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SOI Discussion Paper 2018-02

Sustainable Innovations

Theories, Conflicts and Strategies

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Abstract

Sustainable innovations can help to find ways of addressing major challenges such as global warming and resource consumption. This article begins by clarifying the specific inconsistencies within the concept, before introducing the research on sustainability-oriented innovation processes. This research is geared in part towards sustainability innovations in organisations and in part towards overarching processes of societal transformation for sustainable development. The article concludes by discussing strategies for promoting sustainable innovation and drawing consequences for the sustainable rebuilding of infrastructure.

Zusammenfassung

Nachhaltige Innovationen können dazu beitragen, Antworten auf die großen Herausforderungen wie globale Erwärmung und Ressourcenverbrauch zu finden. Der Beitrag klärt einleitend die spezifischen Widersprüchlichkeiten des Konzepts und führt dann in die Forschung zu nachhaltigkeitsorientierten Innovationsprozessen ein. Diese richtet sich teils auf Nachhaltigkeitsinnovationen in Organisationen und teils auf übergreifende, gesellschaftliche Transformationsprozesse für eine nachhaltige Entwicklung. Abschließend werden Strategien ihrer Förderung diskutiert und Konsequenzen für einen nachhaltigen Infrastrukturumbau abgeleitet.

Contents

1 Introduction: The challenge and its social-science definition[1]

In Germany, as in most highly industrialised countries, lifestyles and business models are too resource intensive, environmentally harmful and socially and ecologically unsustainable to simply carry on without encountering problems. By contrast, *sustainable innovations* should help to achieve sustainability objectives and, in particular, improve the environmental footprint of current lifestyle, business and consumption patterns. Unlike the term *environmental innovation*, the concept of sustainable development, still open to interpretation in many respects, has been associated since the Brundtland Report (United Nations 1987) with the expectation of integrating environmental, economic, (cultural) and social development goals by means of suitable innovations and initiating a change of course at macrosocial level towards future-proof intergenerational and intragenerational lifestyles and business models. There is no room to explore the complicated criteria for defining and assessing sustainability objectives here (for more on that topic, see Grunwald and Kopfmüller 2012; Fichter et al. 2006). Instead, we will consider three key paradoxes that illustrate why sustainable innovations present an immense and at the same time contradictory challenge.

(1) Shaping open-ended futures in an open-ended way: The first paradox is found in the desire to shape open-ended futures by means of equally open-ended innovation processes. Innovations are based on search and development processes that are inadequately defined in factual, temporal and social terms. The regulative concept of sustainable development also requires an open-ended design approach in all three dimensions. When it comes to the objects, periods of change and the groups of actors involved, both sustainable innovations and the sustainable development model are faced with the fundamental dilemma of having to take account of basic insecurities and uncertainties with regard to future assessment criteria, needs and general conditions. At the same time, discussion of sustainable innovation is oxymoronic, involving two promises that are semantically contradictory. While the term "innovation" is also associated with disruptive and "destructive" change, the term "sustainable development" promises the long-term "preservation" of options deemed to be desirable and necessary for meeting needs. However, it is not possible to predict in the development and diffusion phases whether an innovation will prove to be sustainable with hindsight. Instead, a key characteristic of innovation processes is that they take rapid and surprising twists and turns, and that their contexts are subject to the process of "creative destruction" (Schumpeter 2005: 39). Many sustainability innovations prove to be less sustainable in hindsight than originally intended, as the patterns of their use and diffusion contradict expectations in this regard. Take e-bikes, for example.

[1] This work was supported by the German Federal Ministry of Education and Research (BMBF) [grant number 01UT1428B] under its program of research for Sustainable Development (Fona).

The fact that they tend to motorise bicycle transport and increase energy consumption for transportation rather than reducing environmental pollution from individual drivers by getting them to use bicycles instead is one of the unintentional adverse effects of open-ended innovations.

(2) Innovation and exnovation: Closely related to this paradox is the dilemma of innovation and exnovation (Paech 2005; Kropp 2015). Innovation processes are usually driven by the hope of being able to use innovative offerings in the form of new products, services, procedures and technologies to improve one's own competitiveness. State funding of regenerative forms of energy production or low-emission cars also explicitly links the goal of reducing greenhouse gas emissions with the desire to improve sales and business conditions of innovators and their associates. As such, innovation programmes seek to foster a form of growth through the introduction of new and improved solutions. However, instead of requiring innovative "additions", sustainable development tends to demand the reduction of existing options in most areas of activity, that is, "exnovative" processes of elimination. However, the exnovative objective of abolishing excess and unsustainable practices (Paech 2005: 251ff.) stands where innovation does not lead to the absolute substitution of unsustainable offerings, in contrast to the typical innovation dynamics of expanding and complementing existing opportunities.

(3) Sustainable innovation in an unsustainable context: The third paradox consists of the fact that sustainable innovations are expected to achieve their objectives in an unsustainable overall context. The selection criteria applicable in this context show a strong attachment to traditional emphases on growth and alleviation and thus contradict the sustainability objectives of reduced resource consumption and increased responsibility. Strategies for decoupling development and resource consumption replace quantitative growth with a form of qualitative growth in order to better meet needs without diminishing or harming livelihoods. However, the considerable rebound effects (Saunders 2013; Santarius 2014) identified in the past and resulting from additive use, overcompensation and problem-shifting point to the difficulties of diffusing and normalising sustainability innovations in a targeted manner. Notorious examples include putting the old fridge in the cellar to cool beer after replacing it with a more energy-efficient model or the abdication of moral responsibility through sporadic sustainable behaviour (moral licensing effect). The difficulties also illustrate the limited sustainable impact of standalone innovative solutions compared to a fundamental turnaround, which will be revisited later, and the need to take greater account of the obstinacy of diffusion and adaptation.

Research into sustainable innovation is further complicated by a diffuse and normatively biased understanding of both innovation and sustainable development. This creates a considerable gap between the growing significance of both topics and their

systematic processing in a research context (Schwarz et al. 2010: 165). This is why a precise definition of terms is needed, one that moves away from the narrow focus on entrepreneurial and economic development processes and shifts the focus from the dominant economic goals (e.g., Ahrend 2016) to environmental objectives and social conditions. Generally speaking, sustainability research has the *economic* goal of safeguarding prosperity and consumption and economic opportunities and the *environmental* goal of securing natural resources and their key functions and processes. *Social* (*and cultural*) sustainability addresses protection and design goals for social stability, individual and collective health, social resources and the preservation of cultural distinctiveness and development opportunities. However, there are a number of trade-offs between these "three pillars" of the necessarily integrated definition of sustainability (for more details, see Grunwald and Kopfmüller 2012).

By contrast, with its Eco-Innovation Action Plan, the European Commission (2011) is focusing solely on the environmental dimension and defines eco-innovation as "any innovation that makes progress towards the goal of sustainable development by reducing impacts on the environment, increasing resilience to environmental pressures or using natural resources more efficiently and responsibly". However, in order to also take appropriate account of the social dimension, it is essential to have criteria for social participation (environmental justice), development opportunities and socio-cultural fit. For example, Sen (2000) stresses that a sustainable food supply depends not only on corresponding forms of food production and distribution, but also and to the same extent on suitable social and political institutions for coordination and distribution and on individual and collective ability to co-determine and influence sustainable nutritional practices.

Therefore, I consider such development and change processes to be *sustainable innovations* which facilitate, use and diffuse novel technical, organisational, practical, institutional and cultural solutions with the goal of facilitating lifestyle and business models that are transferable globally and in the long term, and contributing to social structures that promote health and fairness and protect the environment. They can only curb resource consumption harmful to humans and the environment and prevent dangerous emissions if they take effect on a "targeted basis" from the idea stage for sustainable options to the implementation and diffusion phase so that their use leads to sustainable routines that improve sustainability footprints as a result and they make an exnovative contribution to curbing unsustainable lifestyles and business models.

Based on this definition, I present in the next section theories and concepts of research into sustainability-oriented innovation processes and subsequently outline methods and strategies for promoting them.

2 Theories and concepts of sustainable innovation

While the development and promotion of sustainable innovations is energetically driven at political level by actors such as the European Commission and the German Government, the latter through its high-tech strategy, these innovations are only in the very early stages of establishing themselves at conceptual and analytical level (Blind and Quitzow 2017: 14). This is also due to the fact that the technological deterministic belief in linear innovation models and their manageability is only slowly giving way to socio-technical insights into the complexity and relationalism of social innovation processes (Konrad and Nil 2001: 10; Kropp 2013: 89). The research community is focusing less on isolated "innovation actions" and more on innovation *processes, systems, networks* and *milieus*, in which technological and organisational development takes the form of social processes. Contrary to older, more dualistic concepts of a technological development with its own logic as the one best way of advanced problem-solving and its (delayed) social impact, the focus thus moves to social emergence and development conditions, such as the role of general financial, legal and political conditions and the significance of cultural expectations and models.

In this regard, technology assessment highlighted the extent to which innovation processes are socially embedded and connected up within society and the associated implicit and explicit interests and negotiation processes. It made visible the impact that different constellations of actors have on innovation processes, their diffusion and their effects with their rationalities, resources and interests, alongside the impact of technical and organisational factors (Simonis 2013).

Depending on the inclusion of the environment surrounding innovation processes, two different approaches can be identified in the research. On the one hand, there are approaches to examining, promoting and disseminating *innovation processes* for sustainability in an organisational context, and, on the other, approaches that take a more comprehensive look at social *transformation processes* in order to analyse the conditions under which sustainability innovations change or fail to change existing unsustainable contexts and "regimes".

2.1 Sustainable innovation processes in organisations

A large proportion of research activities are focused on the development conditions and success factors in the organisational contexts of companies and administrations. This economics-dominated research field takes account of the fact that innovations (in contrast to Gyro Gearloose) arise not as the result of heroic and sporadic "inventions" by individuals, but rather in the context of increasingly network-like (Rammert 1997) and "distributed" (Joly et al. 2010: 22) constellations of more gradual change (Dolata 2013). With regard to sustainable innovations, it is important in this

context to draw a clear distinction between the definition of innovation focused on successful implementation and diffusion and the definition concerned more with the initial invention. While it has been framed in this way within research discussion since Schumpeter, there is a tendency in everyday usage to equate innovation with invention, regardless of whether these remain theoretical possibilities or they are actually implemented and "normalised" (Blättel-Mink 2006: 84). As a result, the key difference is lost between good sustainability ideas and sustainable products, services and practices that are actually disseminated, and intention is confused with reality. However, sustainable practices involving reduced and fairer resource consumption at overall level that are currently failing do so not as often due to a lack of offerings or ideas for sustainable production and consumption processes, but rather as a result of a lack of sufficient demand, diffusion and market acceptance. In short, the problem lies in the diffusion and, in particular, the targeted dissemination of sustainable options (Beck and Kropp 2011; Kropp 2013; Fichter and Clausen 2013).

Only innovation processes that initiate *targeted* change processes up to the implementation and dissemination stage develop a sustainable impact. This applies to product and service innovations and innovative business models (in the private sector), as much as it does to conceptual, organisational, administrative, structural and process-related innovations in other areas of society to which the definition of innovation is extended (Rammert et al. 2016). This is also explicitly true of *social innovations* designed to improve the meeting of social needs (beyond market and state), our individual and collective ability to take action, and opportunities for participation and cooperation (Moulaert et al. 2013). Social innovations can only be distinguished logically at conceptual level from economically and technically motivated innovation processes based on their contribution to socio-political transformation processes. However, because they contribute to changes in social practices and routines, they are receiving increased attention in research into sustainable innovations (Rückert-John 2013).

Within innovation research, innovation processes are typically analysed at different moments, for example, during the invention, incubation, introduction, and diffusion phases. In practice, these partial steps, conceptually distinct from one another, often intertwine, lead into meandering processes and follow arbitrary impulses. A similar analysis has also gained significance in science and technology studies, namely distinguishing between different moments in translation processes, through which innovations take shape as a new combination of existing elements and perspectives and the associated connection and modification of all components (Callon 1986). The first step of determining a problem is referred to as problematisation. It is followed by the incorporation of relevant perspectives, materials, technologies and actors (interessement), the successive definition of interrelated roles (enrolment), and the critical process of mobilisation as another effective representation or mode of implemen-

tation of the innovative new combination. The research perspectives on sustainable innovations can be portrayed effectively based on these moments.

The first question that arises is: which are the actors and places of initiation of innovative processes for sustainable problem-solving, that is, where does the *problematisation* and *invention* originate? It is worth noting that they rarely belong to the established research and development laboratories in the industrial and scientific sectors, but instead frequently arise as the result of targeted problem-solving efforts in environmentally oriented niches, start-ups and counterculture milieus (Fichter and Clausen 2013; Mautz et al. 2008). At the same time, the types of sustainable innovations are different in each of the two contexts. In the established economic, industrial and technological development organisations, the incentives for innovation processes are usually mercantile in nature, meaning that the dominant innovations involve incremental adaptation and improvement for sustainable development. These innovations are designed to be used to respond in a market-compliant way to corresponding regulations and changes in demand. "Radical" innovations, involving high costs and a high risk of failure are avoided. However, innovation processes focused on sustainability often require participants to deal with a high degree of complexity (Ketata et al. 2015) and to largely break with existing practices. Consequently, they create problems in terms of information and knowledge creation, dealing with uncertainties, conflicts, trade-offs, resistance and compatibility with existing interfaces. This is why external impetus is necessary, for example, political forms of innovation management through funding measures, standards, legislation and certificates, which serve to set the pace to ensure that innovative work to promote sustainable development is still undertaken despite these hindrances (Kesidou and Demirel 2012). An analysis of several studies found that, after political impetus, marketing considerations such as perceived consumer preferences, cost-saving potential and expected product superiority play a key role, while environmental issues come last among all influencing factors (Brückl 2007: 85ff.).

By contrast, radical innovations in the name of sustainability often originate with industry newcomers or with pioneers, change agents, user communities and visionaries with an explicit environmental motivation, including individuals from civil society. These actors intentionally seek to bring about sustainable changes, responding to a development model they perceive as a threat by creating innovative alternative models (Mautz et al. 2008; Kristof 2010; Ornetzeder and Rohracher 2012; Fuchs 2017). Whether they are developing regenerative techniques for producing energy or innovations for sustainable mobility, sustainable living and farming, or sustainable food, in all areas of activity, the established organisations (incumbents) tend to contribute improvement innovations with wider diffusion, while the challenger actors usually focus on more fundamental key innovations with a lesser degree of diffusion. Consequently, while both innovation contexts are important, the role of start-up funding

programmes is still underestimated with regard to promoting fundamental sustainability innovations (Fichter and Clausen 2013: 276).

When it comes to *incubation* and *introduction/interessement* and *enrolment*, the challenge is to form corresponding alliances and networks, achieve power to define legitimate and appropriate approaches (*sensemaking*; Weick 1995), and develop the necessary forms of organisation, cooperation and coordination for dealing with complex requirements and trade-offs (Mauntz et al. 2008; Hall and Vredenburg 2003; Urry 2016; Fuchs 2017). Older considerations of exogenous and endogenous innovation processes from organisational research and evolutionary economics shed light on the different ways that incumbent and challenger actors design innovation processes (Rupp 1995). In these fields, innovation design is understood as an activity undertaken by organisations in an attempt to co-design environments of relevance to them. It may follow perceived market changes in a rather reactionary way or reflexively focus on a "change of routine endogenously induced by a search activity" (Rupp 1995: 367) and result in a conscious "active variation" (Rupp 1995: 369) of innovation trajectories, as is typical of sustainability pioneers.

Sustainability innovations whose targeted development and introduction conflicts with widespread meaning positings, implementation positions and unsustainable path dependencies quickly fall victim to reactionary adaptation to existing socio-economic structures. Even when sustainable innovations are understood as a turning back towards supposedly simpler patterns of action or to default (exnovation), there is a need for comprehensive development of objectives and for directional interventions in order to steer development processes effectively towards these goals. Consequently, it is necessary to integrate the initially deviating orientations into existing operational arrangements and models in order to support sustainable development (Kristof 2010: 78; Hall and Vredenburg 2003) and to effectively manage the multi-dimensionality of innovation processes that must be oriented not only towards economic aspects, but also towards environmental and social aspects (Ketata et al. 2015). Environmentally motivated networks appear better suited to successfully securing objectives and dealing with the corresponding complexity. Participants bring with them a high degree of motivation to develop the necessary knowledge, overcome resistance and promote the development of new practices in problem-solving thanks to their social skills in building coalitions (Fuchs 2017b: 243; Kropp 2014). However, at the same time, they reduce opportunities for diffusion, as a result of which many sustainable innovations remain in niches where they are supported by adapted forms of business and the price and quality tolerances of committed customers (Villiger et al. 2000).

On the basis of an empirical study of in-house innovation processes at over 1,100 firms in Germany, Ketata et al. (2015) found that sustainability innovations generally require a specific form of knowledge management when dealing with more complex

performance and success criteria. They necessitate more and broader communicative efforts, greater motivation and willingness to take risks, ongoing individual and organisational learning processes, greater incorporation of external sources of knowledge, and the increased deployment of resources (Ketata et al. 2015: 63ff.). As a result, organisations with high adaptive capacity (to incorporate diverse sources of knowledge and management) and generous resource deployment are particularly successful.

The main difficulty concerns the *diffusion* and *normalisation* (*mobilisation*) of sustainable innovations in such a way that they help to reduce environmental damage and achieve sustainable objectives. After all, while a sustainable product or manufacturer image is honoured by relevant demand groups, many offerings have marketing difficulties or fail in the way they are used to contribute to the expected reduction of sustainability problems. Generally speaking, when it comes to innovations, only the smallest proportion of all innovation processes are successfully marketed and implemented, as it is only in a small number of cases that they are able to build on the existing (unsustainable) foundation without any difficulty (Fichter and Clausen 2013; Kropp 2013).

Rogers defines the diffusion process as primarily communicative in nature, a process "in which an innovation is communicated through certain channels over time among the members of a social system" (Rogers 2003: 5). Accordingly, innovations take a non-linear course, from their adoption by young, risk-taking, educated groups of "innovators" to their take-up by rather diverse, opinion-leading "early adopters", to their acceptance by the "early majority" influenced by the early adopters, thus reaching a "critical mass" (Rogers 2003: 343), to their later establishment among the more sceptical "late majority" and, finally, the older "laggards" (Rogers 2003: 282ff.). While conditions such as market, organisational and admission structures, and the openness and reach of communication channels providing information on the innovation have some influence on diffusion, the main influencing factors are the object-related criteria of the relative benefits (or the perception thereof), the compatibility, the usability (simplicity), the trialability and the visibility of the relevant innovation.

Innovation researchers criticise Rogers' theory of diffusion for being based too heavily on observations from the agricultural and health care sectors and for unjustifiably transferring the adopter groups in these sectors as "the social system" to other markets, yet failing to take sufficient account in conceptual terms of the fundamental relationalism of diffusion processes and their associated learning processes. They also criticise the static description of innovations underlying this model for insufficiently recording success-critical processes of successive change, adaptation and co-evaluative development ("long waves"). Fichter and Clausen (2013) attribute only limited explanatory value to Rogers' approach in their study of the diffusion patterns of 100 different sustainability innovations. For a better understanding of different

degrees of diffusion success, they supplement the role of state protected lead markets, path dependencies (economies of scale, capital tie-in, lock-in effects) to be taken into account, and sector effects from evolutionary economics. Using a system for classifying observed diffusion paths by innovation type, innovation dynamics and sustainability impact, they differentiate between various degrees of diffusion and sustainability success (Fichter and Clausen 2013: 235ff.). According to this system, efficiency-increasing and easy-to-understand innovations that improve on existing ones achieve a higher market penetration more quickly and tend to be independent of state support, but involve greater rebound risks. By contrast, more radical and fundamental sustainability innovations tend to achieve lower penetration rates and take longer to do so, especially if they require a great deal of behavioural change and have more demanding requirements for their use. They are typically introduced by newly established organisations "with a high level of commitment and clear sustainability objectives" (Fichter and Clausen 2013: 243), but without industry knowledge and tried-and-tested sales channels. In the study, the establishment of industrial associations, legal regulations and political funding significantly support the diffusion pattern of radical innovations.

In the final analysis, fundamental key innovations for sustainable development are more likely to come from exogenous drivers and actors, while better market penetration is generally achieved by actors with industry experience. Additionally, the targeted sustainability impact proved to be insecure and in need of steering, and that in the face of a considerable degree of scepticism about steering at overall level regarding innovations in general (Sauer 1999) and sustainable innovations in particular (Kristof 2010). As such, it is not surprising that questions of institutional mainstreaming and context management are receiving increasing attention.

2.2 Sustainable innovations as an element of social transformation (transition)

Transformation and transition researchers are responding to these questions by analysing innovation-related multi-actor constellations. They place the focus on the interaction between established systems and innovative approaches, and on the interplay between proposed technical and organisational improvements on the one hand and socio-economic and general institutional conditions on the other (Grin et al. 2010; WBGU 2011, 2016; Grießhammer and Brohmann 2015; Fuchs 2017). Transformation theories assume that for sustainability impacts to be robust, it is necessary not only to change individual products and processes, but also to open up the co-evolutionary and emergent transformation already taking place in societal systems to the forces of its unsustainable stabilisation for sustainable change. As such, the focus is on analysis of the complex, intended and non-intended interactions between pronounced innovation and transformation processes on the one hand and the estab-

lished nexus of predominant infrastructures, habits, mindsets, logics of action, constellations of actors, policies, business models and regulatory forms on the other. Consequently, the area of investigation is being expanded beyond the organisational level in order to take account from an analytical point of view of path dependencies, general legal and financial conditions, learning processes and forces of inertia on the part of the socio-technical status quo and its institutional mainstreaming in market power, standards, consumer preferences and training content. Thus, attention is turning to comprehensive processes of institutional transformation and the potential influence of these processes in terms of bringing about a sustainable transformation of contemporary societies. From this perspective, there is talk of overarching, cumulative *structural* and *system innovations* and *transformations* (*transitions*) that are placing fundamental patterns of societal culture and order under pressure to change, in order to describe and support the institutional and paradigmatic change processes needed to achieve sustainability objectives.

As such, the priority is to identify the conditions under which sustainable innovations successfully diffuse from "green" pioneer milieus into the dominant regime network of industrial market and actor constellations, canonised knowledge, established solution expectations, economic and consumption patterns, and the unquestionable continuation of unsustainable natural conditions. Even if ambitions of a thoroughly transformational nature are formulated (Schneidewind and Singer-Brodowski 2013; WBGU 2011; Kemp and Lorbach 2006; Grießhammer and Brohmann 2015), debate remains over the extent to which transformation processes can be intentionally steered (Dolata 2008). An awareness of unintended, secondary consequences, errors, ambivalences and the failure of past steering efforts would be beneficial in this context (*reflexive governance*; Voß and Kemp 2006).

In recent years, transformation theories have been related particularly often to the energy transition, the successful implementation of which depends not only on innovations in regenerative production and storage technologies, but also on far-reaching political, financial, organisational and social changes, including innovative forms of governance and steering. This makes clear that, in the principally contingent and open development processes, only a "large number of gradual transformations over a longer period of time [...] give rise to substantial, profound and sustainable social changes that do not involve the simple or expanded reproduction of what already exists" (Reißig 2014: 57). They will only become stabilised and normalised within society if the new problem-solving models replace at least some of the established approaches and institutional orders. To this end, transformational practices need to diffuse beyond the "semantic" level of discursive and symbolic change to the "operational" level of new practices and to change the "grammatical" level (Rammert 2010) of the action-guiding (infra)structures in such a way that the innovations are (or can

be) reflected in correspondingly sustainably oriented institutions and modified products, facilities, technologies and relationships.

It is worth making brief reference here to the multi-level perspective (MLP) of transition management from the Netherlands as an example of transformation theory (Geels 2004, 2012; Smith et al. 2010; Geels and Schot 2007). It is distinguished from linear steering illusions in order to instead take account of the complexity of interacting actors and systems and their unequal action goals: "transition management breaks with the old plan-and-implement model aimed at achieving particular outcomes and is based on a different, more process-oriented philosophy" (Kemp and Loorbach 2006: 110). Drawing on historical studies of innovation trajectories, the MLP models transformation processes as a multidimensional interplay between the micro level of radical niche innovations, the meso level of stabilised problem-solving patterns in regimes and an exogenous macro level (Grin et al. 2010).

When it comes to exerting the desired sustainability oriented influence on complex transformation processes, particular attention is given to the inhibiting forces of prevailing system conditions. They are described at conceptual level as a "socio-technical regime" that needs to be at least partially destabilised, displaced and changed in order to have sustainable innovation processes. By contrast, the societal stabilising effect of this regime, well established at legal, moral and cultural level, is based in technical, economic and cognitive terms on its ability to limit the variability and orientation of innovation and development processes in favour of the status quo by means of the rule systems emerging within them (Scott 1995). Against this backdrop, the multi-level perspective also expects most culturally divergent, sustainable innovations to come from protected niches of innovating, environmentally motivated pioneers at micro level, as outlined in the previous section. In these niches, the non-mainstream, "monstrous" innovations can be protected from selecting market pressure and the focused counter-movement of the regime. However, during their diffusion attempts, they are confronted with the highly institutionalised and reinforced inertia of the dominant regime. They come up against path dependencies, routines and self-evident socio-technical facts, such as the major infrastructural systems for transportation and energy supply. Above the micro level of the niche pioneers and the meso level of the regime, the multi-level perspective establishes long-term development cycles, referring to them as a landscape, in line with Braudel's concept of Mediterranean continuity. This sociologically under-determined level only changes over long-term cycles, but can open a window of opportunity for regime change in the event of major overarching catastrophes (Fukushima), resource depletion (oil crisis) and basic technological innovations.

From the multi-level perspective, a transition to another, more sustainable regime constellation brings about multi-level change within a sector (transportation, energy

supply), spanning the innovative niche (electric cars, solar power), the socio-technical regime as a whole (mobility or energy complex) and the overarching societal macro level (post-fossil fuel society). In this way, sustainable innovations achieve a structural breakthrough with a large number of connected changes that accumulate to form a new regime in a subsequent stabilisation phase. Emphasis is placed on the need for complementary co-evolutions through which, for example, corresponding political steering impetus promotes the success of sustainability innovations in order to change existing legal and cultural rule systems for sustainability objectives. According to the fundamental thesis of the multi-level perspective, as long as overarching change processes fail to create pressure for change in the regimes and windows of opportunity for the sustainability innovations developed in the niches, then the regime will cause the sustainability innovations to adapt on a widespread level to the unsustainable status quo. In recent years, MLP has been refined with concepts from political economy in regard to the resilience of dominant constellations of actors within industry and policy-making (*incumbent actors*) (Geels 2014). Greater consideration is now being given to the narrow capitalistic alliance of decision-makers in the worlds of policy-making and business, along with their resource-intensive, definitional, techno-economic and state-regulatory forms of asserting their interests in order to retain the system to their own benefit. For this reason, the deliberate destabilization and creative destruction of existing socio-technical regimes receives conceptually more attention (Kivimaa and Kern 2016).

From a critical regime perspective, sustainable innovations and exnovations are insufficient as standalone sectoral solutions when it comes to bringing about the necessary, long-term and branched transformation towards socio-technically sustainable systems (Grin et al 2010; Dolata 2013; Geels 2014). Only their cumulative development and consistently exnovative orientation along development trajectories hold promise to effectively reorientate the societal action programmes and institutions in the respective field of activity. The interdependencies between the different innovation processes and variations are described as multi-layered and contested restructuring and transformation processes, as clearly illustrated at present by efforts to promote post-fossil fuel mobility and energy supply. These kinds of contingent processes are characterised "not by early and one-time closing processes that constitute a new and stable technological standard and development pathway that could serve as a reliable framework for socio-economic and institutional restructuring" (Dolata 2013: 277). On the contrary, the rule-altering transformation and learning processes are linked to costs, competitive disadvantages and foreign milieus, call into question established distribution rationale and balances of power, and potentially threaten comfort and prosperity, meaning that they ultimately challenge the industrial innovation regime as a whole (Latour 2014; Klein 2015). For this reason, the necessary steps in the "great transformation" (WBGU 2011) are currently being taken in the form of small steps of pseudo-transformation under the labels of "green economy" and

"qualitative growth", and most sustainability innovations, such as the energy transition, are governed by the implicit promise that nothing needs to change (Kropp 2017).

3 Strategies for promoting sustainable innovations

Presenting the state of research into sustainable innovation and transformation processes has highlighted the significance of supporting political policies and exogenous innovation drivers with a dedicated environmental motivation. It is possible to identify further starting points for promoting sustainable innovations.

3.1 Promoting sustainable innovation processes in organisations

Within corporate settings, it is usually necessary to explicitly steer innovation processes towards solving sustainability problems. In order to firmly embed this orientation in the face of the sustainability goals that are difficult to specify and sometimes ambivalent, it is necessary to use external knowledge sources and protect search and development processes from internally applicable selection criteria for adapting to the status quo. Political measures and environmental orientation at management level or on the demand side boost motivation for this (Fichter et al. 2006, Hojnik and Ruzzier 2016). It is also beneficial to embed the processes in incubators with an explicit sustainability orientation or in corresponding innovation networks (Kirschten 2003), as is happening in some cases with the development of electric vehicles, or to integrate external knowledge-bearers into the innovation processes on a targeted basis, for example as part of user integration methods (Belz et al. 2013). The success of both strategies depends on the level of determination to keep sustainability criteria a priority in prototype development and market launch (Kropp and Beck 2013).

Organisations tend to undertake such efforts only if they are hopeful that this will enable them to better manage future uncertainties. Sustainability-focused models and guidelines for technology development and corresponding regulations and standard-setting processes as instruments of innovative context management increase corresponding expectations. Conversely, it can be seen that multiple changes in general political and funding conditions, as in the case of the renewable energy sector and its expansion in recent years, tend to lead to (a wait-and-see) reluctance and also devalue innovation efforts that have already been initiated. The scientific debate whether voluntary entrepreneurial commitments and sustainability reports help to strengthen sustainable innovations is not yet over. However, given that organisations copy each other's rules for action, which are considered legitimate and desirable, concepts of the organisational environment can be inputted into organisational design (institutional isomorphism; DiMaggio and Powell 1983: 150ff.) and help to disseminate sustainability-

focused guidelines (Luks et al. 2007). When it comes to market development strategies, too, besides general recommendations such as the employment of conducive general conditions, financing and risk buffering to address hurdles to market launch and the provision of support for specific target groups during the initial phase, there are no noteworthy findings (Kristof 2010: 75).

3.2 Promoting sustainable transformation processes

A transformational breakthrough in terms of the sustainable development of innovations and societies has to consist of many small and several fundamental transformation steps. In retrospect, both incremental and radical innovations will be found to have been involved, in some cases in response to perceived risks or actual disasters. It is not possible to predict the effects of transformation processes, consisting as they do of direct and indirect, intended and non-intended changes and involving social distortions (Lange 2010). After decades of reticence in addressing design issues from a social science perspective, the targeted and problem-adequate steering of long-term transformation processes and the examination of the futures imagined in the process are receiving an increasing amount of attention (Urry 2016). In this context, questions are arising as to the legitimacy of blueprints for the future, their subjects and objects, the transformation regimes, and concepts of transformation goals and justice from a global perspective (Barnes 2016). Transformation researchers have so far been concerned primarily with the structural barriers to sustainable transformation processes in industrialised Western nations and with practical proposals for promoting and networking such processes, but without problematizing the overarching action and exploitation patterns.

For example, one proposal from the field of transition management is to employ strategic niche management (SNM) to provide four-tiered support to sustainable transformation processes. This is directed not so much at individual companies as at political bodies and critical citizens, and is based on processes of polycentric cooperation. In this context, trajectories of sustainable innovation processes will be supported and stabilised by an anticipatory decision-making process oriented towards long-term goals in a political context, by accompanying articulation of guiding visions of sustainability, by the formation of overarching networks, and by comprehensive training and learning processes (Geels and Schot 2010; Kemp and Lorbach 2006). In addition to the cooperation arrangements required at cross-sectoral level, the importance of participatory approaches and transdisciplinary experiments is highlighted (Schneidewind and Singer-Brodowski 2013; WBGU 2016) in order to open up opportunities for transformation practices, obtain a better understanding of the conditions for their targeted implementation, and take account of the conditions for success in the application contexts from the knowledge-production stage onwards.

Given that success has been very limited despite these strategies for addressing inertia and the unwavering dominance of growth thinking, interest in subversive societal forces and social movements is flourishing once again, for example, with the climate, degrowth and new food movements (Geels 2014; Kropp 2017).

4 Sustainable innovations require sustainable infrastructural restructuring

Humankind today faces major challenges, most of which are being addressed under the headings of climate change, resource scarcity, biodiversity loss and population growth. And then there is the fact of international networking and with it the increase in complexity in all areas of innovation that makes sustainable innovation all the more urgent and at the same time difficult. Even now, innovations are failing not so much due to the lack of necessary ideas and findings, but rather as a result of a "hostile" overall environment. The strict orientation towards sustainability objectives is still associated with an image of craziness, while luxurious and environmentally and socially insensitive lifestyles and business practices continue to enjoy greater social acceptance than their sustainable alternatives. Time and again, three decades of sustainability research have shown that knowledge, awareness-raising, guidelines and models bring about less change than an internalising cost-structuring system and clear regulatory approaches. Only these can create the innovation climate in which sustainable innovations can arise, be developed in a tailored manner and, most of all, be implemented in a targeted way. Additionally, the diffusion effects of sustainable reduction processes need to be cushioned by society and prosperity models developed that still work without permanent growth (Jackson 2013).

In order to generate greater dynamism in sustainably-oriented innovation and transformation processes in the coming decades, the consistent restructuring of unsustainable infrastructure systems would appear to be the most promising approach. Major infrastructure systems such as those supplying water, energy and food fundamentally determine the structures of societal production and consumption processes. As well as shaping options and scope for societal metabolism, they also express and consolidate the underlying identities and natural conditions. Virtually all of the major infrastructural systems were established in the 19th century and are currently undergoing considerable, post-industrial transformation. This is driven equally by new opportunities at information (technology), economic and socio-cultural level, for example, increasing (digital) networking, global liberalisation and changes in typical supplier and consumer roles and requirements. While scarcity of all key resources in today's infrastructures (oil, uranium, soil, metals, etc.) is becoming an increasingly important issue, it is set to become even more relevant to coming generations. It has long been

clear in this context that opportunities for sustainable development will be "largely determined by environmentally and socially responsible infrastructures" (Töpfer 2005: 6; Schaeffer 2005) and only their global generalisability can produce such business models and lifestyles in high-tech societies that are able to facilitate long-term and international coexistence without creating dramatic vulnerabilities. We will only see effective human and environmental networks emerge in the Anthropocene, along with corresponding innovations, if we have infrastructure systems that have a reduction in environmental and resource consumption and harmful emissions built in at material and discourse level, that require and disseminate regenerative solutions and options for equitable participation, and that bring about functional transformation in line with sustainable development imperatives (Bonneuil and Fressoz 2016).

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