terms of global inequalities as much as its impact on global ecosystems without denying local (including everyday), regional and national scales of problems and action (see below). A critical concept of social-ecological transformations points at a better understanding of the social-ecological dimensions of current transformation processes. This includes a better understanding of scale interactions, i.e., global, regional and local processes, and the systemic processes as much as the actor constellations and power relations involved. What is decisive is a better integration of analytical, normative and strategic dimensions of SET research and to focus more systematically on the challenges for shaping interwoven and conflicting transformation processes and their implication for SRN—i.e., a critical concept of SET. In the following, only some elements of such a critical concept of transformations will be discussed, focusing on conceptual achievements and empirical results provided from Social and Political Ecology over the last couple of years. Thus, the paper will not follow a “conventional” structure but it will mix up conceptual considerations with analytical discussions and empirical results.

3. Sociometabolic Transitions and Social-Ecological Constraints

It is one of the major achievements of the current debate that it emphasizes the interplay of several dimensions of resource use and environmental problems—from climate change and biodiversity loss and other environmental issues, up to resource use patterns and related socioeconomic crises. As discussed above, the debate could benefit from a better integration of long-term and short-term processes and of different spatial scales. Here, the Viennese tradition of Social Ecology offers to better integrate these dimensions. For several decades, this school of thought focuses on the interactions between societal processes and its biophysical environment. Major concepts elaborated in this regard are the concepts of societal metabolism and sociometabolic regimes [57,58]. Similar to the notion of societal metabolism coined long ago by Karl Marx [59], societies are addressed not as pure communication systems and not as to be separated from their biophysical foundations. At the contrary, the historical perspective focuses on the dynamic pattern of the appropriation and transformation of “nature” and its repercussion on societal change. Several concepts (important in the regard are concepts like the colonisation of nature, i.e., the transformations of natural ecosystems to increase yields; [57], operationalised in the human appropriation of net primary production or HANPP indicator [60], Long-term Socioecological Research [61,62] and Socio-Natural sites [63], and in particular, the concept of metabolic regimes and the transition between different regimes [64]) offers an important dimension of SETs often neglected within transformation research. Focusing in particular on large-scale and long-term implications of energy and resource use, sociometabolic regimes are marked by a certain energy system and related basic technologies, which constrains the option space for societal developments [58]. Hunter-gatherer societies, agrarian societies and industrial societies are the major types of sociometabolic regimes [65]. However, not only are there significant variations within each of these types, most existing societies include some features of several if not all of these regimes. For example, hunting and agriculture go hand in hand in many traditional societies, which are at the same time in contact with industrial society and use some tools and resources “imported” from there. In many parts of the world, the transition process between agrarian and industrial metabolic regimes are still ongoing, and about half of the world population is thought to still live rather in agrarian than in industrial society.

Three major messages can be distilled from research on sociometabolic transitions for the current debate, dealing with biophysical constraints: first, the industrial regime is in itself unstable and thus must be considered as a transformation society, due to its dependency on limited fossil energy sources [66]. The transition from biomass to fossil fuels as a main source of energy did not reduce society’s biomass input; indeed, agrarian and industrial societies use roughly the same amount of biomass per capita and year (40–70 GJ/cap/year; [58]). The role of biomass, and hence of land use, changed fundamentally, however. While biomass represented quantitatively almost the entire source of primary energy available for all purposes in agrarian society, it largely served as the basis

for food supply and some specific product groups (clothing, timber for construction and furniture, paper, etc.) in industrialized society. The factor 3–5 growth in primary energy supply associated with transitions from agrarian to industrial society was largely met by adding fossil fuels (and later large-scale hydropower, nuclear energy or renewables, which however still only represent relatively minor inputs today) to society's resource base. This allowed to overcome energetic limitations of agrarian societies (which ultimately were always limitations in access to land) and enabled enormous growth in resource use, and concomitantly economic activity and population density during the transition from agrarian to industrial society. However, this created new sustainability problems related both to the availability of resources and to the end-products of their use, e.g., climate change resulting from fossil fuel combustion.

From this perspective, the need for a “great transformation” and the search for a new energy system [61] is nothing astonishing or suddenly emerging. In contrast, the societal ignorance towards a limited resource base and the “limits to growth” needs to be explained. The crisis of SRN are thus strongly related to the societal inability and political unwillingness to take these limitations into account. From a critical perspective, this crisis is not only a crisis of resource use, but an expression of the societal constraints to shape their basic relations with nature, its energy source and the environmental implication of its resource use [29].

Secondly, the debate on biophysical constraints of societal development can be improved by starting from an analysis of sociometabolic regimes. From a social-ecological perspective, constraints are nothing given and fixed in an untouched nature or anchored in a biophysical system as such; there are always interactions between biophysical systems (e.g., ecosystems, but also the global climate system) and human interventions (e.g., the colonisation of ecosystems, but also fossil energies) that create the constraints [67]. The global climate system will probably function also beyond the Holocene—but the repercussions on human societies are increasingly problematic. From the beginning, systemic thresholds and tipping points must be analysed in a way that these interactions are acknowledged. Seen from these interactions of society and nature, it must be asked which characteristics within contemporary societies are responsible for their persistence in an unsustainable development pathway, i.e., their structural characteristics but also its power relations. However, these characteristics are not only anchored in the deep-rooted structural conditions of capitalism, as sometimes argued by ecological Marxists [68]. More relevant are specific modes of economic growth in certain phases of capitalism, in particular within Fordism, where resource use accelerates. Different transition pathways can be analysed within capitalism in more detail to assess the potential for successful interventions and more sustainable development pathways. For example, the “Great Acceleration” after WW2 [43] is marked by totally different resource use patterns at different times in different world regions [69]—and these differences may provide a starting point to define alternative transformation strategies.

Thirdly, the global scale and the long-term perspective is absolutely necessary for any serious analysis of current SETs. Neither the long-term feasibility—and thus biophysical constraints—nor questions of justice and (global) inequalities can be ignored for any transformation towards sustainability that take this term seriously. As conflicts over access and control of natural resources are becoming more prevalent in the future, resource fairness and justice becomes a major topic of SETs, both between and within countries [70]. Several concepts exist to analyse such large scale and long term perspectives, e.g., unequal ecological exchange between countries [69], and the unequal carbon footprint of households within China [71].

Biophysical Constraints of Land Use from a Social-Ecological Perspective

It is one of the characteristics of the current debate that land and land use becomes an increasingly important topic. High expectations on future economic options of land use (e.g., bio-economy and renewable energies) as much as dependencies and constraints are intensively discussed. Thus, land is a good example for the complexity of biophysical constraints and social-ecological interactions.

Intuitively it seems obvious that land area represents a biophysical boundary. Its size is well known and largely invariable. Most human activities, among those some that are indispensable for survival, such as food production, require land. The earth's land mass amounts to 149 million km². Further, ~12% of this land area is covered permanently by ice and snow, and hence only ~130 million km² of land is potentially usable. Also, ~75% of the ice-free area are already used for infrastructure, housing, cropping, livestock grazing and forestry, although with widely varying intensity [72,73]. Most of the remaining ~25% is dry, rocky, steep or cold, and hence unproductive. Only the last pristine forests (~5–7% of the ice-free land) represent a reserve of fertile land—but using them would entail huge ecological costs such as carbon or biodiversity losses. Almost all additional production from land will hence entail either land-use competition or intensification of land use [74]. Hence, one might be tempted to think that it should be rather straightforward to define planetary boundaries [41] related to land, for example by calculating the “human appropriation of net primary production” or HANPP, i.e., the fraction of potential biomass productivity of land already used by humans, which has been estimated to amount to ~25% in the year 2000 [74]. However, empirical research has shown that in the past it has been possible to raise land productivity by large margins: In the last century, HANPP roughly doubled, but world population quadrupled and economic output grew 17-fold (but to some degree with negative side effects on biodiversity and regulating services; [75]). The transition from biomass to fossil fuels as society's main source of energy played a big role for this decoupling, as it helped in raising yields, e.g., through synthetic fertilizers, increased harvest indices of main crop plants (e.g., improved corn/shoot ratios of cereals) and almost limitless draught power from diesel-driven tractors [76]. Modelling for 2050 shows that further growth of food, fibre and bioenergy production is possible even without deforestation [44], but of course there exist important costs and trade-offs. For example, moving toward organic agriculture will require larger cropland areas and still provide less animal-product calories than the business-as-usual scenario. Sacrificing yield increases in order to reduce environmental pressures from intensive agriculture will reduce potentials to use land for carbon sequestration or biodiversity conservation, except if consumption in terms of overall volume and the fraction of animal products in diets is reduced accordingly. Thus, future options for SET need to consider option spaces for land use and its implications. Trade-offs and land use conflicts are unavoidable and current struggles on large scale land acquisitions (“landgrabbing”) must be addressed properly: the power relations and dominant societal interests involved require a democratisation of SRN [77].

4. Political Dimensions of Social-Ecological Transformations

The challenges of shaping SRN are at the heart of a critical concept of SET [19,78]. This unavoidably leads to questions of politics in a wider sense. Concerning the political, there are two blind spots within the debate about sustainability transformations. The first one is a certain equation of “politics” with the state or governments. Despite much talk about “governance” as participation of various stakeholders, governments and the state are seen as the centre of the political. They are addressed as more or less unitary actors, responsible for the dealing with manifold problems.

However, analytical as well as political-strategic approaches to social-ecological transformation need to consider the inherent conflictive character of the dominant and intended alternative forms of the appropriation of nature and related societal nature relations. The conflicts can be tamed, compromises installed and even broad consensus over dominant societal nature relations and dealing with environmental problems can be reached (beyond the scope of this article is the political-ecological insight that historically-specific societal relations to nature, like those during Fordism, and provisioning systems, like auto-mobility as the predominant mode for mobility, can become for a certain period hegemonic [22,51,78]). What is mostly ignored, however, are the root causes of the ecological and the multiple crisis: the specific constellation of powerful economic actors in line with their political allies, capable of imposing their interests in the colonising and valorisation of nature. This is linked to power-driven discourses and the contested construction of the very meaning of ecological problems and

crises. The ecological crisis has inherently a bio-physical and material but also a symbolic-discursive dimension [19,52,79].

Against the dominant quest for better cooperation, far-reaching sustainability transformations require conflictive strategies and actions mainly against dominant economic and political actors [51]. Moreover, for far reaching transformations of Northern modes of living, we need new mechanisms to integrate more or less large parts of the population into political processes and new institutions able to question the existing mode of production and living—i.e., a democratisation of political and social life [53]. In contrast, the mentioned “new critical orthodoxy” of sustainability transformations seems to trust very much in existing political and economic institutions and actors.

A second blind spot within the transformation debate is an under-determined understanding of political steering and the state themselves (we are aware of the fact that the “political” is much more comprehensive, including the public, civil society and even the site of production, consumption and the private. However, in the paper we focus on the state as a central instance of the political). A good example is the already mentioned overview by Nalau and Handmer with a specific focus on the interlinkages between sustainability transformations and policies. “Transformation has recently emerged as a suggested approach to manage change in societies given the increasing complexity of policy problems. . . . well-planned and facilitated transformation calls for a careful consideration of what exactly needs to be changed and how” [10] (p. 355). The latter part of the quote motivates also our approach. However, we see the management perspective as reductionist when it mainly consists of a call for “new regulatory frameworks” or—in other contributions—a “strong and activating state” [14]. Here, politics is equated with public policies. In the debate on social-ecological transformation, policymakers—and behind them governments or states—are often assumed to be interested in handling collective problems, and hence in creating general welfare.

Instead, we argue, that beside the focus on policies (e.g., certain environmental measures) the very structures of polity (i.e., institutionalised forms of policies) and of politics (i.e., actors and conflicts about structures and political strategies) needs to be transformed towards sustainability. Again, to achieve this we need an adequate understanding of the state and the political.

Historical-materialist social, state and governance theory made important contributions to PE (for historical-materialist state theory in general see [80–84]; for the linking with PE see [37,52,78,85–91]). The analytical challenge is to conceptualise the state not only as a potential motor of sustainability transformations—this is important enough and dealt with in literature on the “green state” [92] or “environmental state” [93,94]. Beyond this it is key to understand how the state is deeply linked to un-sustainable modes of production and living, its links to dominant or even hegemonic social practices and rationalities, values, and discourses and how it became historically and still is crucial in the “generalisation” (Verallgemeinerung) of the fossilist metabolism.

In line with most state theoretical approaches, we understand the state as a specific materialised social institution that creates collectively binding decisions. Moreover, mainly the national state disposes over specific means to exercise a legitimate monopoly of the use of coercion (cf. on the recent debate about the internationalisation of the state: [52,95]). However, and in contrast to many other approaches, historical-materialist state theory considers the state not as a neutral entity, nor to be a mere instrument of capital or dominant social forces, but as a social relation. Therefore, the structures and actions of the state and modes of governance cannot be explained by themselves but rather through the consideration of social forces, practices and discourses, the (changing) societal context as well as the contested functions or tasks of the state in societal reproduction, e.g., the reproduction of existing societal nature relations. The latter implies that the state mainly secures and stabilises existing social relations like the social division of labour (along class, gender, and race, and also internationally); private property of the means of production and the private appropriation of the results of social production and the production of nature. Therefore, the institutional materiality of the state has to be understood against the background of the capitalist mode of production.

When it comes to this institutional materiality, it is a matter of fact that ecologically unsustainable societal structures and processes are deeply rooted in the state apparatus, its personnel and rules, their methods of functioning and their knowledge, and their modes and practices. As Nicos Poulantzas famously put it: the state can be understood as “a specific material condensation of a given relationship of forces” [80] (p. 73). This points at the co-constitutive character of society and state.

Moreover, the relational perspective considers the state as a “strategic field and process of intersecting power networks” [80] (p. 136) where—especially under more or less democratic conditions—different societal and political forces try to promote their interests, norms and values. Social-ecological conflicts are fought out and forces in favour of sustainability transformations act also on this strategic field that is asymmetrically structured and the conflicting actors pursue their strategies in alliances with state personnel and under specific rules and conditions (e.g., as “growth acceleration laws” in times of economic crises or selective environmental laws that don’t affect economic interests). In that sense, the state is crucial to deal with manifold societal, economic and political conflicts and to facilitate the creation of consensus through stabilised and shifting relations of forces and compromises with its means of force, law and regulations, discourses and legitimacy, and material and immaterial resources. Hence, the state maps out the multiple terrains of struggle in the relations of production, through labour laws, education processes etc. In that sense, the state is crucial in giving interests and constellations of forces certain durability, in organising compromises and alliances as well as possible hegemony.

Of utmost importance for a political-strategic transformation perspective is the fact that the state as a materialised institution develops contradictions, tensions, and explicit struggles between societal forces—within the power bloc or beyond—it also takes the form of contradictions between different apparatuses and branches [84]. Bob Jessop [96] (p. 364) proposed that societal practices and forces need to be able to develop and pursue hegemonic projects that potentially become state projects. Those projects might create a certain unity of the highly heterogeneous state and its policies.

Dynamics of Resource Extractivism as Powerful Global Social-Ecological Transformations

A relational and political ecology understanding of politics and the state can be clarified by looking at the recent dynamic in Latin America. In the context of the worldwide raw-materials boom in the first decade of the 21st century, the question of the opportunities and limits of raw-materials-based development has moved to the forefront of political and scientific debates. In particular, this issue is being discussed intensively and controversially in Latin America. Development paths based on the production, extraction and export of raw materials and natural products—including agricultural and forestall ones—with the goal of reducing poverty and social inequality by means of enhanced export revenues and their distribution, have been analysed and criticised under the terms “extractivism” and “neo-extractivism” [97–100]; applying the concept to other regions, [77,101]. This was not at all new, but due to the historically unseen rise of prices for raw materials since 2003–2004, governments had an enormous space of action. This becomes obvious in 2017 as we can see in many countries that the downturn of the oil price since 2014 puts the distributive policies of this model in danger.

The so-called pink tide in Latin America with such an emphasis on distribution started when progressive governments came into power. This was expressed through the electoral victories of several left wing presidents since Hugo Chávez in Venezuela in 1998. However, they wanted to go beyond distributional politics. In principle, all governments wanted to reduce the dependency from the world market. Also, in the Andean countries there existed conflicting projects about the dominant and desirable forms of the appropriation of nature. Indigenous struggles and broad anti-neoliberal alliances led in Bolivia and Ecuador to progressive governments and the development of new constitutions. They came into force in 2009 in Bolivia and in 2008 in Ecuador, respectively, and proclaimed a harmonious relationship between society and nature. For the first time in history, the Ecuadorian constitution acknowledges in its article 72 the “rights of nature”. However, in recent years their politics resulted in many respects in political frustration of many progressive social forces [100,102–105].

Analyses of the global resource boom are often undertaken from a PE perspective. This is especially the case when it comes to the role of politics and the state. Given the economic problems due to falling resource prices and demand and after the victories of right-wing candidates in countries like Argentina, the parliamentary victory of the right in Venezuela and the impeachment of the progressive Brazilian president, one of the intensively discussed questions in Latin America is: why were the governments not able—and in many cases even not willing—to reduce in an historically exceptional situation the dependency from the world market and foster certain forms of industrialisation and an internal market?

From the outlined political ecology perspective, it is accurate, in such world regions as Latin America, to characterise the state historically as “extractivist state” and currently as “neo-extractivist state”. This might elucidate the social, and in fact political, rooting of “extractivist” projects formulated by manifold socio-economic and political actors—especially national and transnational corporations in the mining, fossil fuel and agricultural sector—and secured by international constellations, i.e., investment into resource extraction and demand for natural resources. However, the state is not only the executive instrument of dominant national and international groups or classes interested in resource extraction, but also is prepared to ignore, or, if resistance emerges, suppress other groups or classes. Although it is that, too, often enough; rather, it may also act as a mediator between interests and a “strategic terrain” that is dominated by powerful forces. Therefore, it will not be neutral but privilege certain interests over others [104,106,107]. Particularly, a hegemony-theoretical perspective oriented toward Antonio Gramsci might elucidate the fact that the development model of neo-extractivism has also ingrained itself into the mode of living of wage-earners, especially that of the Latin American urban middle classes. Resource use conflicts are denied, actors who oppose official politics are coopted, ignored or suppressed. A reflection of dominant and problematic resource use patterns were—and still are—not at all part of political debates; critical research is under pressure.

It is important to note that political conjunctures might change for shorter or longer moments social power relations as it was the case after 2000 with a certain political weakening of the bourgeoisie, especially in countries like Bolivia or Ecuador. However, a critical reflection on the state—especially the post-colonial state—helps us to look at the deeply rooted state structures, the bureaucratic links to the bourgeoisie, ongoing dependency from international conjunctures and to avoid a confusion between a change of government with the transformation of the state.

Given the scope of our paper, we can learn from recent developments in Latin America even more. It is obvious that the short-term perspective of governments, the extractivist industry and the beneficiaries of the price boom prevails by large any long-term perspective that is mainly formulated by indigenous peoples, local farmers and their associations—supported by critical intellectuals—who experience the negative impacts of neo-extractivism at first hand. Concerning the multi-scalar character of many dynamics, neo-extractivism shows that the mode of development in particular Latin American countries is linked to the consolidation of resource-intensive modes of production and living in the global North, the economic rise of countries with “emerging markets,” and the resulting growing global demand for resources. Moreover, high prices in the raw-materials sector as the basis of neo-extractivism are not only due to any rise in demand, but also to the discovery of their suitability as a field of investment for overaccumulated capital, which might be called the “financialisation” of nature [23]. This means that not only the analysis of patterns of resource use and the processes and structures linked to them need to consider socio-economic and political dynamics elsewhere. This is also the case for the political-strategic and normative orientations at sustainability transformations.

Against governmental discourses and promises, during the boom of resource prices and related state income it was not at all clear whether the neo-extractivist development dynamics lead to a reduction of inequality and poverty at all (cf. [108,109]). However, neo-extractivism became dominant and even hegemonic because distributional politics towards the masses without questioning social structures enables societal compromises and fulfilled the socially dominant imaginary of “progress”, but took place at the cost of nature.

5. A Transdisciplinary Approach to Social-Ecological Transformations—The Example of the Global Water Crisis

The topic ‘water’, with all its aspects of management, conservation, use and cross-sectoral linkages is a good example for illustrating why a transdisciplinary approach is central to a critical concept of SET. In this chapter, we start with a description of key characteristics of the global water crisis, its historical development, and endeavours for solving it. Using the concepts of regulation and transformation of SRN, we then take an analytical perspective on this process. We argue here that the ongoing transformation faces a variety of challenges and that an open, creative, and transdisciplinary research process is needed in order to shape this transformation in the sense of SET.

Water is essential for human welfare and healthy ecosystems. Today, however, it is highly under pressure up and beyond critical thresholds, leading to limitations or even breakdowns of entire social-ecological systems [75]. Since the early debates on regional water crises [110,111], a broad agreement on the existence and even aggravation of a global water crisis has developed [112–116]. This global water crisis is characterized by complex problems, which involve the interplay between local and regional scales and their underlying dynamics (ibid.). In particular, these problems refer to the issues of water availability including overuse, water pollution, and access to water. If left untackled, they challenge ongoing endeavours for bringing water, sanitation and food to the people and preserving the integrity of ecosystems. The emergence of such problems is usually not caused by only one, but by multiple interacting factors, which relate to how water is abstracted, made available, allocated, used, and finally released back into the environment.

Historically, the formation of the consensus that insufficient water availability is primarily not based in physical scarcity but in how water is managed was accompanied by the perception of an increasingly globalised crisis. This triggered the development of integrated approaches towards a more holistic management of water. The first regionalised approaches of co-ordinated management were brought on the international agenda at the International Water Conference in Rio del Plata (1977). The Conferences in Dublin and Rio de Janeiro in 1992 then marked milestones for the reanimation of already existing approaches for an Integrated Water Resources Management (IWRM) [117]—their arguably limited success in solving the global water crisis notwithstanding. Legislative processes in Europe (EU-WFD 2000) and normative processes of the United Nations (MDG 2000, SDG 2015) followed. Finally, scientific analyses of the role of water in various conflict situations [118] and of global water flows [119] made it eventually clear that the global dimension of water and in particular the societal impacts on water cannot be ignored anymore.

From the SRN perspective, the global water crisis addresses complex patterns of relations between natural water resources and social actors like households, farmers, enterprises, and suppliers [120]. In the Frankfurt approach to SE these patterns are also referred to as “first-order regulations” or “patterns of regulation” [19]. On a higher level, the manifestations of the crisis mentioned above are embedded in overarching structures and their dynamics: policies, multilateral treaties, and globalised markets are intentionally created second-order regulations, which influence how water is managed. They are defined by power relations, perceptions of rising social inequality, and global change processes like urbanisation and climate change. Such second-order regulations are also described as “modes of regulation” in SE (ibid.).

This shortened description of the development of the global water crisis suggests how signs of a looming crisis can cause intended and unintended transformation processes. IWRM, for example, was developed as a response to the crisis discourse and laid out guidelines for transformations towards a sustainable water management (with a focus on balancing the interdependencies between water and other resources). In the European Union the adoption of the EU Water Framework Directive (EU-WFD) in 2000 carried this concept into environmental legislation—even though the legislative process did not explicitly refer to any crisis discourse. The Millennium and in particular the Sustainable Development Goals (MDG and SDG) have put water also on their agendas. Moreover, the rights to water and sanitation have been recognized as human rights in 2010.

IWRM and the EU-WFD were important triggers for transformations towards sustainable water management because they have a direct impact on how knowledge about solutions is generated and how they are brought into practice. They serve as valuable boundary objects for different actors and disciplines, respectively as an important sectorial legal framework. Nevertheless, partly competing sectors like agriculture, industry, and energy production tried to react to water shortages by adaptation and also by structural changes such as building reservoirs and implementing long-distance supply schemes or new technologies for intensified water abstraction. As a consequence, the risk of overuse increased, problems were not solved but shifted, and new conflicts emerged. The close connection between the agricultural and water sectors, for example, led to conflicting developments as demonstrated by the case of subsidies for certain water-intense agricultural products, which counteract measures for more efficient water uses or against water scarcity [121]. Water pricing with environmental levies had unintended effects and the implementation of drip irrigation or other water efficiency technologies in agriculture allowed an extension of irrigated land, causing the desired reduction of agricultural water use to fail [122]. Cities started to privatise their water supply and sanitation for improved economic efficiency but with the risk of higher barriers for interaction with other sectors [123,124]. This can be seen as part of commodification and commercialisation of water use. Often, these transformative actions were not coordinated and were driven by specific, isolated interests without an overall perspective. Thus, a truly transdisciplinary approach to the global water crisis is required, able for developing such a perspective.

The challenge of transformations towards sustainable water management is to move from partial solutions to an integrated and thus more sustainable balance of regulations concerning the competition on water with less unintended side-effects and critical trade-offs. In order to achieve that, we need to look at the issue of regulation of water-related SRN from a historical perspective. Many of today's patterns and modes of regulations developed over centuries and thus incorporate partly obsolete conditions. Therefore, old principles of water regulation—which are still strong drivers for long-term developments and action—may not hold anymore for the 21st century. An example is the shift from the principle 'one water for all purposes' to the more differentiated view of 'water of different quality for different purposes' [125,126] including the understanding of wastewater as a resource. Politicians and the international community are currently joining forces in order to achieve a consensus about this paradigm shift [127]. What becomes apparent is that it opens a space for innovative patterns of regulation. The differentiated management of blue, green and grey water flows along with corresponding alternative technological, infrastructural and socio-economic solutions can serve as an example here (*ibid.*). Furthermore, Goal 6 of the SDG addresses water prominently, has strong cross-linkages to several other Goals like food, health, energy, cities, climate change and biodiversity, and relates also to water and sanitation as human rights. The SDG call on developed and developing countries to take integrated action and apply holistic thinking depending on their specific needs. These developments pave the ground for a social-ecological transformation of water management. They are, however, not the answer for everything as the issue of groundwater shows: Groundwater is neglected in the SDG despite its huge importance for water supply and its critical condition in many regions worldwide. All these things considered, sustainable water management approaches will show a higher complexity than previous ones because of the close coupling of scales and sectors. Cities, for example, are important drivers of development and in case future urban water supply and sanitation take the shift of paradigms seriously, infrastructures, resource flows and their governance will be transformed within the cities and in relation to the hinterland. Finally, relevant stakeholders have to become much more part of feedback processes in water management. This leads to new participatory structures, which are more adaptive to ongoing dynamics.

Shaping the transformations towards a sustainable water management is an open and creative process. This means that, in addition to empirical studies, new knowledge needs to be produced by differentiating, critically assessing and (re-)integrating what we already know. The combination of well-known technologies for innovative solutions in the case of greywater use and circular water

economy is an example for this. The knowledge to be integrated is plentiful: natural science models and data from geohydrology, for example, have to be combined with an improved understanding of water governance regimes and institutions, innovative technological options and their requirements, and socio-economic and cultural practices of direct and indirect water users. Heuristic and analytical approaches like the concept of social-ecological systems (SES) as complex, adaptive systems [19,128] and a theoretical and conceptual foundation of 'regulation' [129] allow for the analytical decomposition of problems and the innovative (re-)composition of solutions. They also help to make new ideas like the water-energy-food nexus (FAO 2014) analytically accessible and to open up a participatory research agenda, which extends the knowledge base by incorporating extra-scientific knowledge [130].

Transdisciplinary research, which includes interdisciplinary cooperation, is able to capture the complex and multi-dimensional character of the global water crisis. This mode of research aims to produce the three types of knowledge [131] that are necessary to link the analytical, political-strategic, and normative dimensions of social-ecological transformations: system knowledge for a better understanding of the structures and processes that fuel the global water crisis, orientation knowledge about the requirements and standards of a future sustainable water management, and transformation knowledge on how the process towards a sustainable water management can be shaped. In doing so, transdisciplinary research adopts a (self)reflexive and (self)critical attitude: it routinely scrutinises its own procedures, methods, and practices of knowledge production as well as the different new roles for scientists that come along with it [131,132].

6. Conclusions and Outlook: A Critical Approach towards Social-Ecological Transformations

This paper argues that the current debate on transformations towards sustainability can be improved by a critical, inter- and transdisciplinary approach to social-ecological transformations, based on conceptual and empirical achievements from SE and PE. As shown above, several analytical challenges can be addressed building on existing work. An integrative perspective that aligns analytical, normative and strategic dimensions is at the centre of our proposal. For sure, this integrated perspective can only be developed within a wider research community, due to the broad array of competences required.

First, a focus on resource use patterns and their implications on ecosystems (especially biodiversity) and food, biomass production and water are important elements in this regard. It can be demonstrated that current societies are in themselves unstable and crisis driven "societies in transformation" and that it is a historically open question whether existing resource use patterns can be re-regulated in a sustainable way.

Second, resource use patterns evolve over long periods and are based on as well as stabilisers of power relations and hegemonic constellations. We argue that a relational perspective is the differentia specifica for a critical concept of transformation. According to Marx, modes of production correspond to the 'relations of production—relations which human beings enter into during the process of social life, in the creation of their social life' [133]. The concept focuses on structures and processes by means of which society organises its material foundations (i.e., its metabolism with nature), socioeconomically, politically, culturally, and subjectively. It identifies dominant societal structures and processes and their necessarily contradictory and crisis driven reproduction. In that sense, resource use patterns might become hegemonic. However, in times of crisis or catastrophes or at particular scales—often the local one where those who are negatively affected by certain patterns live—existing SRN can be contested and shaped. The degree of shaping—a smooth modernisation or a profound transformation—depends on power relations and strategies, on feasible alternatives and biophysical constraints.

Third, inter- and transdisciplinary research had developed conceptual approaches and empirical methods to address the complex dynamics of SRN. However, the challenges of SETs are going further and require additional conceptual and empirical work to contribute to an improved strategic approach for sustainability transformations. Therefore, a critical understanding of current

transformations towards unsustainability must be developed, that allows for improved strategies towards sustainability.

Fourth, this critical approach requires a consideration of the interplay of change and persistence, critical developments, ruptures and discontinuities, instead of simply linear developments. A major challenge is the interplay of several overlapping transformation processes, both intended and unintended, that requires an analytical perspective comprehensive enough to address the societal context (including the barriers for SET) and the side effects of certain processes while not neglecting the case specifics. It should also give a better picture of the potentials and obstacles of initiatives and proposals for sustainability transformations, i.e., the political-strategic and normative dimension.

Fifth, from a social-ecological and political-ecological perspective, SET always occurs: SRN are always regulated and only temporarily stabilized and the modes of regulations create the causes for further transformations. This is not a minor statement because it makes the respective analyses sensitive for the fact that the dominant tendencies or “grammars” of transformation need to be reflected [15]. Thus, from our perspective the question is not whether SRN will transform but what dominant tendencies or “grammars” stand behind such transformations. We assume three strong tendencies (“grammars”) that structure the industrial and fossilist mode of production and regulation of SRN: one such a grammar is the colonising of nature or land taking, a tendency that exists throughout history and is shaped by societal power relations and domination. “Nature” is increasingly shaped by human activities, whereas global societies are increasingly affected by repercussions and crises tendencies, but in an unequal way in the Global South and the Global North. Beyond the pure economic rationality of capitalism, this grammar is deeply anchored within the dominant dualistic European pattern of understanding and its belief in the domination of nature [134] (cf. [135]). Therefore, it requires a plurality of worldviews and knowledge types, open for alternatives to the dominant modes of regulation of SRN.

The second is the capitalist grammar of capital accumulation, the growth imperative and the predominance of the production of surplus values over the production of use values. The former goes hand in hand with the valorisation and overexploitation of nature (and the work force) and forms certain modes of regulation [19]. In that sense, political economy is “political ecology’s bread-and-butter” [90] (p. 343) and crucial for our approach, too. This does not mean that all societal relations are structured along capitalist imperatives; they might co-exist with subsistent, solidary and cooperative forms of production and living. Moreover, non-paid care work is decisive to organise the material and symbolic reproduction of societies and, hence, the appropriation of nature [136]. In fact, different modes of regulations do not merely co-exist and are often co-constitutive but also conflicting with each other [51]. Thus, the destructive “logic” of the valorisation of nature for capital accumulation is not without alternatives. In fact, these tendencies are contested, counter-tendencies can evolve—and do evolve—due to severe crises and social struggles of actors that intend to impede the destructive tendencies of dominant regulations of societal relations to nature. We assume that such struggles are decisive for alternative resource patterns and that a closer analysis of such resource use patterns in space and time may provide a starting point to define alternative transformation strategies (see above Section 3)—but this of course needs further investigation. Moreover, broader analytical lenses are required to understand societal and socio-ecological dynamics, e.g., a more comprehensive understanding of the economy and societal reproduction that goes beyond the formal market and money economy and towards considerations of non-monetarised forms of production and labour and related societal nature relations [136].

The third tendency or “grammar” is related to our strictly multi-scalar perspective that does not lose out of sight the global. We argued that—despite the relevance of the local level and in particular local struggles—the claims for sustainability transformations are, in principle, global but in fact they refer mainly to national or regional scales. The national scale, however, is dominant due to the density of the national political systems (compared to the international one) and the dominance of strategies of competitiveness that are mainly pursued at the national scale. This is the

basis that capitalist development occurs unevenly, both in space and in time. It also installs a powerful mechanism or tendency to externalise the negative preconditions and consequences of production and consumption to other regions. Biesecker and Hofmeister [136] call this a constant and absent “shadow of externalisation” that drives societal dynamics in certain regions, makes life more attractive at the cost of the living conditions in other regions. These complex processes of externalisation are a cornerstone of constant social-ecological transformations and need to be considered and changed by any project of sustainability transformations.

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