The Role of Innovation in a Socio-ecological Transition of the European Union

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Abstract

This paper analyses the role of innovation and innovation policy in a purposive socio-ecological transition of the European Union. More precisely, we ask which kinds of innovation will be required to achieve the aim of a sustainability transition and which kinds of innovation, conversely, will fail to deliver the desired outcomes. While it seems obvious that any such transition will inevitably have to involve a variety of technological, social and systemic innovations, much of the relevant literature exhibits a somewhat uncritical trust in the powers of innovation that needs to be qualified and critically reassessed. The paper analyses three dominant strands of literature, namely the multi-level perspective on socio-technical transitions (MLP), the innovation systems approach (IS) and the long-wave theory of techno-economic paradigm shifts (LWT). All three are epistemologically rooted in evolutionary economics, which provides them with an understanding of social change that is difficult to reconcile with the task of a purposive and goal-oriented transformation of society. This tension, we will argue however, can be quite productive since it protects us, on the one hand, from taking up a voluntaristic and romanticist position that is entirely inebriated by the normative purpose of change, and on the other from a technocratic position that puts unwarranted trust in the powers of progress and market forces. In order to reap the fruits of this productive tension we need to confront the innovation literature with the biophysical reality of the socio-ecological transition of industrial societies from a fossil energy regime to a post-fossil one and recover the political core this transition will have to consist of. The type of innovation most urgently needed for a successful sustainability transition, we argue here, will be of a political and not of a technological kind.

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1. Introduction

The perils of climate change, the rapid loss of biodiversity, the increasing scarcity of natural resources and the impending peak of global oil production have created a far-reaching consensus in Europe and beyond that industrialised societies need to radically transform their economies to become environmentally sustainable and independent of fossil energy. This colossal challenge of the 21st century has been characterised as the need for another *Great Transformation*, comparable to the historical transition from the agrarian to the industrial age (WBGU 2011; Haberl et al. 2011). Analytically, the transition ahead of us can be defined as a socio-ecological transition (SET), that is, a transition between two socio-metabolic regimes (Fischer-Kowalski 2011; Fischer-Kowalski *et al.* 2012). A socio-metabolic regime is 'rooted in the energy system a society depends upon, that is the sources and dominant conversion technologies of energy' (Fischer-Kowalski 2011: 153) and can be characterised by the socio-metabolic profile of the society involved. The current industrial socio-metabolic regime is predominantly driven by *fossil* sources of energy and the corresponding technologies and its socio-metabolic profile is characterised by a high per capita consumption of both energy and materials. The previous agrarian regime, by contrast, was driven by a solar energy system (as in the controlled use of biomass, wind and water power) and characterised by a much lower per capita consumption of energy and materials. The industrialised societies are now purposively striving to embark on a path away from fossil fuels and towards 'other' energy sources. It will also need to involve a lower per capita consumption of materials. In the absence of a *silver bullet* technology on the horizon that provides renewable, sustainable, abundant and cheap energy, however, it looks like this SET will have to turn 'back' to a solar energy regime, albeit on a technologically much more advanced level. This then raises the crucial question whether the highly concentrated and energy-rich 'accumulated sunlight' in fossil fuels can be effectively replaced by 'present sunlight' to an extent that allows for the continuation of industrial civilisation (cf. Haberl and Erb 2006; Haberl *et al*. 2007; Sieferle 2001).

What further complicates the picture is the fact that the incipient 'sustainability transition' is still superseded by another, countervailing SET that currently dominates the global scene: it is frequently overlooked that 'two thirds of the world population are currently within a rapid transition from the agrarian to the industrial regime' (Haberl *et al*. 2011: 1) and thus from a solar to a fossil energy system. While the richest third of humanity is hesitantly (and somewhat reluctantly) embarking on a slow journey towards a more sustainable socio-metabolic regime, the majority of the world population (most notably the so-called emerging economies, such as China, India and

Brazil) is in the middle of a rapid transition towards a high-energy social metabolism driven mainly by fossil fuels. While the metabolic rates of the industrialised countries are stagnating at a high level those of the emerging economies are catching up fast. The result of this twofold SET is that global metabolic rates have been soaring with an accelerating tendency since the turn of the millennium (UNEP 2011; Krausmann *et al.* 2009).

The above considerations suggest that the world will face some kind of SET *in any case* – be it a successfully launched 'sustainability transition' or one that results from the mere exhaustion of the fossil energy regime in combination with the depletion of critical natural resources and the negative effects of environmental pressures like climate change and biodiversity loss (Randers 2012; Turner 2008). While we do not know the exact contours of the SET ahead of us, it seems certain that the status quo of socio-economic development cannot be sustained much longer on a global level. Not only will we run out of cheap energy, but also will we run out of planet, so to speak (Rockström et al. 2009). The crucial question arising from this assumption is to what extent societies can influence whether the inevitable SET ahead will be a *controlled* sustainability transition or an *uncontrolled* transition to a new kind of equilibrium on a lower level of complexity, i.e. some sort of *collapse* (Tainter 2006). The guiding question of this paper is therefore to what extent innovation can contribute to the former type of SET and help avoid the latter.

Innovation and innovation policy doubtlessly play an important role in both the incipient sustainability transition and the on-going industrial transition of emerging economies. But while the prevalent *industrial* transition is driven by the inherent dynamics of a globalising world economy and by the universal quest for economic growth, material prosperity and political regime stability, the incipient *sustainability* transition is driven by *normative* goals that are, to some extent, countervailing these dynamics. Innovation, one might say, has traditionally been at the service of the former project of economic expansion and growth, but has now to be put at the service of the latter (Alkemade *et al*. 2011; Weber and Rohracher 2012). Innovation policy thus needs to become instrumental to transformation policy. The *normative* nature of the sustainability transition furthermore makes it an irreducibly *political* project, whose goals and objectives will always challenge vested interests and remain disputed (Meadowcroft 2009; 2011). It is thus possible that the projected sustainability transition will be less symbiotic with growth-based technological progress and more conflictual and messy than many scholars of environmental innovation seem to recognise. Until now, 'transition and innovation policies are only aligned when they stimulate innovations that contribute to both economic growth and sustainable development', as Alkemade et al. (2011: 126) put it. But it might well be that this smooth coupling of the objectives of sustainable development and economic growth turns out to be illusionary, as long as further growth continues to stimulate further resource consumption and as long as the leakage and rebound effects inherent to efficiency-driven innovations remain unresolved (cf. van den Bergh 2012a, 2012b). We would then have to re-examine the types of innovation that are required to propel a sustainability-transition that is radical enough to effectively shift the trajectory of societal development onto a sustainable terrain. These might be of a different kind than the ones that have hitherto supported the 'ecological modernisation' (Mol *et al.* 2009) of industrialism. Doing things more efficiently might no longer be good enough. Doing things differently altogether might become the main challenge for future innovation.

In this paper we will try to identify some of the challenges innovation policy will need to address when put at the service of a thorough sustainability transition. We will discuss the limits of traditional innovation thinking and propose an analytical framework that might help to elaborate the contours of a 'transformative innovation model' for the transition ahead. In the next section, we will discuss the contributions of three influential strands of literature in the field of environmental innovation and transition studies. These are the multi-level perspective on socio-technical transitions (MLP), the innovation systems approach (IS) and the long-wave theory of techno-economic paradigm shifts (LWT). All three strands of literature are rooted in evolutionary economic theory, which makes them vulnerable to 'naturalising' the market as a selection environment and to neglecting alternative selection mechanisms. Section three will examine the role of technical and social innovation, respectively, for a sustainability transition and discuss opportunities and limitations in these concepts. In section four, finally, we will propose an analytical framework, based on the distinction of so-called 'agentic operators', which will help us systematise our critique and propose a way forward for transformative innovation. Section five will relate our findings to the three "European response strategies" developed in the NEUJOBS deliverables D1.1 and D1.2 (Fischer-Kowalski *et al.* 2012), before Section 6 will conclude with an outlook on an agenda for further research.

2. The multi-level perspective (MLP), innovation systems (IS) and long wave theory (LWT)

2.1 Multi-level perspective

In recent years the multi-level perspective on socio-technical transitions has developed into an influential strand of literature in the field of environmental innovation. The following summary of the theory builds mainly on a recent piece by one of the theory's most eminent proponents, Frank Geels (2011). Combing concepts from evolutionary economics, science and technology studies, structuration theory and neo-institutional theory the MLP builds on an analytical distinction of niches, regimes and landscapes as functionally distinct but interrelated levels that shape the process of socio-technical transitions. Niches are the locus of radical innovation; they are '"protected spaces" such as R&D laboratories, subsidised demonstration projects or small market niches where users have special demands and are willing to support emerging innovations' (Geels 2011: 27). In this perspective, niches 'are crucial for transitions, because they provide the seeds for systemic change'.

Such systemic change can only occur, however, when and if radical innovations manage to pervade and restructure the level of the socio-technical regime. Since transitions are defined in the literature as shifts from one regime to another, this is the crucial level for transition research (ibid. 26). The socio-technical regime forms the 'deep structure' that accounts for the stability of an existing socio-technical system. It 'refers to the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems' (ibid.), such as 'cognitive routines and shared beliefs, capabilities and competences, lifestyles and user practices, favourable institutional arrangements and regulations, and legally binding contracts' (ibid.). The rules of a regime account for the stability and lock-in of a concrete socio-technical system (Geels and Schot 2010: 20).

The landscape level, finally, 'highlights not only the technical and material backdrop that sustains society, but also includes demographical trends, political ideologies, societal values, and macro-economic patterns' (ibid. 28). What defines the landscape level analytically is that it presents 'an external context that actors at niche and regime levels cannot influence in the short run' (ibid.).

A typical pattern of a socio-technical regime transition would be that '(a) niche-innovations build up internal momentum, (b) changes at the landscape level create pressures on the regime, and (c) destabilisation of the regime creates windows of opportunity for niche innovations' (ibid. 29). Historical examples of radical innovations like the automobile show an impressive journey from their start in a niche, through the domination of entire regimes to their structuring of the global socio-technical landscape.

When applied to the sustainability transition the argument goes that changes on the landscape level like scientific evidence of the dangers of anthropogenic climate change, increasing depletion of critical natural resources and the rise of the oil price as a sign of an impending peak of oil production start destabilising the socio-technical regimes of advanced industrial societies, thus opening up windows of opportunities for radical innovations that promise solutions for some of these problems. The main task from the multi-level perspective is then to *manage* the all-important interaction between niches and regimes in a purposive and goal-oriented way. To support a sustainability transition means to help radical environmental innovations get off the ground in niches and pervade the socio-technical regimes. In order to do so these innovations must break established rules and structures in the regimes, which lock them into their current state. The purposive management of the interaction of niches and regimes has become a central concern within the MLP literature, and led to the development of specific sub-strands like that of Transition Management (TM) (Rotmans and Loorbach 2010) and Strategic Niche Management (SNM) (Kemp *et al.* 1998).

Drawing on evolutionary economics, the MLP and its transition management variants apply the Darwinian concepts of variation, selection and retention to the socio-technical evolution of modern societies. Regimes are conceived both as *retention* structures and *selection* environments for innovations (*variation*) (Geels and Schot 2010; Smith and Raven 2012). In their capacity as selection environments for innovative variants regimes comprise a number of structural features that work as selection mechanisms: market mechanisms and dominant user practices, established industry structures, dominant technologies and infrastructures, socio-cognitive processes in the established knowledge-base, public policies and political power as well as the cultural significance of specific regimes have all been mentioned as important structures involved in processes of retention and selection. (Smith and Raven 2012). The aim of transition (and strategic niche) management now is to introduce a certain measure of agency into these processes. Whereas variation in capitalist market environments is usually driven by the profit motive (i.e. by firms' interest to survive in the market and, ideally, to grow; see Perez 1983), the aim is now to introduce 'directed variation' that is not only driven by market interests but also by other (sustainability-related) intentions (Geels and Schot 2010: 38).

The strategic focus within the transition literature is clearly on equipping niches with directional agency and to protect them from mainstream selection pressures. While regimes are understood as complex and stable environments that cannot be changed easily, niches are the locations where the seeds of change can be nurtured and where change can be prepared and planned strategically. Smith and Raven (2012) point out that agency in niche protection involves processes of shielding the niche from mainstream selection pressures, of nurturing path-breaking innovations in protective spaces and of empowering such innovations to be selected by the regime to become mainstream or even to 'institutionalise niche practices within a reformed regime' (ibid. 1030). Elzen *et al.* propose the concept of 'anchoring' to describe activities to create 'new connections between a novelty and its environment' (2012: 4) so as to help the innovation get off the ground and leave the protective space of the niche.

The focus on niches and protected variation within the MLP literature is comprehensible, as it cautions against a too voluntarist perspective that assumes the possibility of deliberately changing entire regimes at will. At the same time, however, this focus on niches and niche actors glosses over the fact that the main problem in a sustainability transition might not be the ready availability of innovation and ingenuity to develop new solutions, but the very mechanism of selection that lock in the status quo and retain incumbent structures and technologies. The MLP tries to address this problem by encouraging forms of agency that enhance the chances of selection for path-breaking innovation, but it tends to do so by proposing ways of making these innovations more 'competitive' within the existing selection environment. This strategy, however, is in danger of reproducing the lock-in it attempts to overcome in that it accepts the existing selection mechanisms of the market, of consumer choice and of incumbent socio-technical structures as the legitimate and appropriate forces to drive disruptive, transformative and radical change.

What this perspective neglects, then, is the fact that the evolutionary dynamics of modern industrialism, which serve as the epistemological foundation of the MLP, could only unfold in an environment that was characterised by an expansive (fossil) energy regime. The entire 'evolution' of modern economy has been the evolution of the fossil energy regime and was based on the availability of ever increasing quantities of cheap, concentrated and abundant energy. The selection mechanisms at work were and are geared towards further expansion and growth of the system. When left to the evolutionary dynamics that were unleashed some 250 years ago, it is not hard to predict that the system will tend to use up all the available energy it can find until it runs into the landscape pressures of resource shortages and severe environmental degradation. This is just another way of saying that it is not very likely that normative societal purposes like a sustainability transition will not stand a good chance of being favoured by selection mechanisms that do not account for normative criteria. Put differently still, it means that it might be more important to focus on innovating the selection mechanisms of modern societies and to equip them with normative and 'sustainable' selection criteria than to focus on getting sustainable innovations selected by unsustainable selection environments. This, of course, means that the main task in a sustainability transition is about politics and not about technology.

We thus suggest focusing on 'selection' instead of 'variation' and on regimes instead of niches. This is not because variation or niches are unimportant, but because as soon as the selection mechanisms in place started accounting for *normative* goals like a sustainability transition there would be no lack of productive niches producing plenty of innovative variation. The *strategically* most important operation is selection, not variation. When the selection mechanisms are favourable, the required variation comes all by itself. In a way, then, our critique of the MLP and other evolutionary approaches to innovation is that as long as we subject change entirely to the mechanisms of an evolutionary process that is itself based on unsustainable grounds (namely a fossil energy regime), we will only help an unsustainable system become more efficient and thus expand its unsustainable lifespan (see the discussion of macro-economic rebound and other problems of technological innovation in the next section), but we will do little to bring forward those radical forms of change that are required in a sustainable SET. A sustainability transition, however, being a *normative* project, requires innovations that help *cut off* or *suspend* the very dynamics of socio-technical evolution in order to shift societal development onto a radically new trajectory. New selection mechanisms need to be developed that help modern societies to *emancipate* themselves from a socio-technical evolution that is tied to an unsustainable energy regime. In section four we will propose an analytical framework that could help innovation research to re-focus on mechanisms of selection and on regime-change rather than niche-protection.

2.2 *Innovation Systems*

Another influential strand of innovation research is the innovation system (IS) approach. Rooted in evolutionary economic theorizing, it was developed as a policy concept in the mid-1980s (Freeman 1987; Lundvall 1992; Carlsson and Stankiewicz, 1995; Edquist 1997). In contradistinction to the MLP, the IS approach does not focus on the interaction between different levels of socio-technical emergence, but on the interaction of actors, networks and institutions in steering and influencing innovation dynamics. According to Jacobsson and Bergek (2011: 45), innovation systems are composed of a set of structural elements: actors in the whole supply chain, networks, institutions, and, in some approaches, technology (see also Markard and Truffer 2008: 599). While actors can be individuals or organisations (private firms or sub-firm units, governmental and non-governmental agencies, universities, research facilities, banks, associations, etc.), institutions are conceived along the lines of neo-institutional theory like in the MLP as formal and informal rules, 'comprising laws and regulations, socio-cultural as well as technical norms, shared expectations, etc.' (Markard and Truffer 2008: 598). Over the years, different types of innovation systems were analytically distinguished and conceptualised, including national innovation systems (NIS), sectoral innovation systems (SIS), regional innovation systems (RIS) and technological innovation systems (TIS) (Jacobsson and Bergek 2011: 42).

According to Jacobsson and Bergek (2011: 42), '[t]he key contribution of innovation system analyses to the study of sustainability transitions is […] that it provides policy makers with a tool for identifying system weaknesses. It promises, therefore, to inform policy makers of the problems that an intervention needs to solve in order to promote the growth of a particular system or to influence its direction'. There is no consensus in the literature on how to assess the performance of an innovation system but commonly proposed indicators of success are the diffusion of the innovative technology or product under study, the generation and diffusion of knowledge or the creation of new markets (Markard and Truffer 2008). With respect to sustainability transitions the most productive approach within the innovation systems literature so far has been the technological innovation systems (TIS) approach, which focuses on the development and diffusion of *specific* technologies, rather than on the general conditions of innovation in nations, regions or industry sectors.

Within the TIS approach, Jacobsson and Bergek (2011) have defined a set of system functions that support the overall 'goal' of the system, i.e. 'the development, diffusion and utilisation of new technologies' (46). These functions are knowledge development and diffusion, entrepreneurial experimentation, influence on the direction of search, resource mobilisation, market formation, creation of legitimacy and the development of positive externalities (e.g. knowledge generated or investments made by one firm that benefit other firms 'free of charge' and therefore strengthen the entire TIS) (ibid. 47; for similar sets of functions have been defined, e.g., by Hekkert et al. 2007 and Chaminade and Edquist 2005). The more of these functions are performing well, the more successful a TIS will be. The purpose of TIS analysis, then, is to analyse possible system weakness pertaining to one or more of these functions. In most cases such weaknesses are the result of the misalignment of system components in the sense that certain structures of the system, for example, hinder actors at co-operating and thus at diffusing knowledge, or in that the institutional preconditions for entrepreneurial experimentation are lacking. Institutional frame conditions such as funding schemes or research frameworks heavily influence the direction of search for new technological solutions and can potentially lead a TIS into a dead end. Similarly there is a range of institutional or organisational conditions for successful (human and financial) resource mobilisation and market formation. In the absence of a specific regulatory framework, for example, a new technology will have severe difficulties developing a market or attracting human and financial capital. Similarly, a range of institutional, actor-specific and organisational conditions have to be met in order for a new technology to be provided with the political and cultural legitimacy to be diffused successfully. Jacobsson and Bergek (2011) give a host of examples for the role of functions in concrete TIS and for system weaknesses pertaining to them.

In sum, the IS approach looks at the actors and institutions of specific innovation systems with goal of identifying points of policy intervention that would help enhance the overall performance of the system. The focus of the IS approach is thus on the politics (the socio-institutional setting) of innovation rather than on the economics of innovation in a strict sense. This, of course, makes it a very interesting approach in terms of addressing the purposive, normative and goal-oriented nature of sustainability transitions. Since such transitions are widely believed to depend on the development, diffusion and comprehensive use of radical environmental innovations, the IS approach can help identify the points of intervention necessary to stimulate and support the success of such technologies. This being said, however, the approach arguably suffers from similar constraints as the MLP as it grounds its entire ontology in a *particular* evolutionary process (based on *particular* selection mechanisms) that it assumes as 'given'. While there are good reasons to describe the history of socio-technological development (at least since the inception of the fossil energy regime) in these terms, it is questionable whether its future is to be conceptualised within the *same* evolutionary dynamics that have characterised its past. If societies and their political systems leave the development, diffusion and use of radically new technologies to the internal forces of markets, consumer choice (and thus personal utility) and investment opportunities, a whole sector of alternative trajectories is excluded from becoming realised. This sector (or option space) is one that can only be tapped by other than the selection mechanisms that have hitherto dominated the evolution of technology. And these other selection mechanisms have to be socially and politically *constructed*, if they are to play a role in future developments. It is therefore expedient to note that while both the MLP and the IS approach are productive and fruitful approaches in analysing past and current innovation dynamics without any normative pressure for radical change, they might not be equipped with the analytical tools to guide a radical, purposive transition such as the sustainability transition to a post-fossil energy regime. These tools, we argue here, need to be developed and incorporated into evolutionary approaches to socio-technical change.

2.3 Long wave theory – a sustainable 6th Kondratiev?

The theory of long waves or techno-economic paradigms (TEPs) is the third approach to innovation thinking we want to discuss here. It combines the theory of long waves of economic development put forward most prominently by Nikolai Kondratiev (1935; 1998) with the evolutionary economic theory of Joseph Schumpeter that posits radical technological innovation as the 'single root cause of the cyclical behaviour of the capitalist economy' (Perez 1983: 359). Thus, Kondratiev-waves are conceptualised as a succession of techno-economic paradigms, each based on a decisive technological innovation (like the steam engine, the automobile or microelectronics), a core input (e.g. coal, oil or silicon microchips) and a carrier branch that drives the development (like railways, automobiles or the computer industry). Five such long waves or TEPs have shaped capitalist development since the Industrial Revolution at the end of the 18th century. The first was based on the water-powered mechanisation of industry and on the iron industry and started in the 1770s. The second was based on the steam engine and the steam-powered mechanisation of industry and transport, dating back to the 1830s. The third was based on the electrification of industry, transport and the home and started in the 1870s. The fourth TEP was based on the motorisation of society, with the key innovation being Ford's assembly line and Model-T automobile from 1914. The fifth and current TEP, finally, is based on microelectronics and started in the 1970s (cf. Freeman and Louçã 2001; Perez 1983, Kattel et al. 2011).

The succession of TEPs transforms societies economically and technologically in that it leads to extended phases of economic growth but also to socio-economic crises of 'creative destruction'. Typically, the new wave emerges out of the crisis of the old: as profit rates decline in the application of the incumbent paradigm, more and more 'idle' capital is invested in new technologies that promise greater potential for future profits. In socio-economic terms, however, the greatest disruptions occur when a new TEP is in its explosive growth phase competing fiercely with the established paradigm. It is the phase where investment bubbles in the new TEP occur, leading to great financial crises, and where societies have to adapt institutionally and organisationally to the new paradigm (reacting to new forms of employment, new industries, the destruction of old industries and infrastructures and concomitant political changes). After this turbulent phase, the new TEP will continue to grow, promising a short period of sustained growth that Perez (2002) calls the 'Golden Age' of a TEP.

The study of TEPs is interesting for scholars of socio-ecological transitions for several reasons: Firstly, if the theory is a valid interpretation of capitalist development, it offers opportunities for ex-ante analyses of long-term socio-technical change in that 'the recurring features of Kondratiev waves can be used to extrapolate forward to possible future waves' (Köhler 2012: 11). An interesting question, from a SET perspective is, then, which new technologies might qualify for constituting the next TEP and what contribution to a sustainability transition they could offer. Secondly, if a sustainability transition is our normative goal, the role of purposive agency in steering a TEP or in deciding which technology will dominate the next half century or so is decisive: can long waves be influenced or even 'managed' in a directional and purposive way? Or are modern societies exposed to an evolutionary dynamic that is, more or less, beyond their control? The third and perhaps most important issue, however, regards the energetic basis of the long waves and the question whether a 'post-fossil' energy regime could sustain a sixth wave of capitalist development at all.

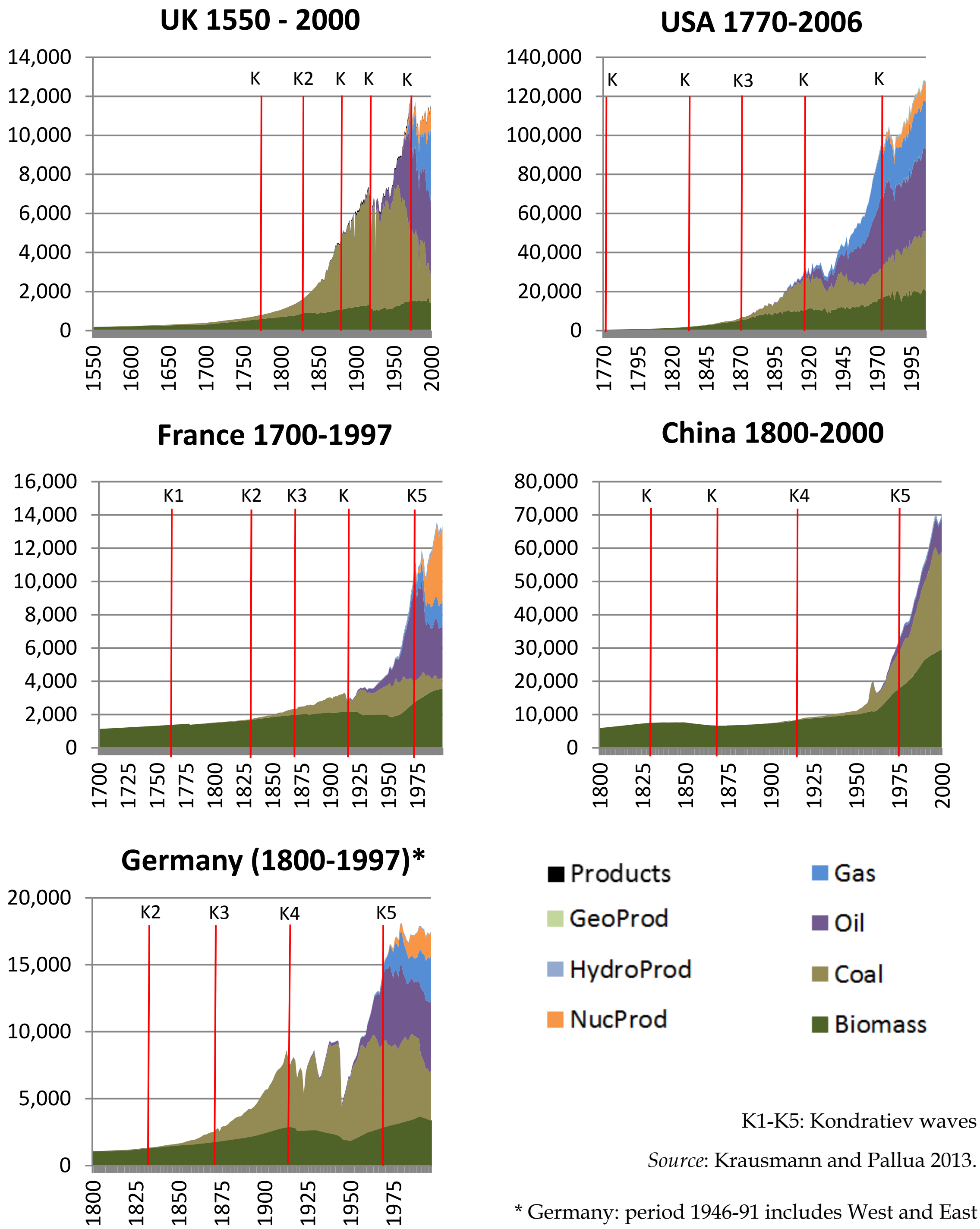
With regard to the forecasting of the next long wave, most literature regards biotechnology and nanotechnology to be the 'hottest' candidates for the role of key technologies and sees further potential in the development of information technologies (cf. Dewick et al. 2004; Dewick et al. 2006; Green et al. 2002; Drechsler 2011). To what extent these technologies have the potential to carry the burden of a sustainability transition is, for obvious reasons, difficult to establish. Dewick et al. (2004) offer an ambiguous, yet slightly optimistic outlook on these technologies: They argue that on the one hand, the most significant sectors in terms of greenhouse gas emissions are 'likely to see increased sectoral output as a result of developments in the manipulation of organisms, information and materials' (2004: 290). Nevertheless, the same technologies 'will also increase the resource efficiency of these sectors, probably by a higher magnitude, the net effect of which will be a reduction in greenhouse gas emissions' (ibid.). If the net effect of these new technologies will indeed be energy-saving, the main question then would be whether the expected gains in energy efficiency will be enough to de-carbonise the entire economy, that is, to stimulate and lead a wholesale SET. A possible alternative scenario is that the new TEP would indeed establish new standards of efficient production that stimulate a new wave of capitalist growth, but that this growth would 'eat up' the energy savings due to macro-economic rebound effects (see discussion below). Hence, it seems difficult to assess the chances of a purposive sustainability transition through the prism of the TEP framework alone. In any case, it seems, political steering and decision-making will have to play an eminent role if the next TEP were to be a 'sustainable' one.

But it is precisely the question of political agency that the TEP framework is somewhat ill-equipped to address. For the TEP framework, technology is the moving force behind development, and it is difficult to influence or forecast future inventions and discoveries. The ontology of the TEP framework grants explanatory priority to the 'landscape level', to use the MLP terminology, whereas 'niches' and even 'regimes' are of secondary importance. Consequently, Geels and Schot (2010: 17) admonish that long-wave theory is 'too much focused on the macro-environment of socio-technical systems […] and does not provide many insights into how these transitions happen'. Similarly, Köhler contends that in the neo-Schumpeterian perspective of long waves '[t]here is no explicit treatment of agency and this means that there is no theoretical basis for proposing ways in which society can influence the development of a Kondratiev wave' (2012: 13). However, proponents of the TEP framework seem to be aware of this shortcoming and propose to put the question of agency centre-stage on the research agenda. Thus, Kattel *et al.* (2011: 15) regard the interplay of governance structures with technological development in long-term evolutionary processes to become 'one of the fundamental issues' for shaping the next techno-economic paradigm. More concretely, they ask whether it is possible 'to steer the development of technology into ethically more desirable directions, i.e., change the frame of reference proactively' (ibid. 15-16). Despite these ambitions to extend long-wave research into the realm of political agency and techno-political governance, the methodological repertoire for doing so seems to be limited to those approaches that have been discussed above, namely the IS and MLP frameworks. One of the leading scholars in the long wave camp, Chris Freeman, for instance, is also a prominent figure in the IS approach, having introduced the concept of National Innovation Systems (NIS) in the 1980s (Freeman 1987). Just how much scope there is for applying the IS approach to the analysis of purposive change in TEPs is a question that future research will address. Other scholars, like Jonathan Köhler (2012), argue for a cross-fertilisation between the MLP and TEP frameworks in that 'agency in the niche-regime interactions emphasised by the MLP could be used to extend the analysis of Kondratiev waves', while the TEP framework could 'contribute to the consideration of landscape dynamics in the MLP' (2012: 1). The shortcomings of both approaches (IS and MLP) with regard to addressing the fundamentally normative challenges of a purposive SET were discussed above and it remains to add that if the TEP approach wants to avoid the same problems it should not adopt these approaches without major revisions of their evolutionary conceptions of political agency.

The third and perhaps most important issue we want to address with respect to the TEP approach is the question whether a future low-carbon Kondratiev wave is a plausible scenario at all. While Kondratiev waves or TEPs represent cyclical patterns of innovation, economic growth and socio-economic crisis, the historical metabolic profile of the five historic waves so far shows the pattern of an upwards spiral. Thus, these waves have shown cumulative metabolic rates, which means that each wave added further energy and material consumption to the previous one. As Köhler (2012: 6) points out, 'the first four waves were based around intensified use of energy resources, which increased pollution through new industrial activity'. Similarly, Pearson and Foxon (2012: 125) point to the fact that previous industrial revolutions were '*high carbon* industrial revolutions: […] their success was built on the exploitation, largely unconstrained by environmental or other regulatory concerns, of fossil fuel stocks that freed the economy from constraints it would otherwise have faced'.

Hence, the first wave started with the massive use of coal for iron smelting and heating. The second wave, based on the steam engine, added further massive coal consumption. The electrification of society in the third wave and the introduction of high-quality steel did not reduce the use of coal but added further uses for it, including the generation of electric power. Only the fourth wave offered an alternative to the steam engine by introducing the oil-operated automobile. While fossil oil supplanted the use of coal to a certain extent, however, the new key technology and associated production style added a huge surge in energy consumption by introducing modern consumer society. A stabilisation of per capita domestic energy consumption (DEC) in the most advanced industrialised countries on a very high level can only be observed in the current fifth Kondratiev. *Figure 1* shows the domestic energy consumption of selected countries through all five Kondratiev waves.

Figure 1. Domestic Energy Consumption (DEC) in selected countries in Petajoule (PJ) for the longest time period available



K1-K5: Kondratiev waves

Source: Krausmann and Pallua 2013.

* Germany: period 1946-91 includes West and East

The particularly steep rise in the DEC of China is suggestive and newest data (not represented in the figure) for the years after 2000 suggest that a stabilisation is nowhere in sight due to the continued coal-fired expansion of the Chinese economy. Within this sample of countries, France is the only one that significantly reduced its reliance on fossil sources of energy, notably by replacing them to some degree by another non-renewable source of energy - nuclear power.

What these figures draw attention to is the fact that the entire phenomenon of Kondratiev waves (and thus evolutionary economic development) is one that exclusively occurred *within* the fossil energy regime. The first wave starts in the 1770s in Britain, heralding the age of coal. And while the latest wave does not seem to add further to the (per capita) energy consumption in the most advanced industrialised countries, it is based on a record level that would have been unimaginable only 40 years ago. Two important questions follow from this:

First, can a new TEP be envisaged that de-carbonises (by virtue of its technology-inherent properties) not only the new segment of growth industries which it adds to the inherited structure but the *entire* economy? The energy consumption in the Fifth Kondratiev, at least, does not suggest as much, since all it achieved so far in this respect is a stabilisation but not an effective reduction in per capita energy consumption. And, relatedly, can such a new, sustainable TEP be expected to not only decarbonise the legacy of its predecessors but also *add* a further wave of capitalist *growth and expansion*? It is of course difficult to make predictions about these questions but with the metabolic profiles of the hitherto Kondratievs in mind, which were all based mainly on cheap fossil energy, it is difficult to imagine that any technological innovation within reach today (ICT, biotechnology, nanotechnology) could help decarbonise the entire economy *and* add further growth to the system. The only exception, perhaps, would be a so-called *silver bullet* technology that would add cheap and abundant energy to the system that is at the same time carbon-neutral and renewable.

These considerations are important when contemplating the possibility of a *low-carbon industrial revolution*, as would be necessary for a sustainable next Kondratiev wave. As Pearson and Foxon (2012) point out, such a prospect faces a range of serious challenges. Firstly, while the low-carbon technologies within reach today are good at helping decarbonise the existing economy in that they substitute 'green' alternatives for unsustainable ones, 'they do not offer significant private benefits to users beyond the social benefits of lower carbon emissions' (2012: 125). *Green* electricity, for example, is not better at powering our gadgets and appliances than *grey* (fossil) electricity – it is just environmentally more sustainable. What is worse, it is more expensive and therefore even less attractive from the perspective of private utility. Hence, most low-carbon technologies today help save materials and energy but will, by themselves, not contribute to a next long wave, which would require a radical expansion of economic activity and new levels of consumption. If current low-carbon technologies stimulate growth, it is via macro-economic rebound effects, which means that they help save energy (and thus stabilise energy prices) which is then invested in more economic growth elsewhere. Any new key technology offering additional private user benefits and thus stimulating a new growth cycle in capitalist development, by contrast, would almost necessarily add further energy and material consumption (although conceivably on a very high level of energy efficiency). This would obviously counteract the objectives of societal de-carbonisation. Hence, the vision of a low-carbon Kondratiev (understood as another cycle of capitalist *expansion*) is facing a double challenge: to offer technologies to de-carbonise the existing economic system (the legacy of the first five Kondratievs) without destroying its level of consumption and productivity *and* to offer technologies to create *another* cycle of economic growth and expansion without adding further carbon to the atmosphere.

In the face of these challenges, Pearson and Foxon warn that 'there has been a tendency to neglect or misunderstand the role that the availability of cheap, high quality, carbon intensive energy sources has played in the co-evolutionary developments in technologies, related institutions and business strategies that have underlain the unprecedented economic growth and creation of wealth in Western countries over the past 250 years' (2012: 125). As a consequence they suggest that 'for the low carbon transition to really "work", it may prove necessary to transform our energy and related systems and institutions in more profound ways than we have yet acknowledged' (ibid.). In other words: a new techno-economic paradigm alone may not do.

The discussion of the three dominant paradigms in innovation studies so far has revealed severe limitations of evolutionary economic theory to adequately capture and respond to the challenges of a sustainability transition. These limitations, however, are not inherent to evolutionary theory as such, but are resulting from its specific application to economic theory. The problem is the level at which the selection environment for processes of innovation is conceptually defined. In economics, the market obviously constitutes a 'natural' selection environment for product innovation. This is all well as long as the only thing that interests the analyst is the economy itself (as an abstract model based on monetary values) and not its relation to the *natural* environment. As soon as we are talking about a SET, however, we have to include the biophysical world and its limitations into the analysis, which constitutes the ultimately much more relevant selection environment. Put differently, climate change or the depletion of oil will be powerful selection mechanisms once they become relevant parts of our reality. The market, on the other hand, cannot anticipate this reality and therefore ignores it: as long as there is oil, it will be burnt; as long as the climate is favourable to economic growth it will not be spared. The market itself does not have any mechanisms to 'internalise' these biophysical 'externalities' before they enter the market in the form of scarcity.[1] But this is just another way of saying that the market as

[1] The emergence of ecological economics as a discipline has been based precisely on the critique of the substantive failures of orthodox economics in addressing the biophysical foundations of reality (see e.g. Spash 2012; Røpke 2004; Røpke 2005). Markets are often alleged to 'fail' at 'internalising externalities', that is, at integrating the biophysical long-term interest of humanity into their mechanisms of pricing. This argument, however, presumes that a 'healthy' or 'functioning' market would be able to internalise all relevant externalities and that 'market failure' is a pathology of an otherwise perfect mechanism for which there are remedies. We contend this view and argue that it is the very nature of markets to neglect their environment. Put in systems theoretical terms, markets are autopoietic and therefore functionally autonomous subsystems of society that resonate with their environment (they react to changes in demand and supply) but are not causally determined by it (Maturana and Varela 1975; Luhmann 1986): there is no causal mechanism that translates the complexity of the environment into the operations of the market. Instead, the price system is the prime example of a mechanism for complexity reduction reacting only to the binary impulse of demand and supply, eclipsing the complex reality behind it. This means that markets will react to a changed environment (fuel scarcity, other forms of scarcity as a consequence of climate change), but are functionally unable to anticipate these changes or to prevent them. This, we insist, is the domain of politics, that is, of a subsystem that is guided by normative reasoning, and not of markets. Hence there is no failure of markets, as markets cannot be burdened with the foresight and judgement that is the functional domain of politics. The conceptual difference is that in the 'market failure' approach, everything could in principle be coordinated by markets given that they are made to 'work', whereas in our reading, markets are good at coordinating economic

(the only) selection environment for environmental innovation is a sure way to run into an uncontrolled SET that might take the form of collapse. The consequence of this is that we need a socially constructed, purposively designed set of selection mechanisms that manage to pre-empt the external selective pressures that the biophysical constraints will impose on us once we hit them. Evolutionary theorist Donald Campbell has coined the term 'internal selection' to describe 'selections on the dynamics (behavioural, developmental, or evolutionary) of a system or a kind of system that arise from internal conditions and activities of the system' (Bickhard and Campbell 2003: 242). If internal selection is possible, what is required, then, is the systemic anticipation of external selection pressures (biophysical constraints) and their consequent representation in internal selection systems (*cf. ibid*: 229; Campbell 1965). The anticipatory part is what climate and environmental science have been doing for decades and there exist effective and efficient structures and institutions like universities, the IPCC, UN bodies etc. for this purpose. The more problematic task is the design and implementation of internal selection systems that function as representatives of the anticipated external selectors, since this is a genuinely political task and one that involves the purposive disruption of otherwise smooth processes of market selection. But it is precisely this disruptive task of the internal representation of future external selection pressures which will make the difference between a sustainability transition and a forced transition towards collapse. Constructing and implementing the institutions necessary to set up that kind of internal selection system, however may require systemic and institutional innovations of an unprecedented scale. While technological innovation will continue to play an important role in greening industrialised economies the types of innovation most likely to influence the direction of the coming SET will be of institutional, systemic and structural types and therefore 'social' in nature. A discussion of technological and social innovation is therefore our next task.

3. Technological and Social Innovation

The mainstream of environmental innovation literature today (including the MLP, IS and LWT approaches discussed above) is firmly embedded in the paradigm of 'ecological modernisation' (as reflected in the 'European response scenario 2' of the NEUJOBS report on Socio-Ecological Transitions [Fischer-Kowalski *et al*. 2012: 76]) which focuses on technological and managerial solutions within a rather linear trajectory of economic development involving mainly incremental forms of change (cf. von Weizsäcker et al. 2009; Spaargaren and Mol 2009; Jänicke and Lindemann 2010). The main thrust within this paradigm is directed towards the idea of 'de-materialising' the economy by gradually improving its resource efficiency to the extent of radically 'de-coupling' economic development from energy and material input (UNEP 2011; EC 2011; BIOIS 2012; Schmidt-Bleek 2008). That way, it is hoped, the growth-based market

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exchange whereas the normative contours of reality have to be shaped by politics. Hence our contention that it would not be a *market failure* if markets were to burn every barrel of oil that is still to be found, but rather a fundamental *failure of politics* in controlling markets. To be sure, this view does not preclude the use of market mechanisms to attain politically defined ends (like cap and trade regimes), but these markets are recognised as political constructs whose aim it is precisely to keep markets from doing what they would *naturally* do (ignore their environment).

economy that has been dominating the fossil age can be preserved for the future. Environmental innovation, within this dominant paradigm, is mainly conceived of as technological innovation (Huber 2004). While there should be no doubt that technological innovation will continue to play an important role in any future development, its prominent position at the centre of environmental political discourse, however, is increasingly being challenged.

3.1 The limits of technological innovation

Van den Bergh (2012b) mentions a range of 'innovation leakages', most notably rebound and 'green paradox' effects, which constitute severe limitations to the role technological innovation can play in solving environmental and climate problems. Rebound effects occur when efficiency improvements release resources (energy, time, money, etc.) that are then used to increase consumption and economic activity, thereby (over-) compensating the efficiency gains. In a growth-based economy, efficiency gains are used to stimulate further growth until the saved factor reaches another constraining limit (so-called macro-economic rebound, Barker *et al.* 2007). Hence, efficiency gains tend not to reduce the overall use of resources but fulfil the function of relieving scarcity constraints. The economy will, according to this logic, always approach these constraints asymptotically since it will tend to use up resources that are released by efficiency improvements in order to achieve further growth. Within the logic of growth, the increased efficiency of general purpose technologies 'will stimulate their diffusion to new activities, sectors and applications' (2012: 5), hence leading to a rapid proliferation of instances of energy and material use (witness the multiplication of electric household appliances and 'gadgets'). The so-called 'green paradox' (Sinn 2012) describes a similar effect: Here, the conservation of energy in an unregulated market helps depress the price of energy which, in turn, stimulates its consumption. This problem is particularly pertinent in a global context, where it is called (carbon) 'leakage': conservation efforts or voluntary frugality in one part of the world would release (material *and* monetary) resources that would be consumed/spent in other parts of the world (Alcott 2008). The size of innovation leakages may of course vary by sector, region and product and is hard to quantify overall. Certain leakage effects are contested: for example, car owners might not drive more simply because their new car is more fuel-efficient (Gillingham *et al*. 2013). However, they might invest the money they saved in fuel in other products that cause additional GHG emissions, and the decrease in fuel-demand will relax prices which will in turn stimulate new demand and delay investment in alternatives. Hence, it is fair to argue that innovation leakages are particularly relevant as a macro-economic phenomenon in a growth-based system, as they stimulate new growth and new demand. Only in a (hypothetical) growth-less system would efficiency gains be realised without significant leakage effects.[2]

[2] In actual fact, massive efficiency gains have been steadily realised in industrial economies for the last hundred years or more and have been a pre-condition of economic growth (in terms of increasing labour productivity and energy productivity per unit of output). It is hard to see how this natural tendency of capitalist development should now lead to anything other than further economic growth, just as it has done in the past. 'Decarbonisation' per unit of output has thus been a normal pattern of development in many industry sectors but has been more than offset by the economic growth it triggered.

Another problem environmental innovations on the product level have to face is that 'they are usually factor-saving (in the factor energy) rather than quality-improving. This means there is no observable difference in the functionality of alternative technologies for consumers – witness "green and grey" electricity' (van den Bergh 2012b: 2; see also the discussion above as well as Pearson and Foxon 2012; Geels 2011: 25).We would add that adopting alternative technologies for their environmental (social) benefit rather than for their utility (private benefit) presupposes an ethical commitment and often an extra budget. Hence, alternative technologies or production styles (like organic agriculture) are often tailored for a relatively wealthy, highly educated and ethically 'aware' niche of Western consumers.[3] At the same time (and often by the same companies) the large majority of the market is continued to be supplied with products and technologies that satisfy private utility and constrained budgets (witness the niche for expensive recycled paper and the mass of cheap virgin fibre paper provided by the same companies). This phenomenon reflects a societal tendency (not only) in the global North to sustain unsustainable consumption patterns due to the sustained preference of private utility over social benefits in consumer choices (Blühdorn 2007a, b). This, as will be further discussed below, has to do with a particular misconception of contemporary 'consumer politics' that involves the overburdening of the consumer with the tasks of the citizen, or, to use Jon Elster's terminology, the 'confusion between the kind of behaviour that is appropriate in the marketplace and that which is appropriate in the forum [i.e. politics]' (Elster 1997: 10). This, of course, is a political problem with complex ideological implications that involve questions of power and questions concerning the control over social steering mechanisms. Innovation, we need to acknowledge, is not an innocent term that can be restricted to the art of engineering and the laboratory. There are many indications that the innovations modern societies will need to implement the 'sustainability transformation' described in the NEUJOBS European Response Scenario 3 (Fischer-Kowalski et al. 2012: 77) , will concern precisely these mechanisms of societal steering – and hence they will involve the question of how to organise politics and power struggles. The cautious way of putting this is that 'the major part of the reduction of greenhouse gas emissions in the coming decades is unlikely to be realized through technological innovation. Instead, it will come from environmental regulation that alters consumer and producer decisions about environmentally relevant inputs and outputs' (van den Bergh 2012b: 3). The less cautious way of putting it is that effective environmental innovation will be about politics first, and then about technology.

[3] One might argue, though, that the larger a share of the available income is spent on sustainable goods, the smaller a share remains to be spent on unsustainable goods. That way, the expensive eco-products have a limiting effect on the available budget for polluting products. The problem with this argument is, however, that the fact that eco-products are expensive means that only a wealthy minority can afford them and this minority usually only spends a fraction of their budget on them that does not 'hurt'. The implication is that the budgetary substitution effect is rather weak as it pertains only to a small portion of the population and to a small portion of their budget. The effect could of course be widely enhanced if eco-products would substitute their unsustainable alternatives without leaving a choice for consumers. The side-effect would conceivably be a reduction in overall spending power and a crisis of the growth-based economy.

3.2 How to achieve structural innovation?

The types of innovation primarily required for a sustainability transition are thus of 'social' nature in that they concern the ways societies organise processes of production, consumption, distribution and economic and political steering. Westley and Antadze (2010: 2) define 'social innovation' accordingly as 'a complex process of introducing new products, processes or programs that profoundly change the basic routines, resource and authority flows, or beliefs of the social system in which the innovation occurs'. Crucially, social innovations 'challenge the system that created the problem that they seek to address' (2010: 15). Thus, a social innovation that has a 'broad and durable impact […] will be *disruptive and catalytic* […]; it will challenge the social system and social institutions that govern people's conduct by affecting the fundamental distribution of power and resources' (2010: 3).

But how are these disruptive innovations that challenge the structures of society at the system level envisaged to come about? What should they consist of? And who should be their agents? Interestingly, much of the innovation literature relies on rather conventional answers to these crucial questions, in that it puts its hopes in so-called 'social entrepreneurs', 'institutional entrepreneurs' and 'change agents', which points again to the tendency in innovation research to rely on an evolutionary framework within which innovation occurs in certain niche activities and is carried out by niche actors, whose efforts may or may not spill over to higher levels of social organisation. While social entrepreneurs are 'the individuals who initiate or create innovative programs, products, or processes and seek to build an initial organisation that can bring that innovation to market' (Westley and Antadze 2010: 13), institutional entrepreneurs are 'those individuals or networks of individuals who actively seek to change the broader social system through changing the political, economic, legal, or cultural institutions, in order that the social innovation can flourish' (2010: 14). Both types of actors are also referred to as 'change agents': According to a recent flagship report by the German Advisory Council on Global Change (WBGU), these change agents 'propagate innovations by questioning "business as usual" policies and creating alternative practices, thereby challenging the established world views and paths, attitudinal and behavioural patterns, as well as providing others who think as they do (followers, early adopters) with a constant motivation for a self-sustaining change' (WBGU 2011: 243). Agency is thus understood in a systemic way to spread its effect from one scale or level to the next, depending on opportunities and resources, alliances and circumstances. Agency for change is again conceptualised as being embedded in and dependent from evolutionary processes of selection, variation and retention – starting from within niches and diffusing across scales. And once again these evolutionary approaches to social innovation rely on the market as the central selection mechanism, or at least as the central metaphor organising their understanding of change and agency (witness the prominence of the term 'entrepreneur' in agency for change). This might be due to the fact that the entire field of innovation studies is rooted in evolutionary economics, but it is also an interesting pointer to the dominance of market ideology in sustainability studies. If, however, the critique of *technological innovation* on the product level is to be taken seriously, we must ask whether the much more radical notion of *social innovation* as presented, for instance, by Westley and Antadze, can be filled with life if left to the market and its social 'entrepreneurs' alone. Social innovation that relies mainly on the market as selection environment and does not involve the construction of internal selection systems able to respond effectively to anticipated external selection pressures will inevitably face the same problems that have been described above for technological innovation.

One of the obvious solutions to this dilemma is the return of the state to the scene of environmental governance. The German Advisory Council on Global Change (WBGU 2011: 175), for example, calls for a 'new statehood' to actively drive forward the forthcoming transformation and Anthony Giddens (2009: 91) demands a stronger role for the state as a 'prime actor' in combatting climate change. When these commitments to the state are read more closely, however, they quickly reveal themselves to be not much more than 'the emperor's new clothes', namely a re-assertion of the subordinate role of the state within a market-based context of 'transition management' and 'climate governance'. Hence, WBGU, apart from calling for a national climate law that sets binding decarbonisation targets until 2050, focuses on the concept of 'change agents' as the main vehicles for change (WBGU 2011: Ch. 6), while Giddens regards it as the main function of the state to act as a catalyst and facilitator (2009: 91). A more substantial and self-conscious role for the state than 'to act together with enlightened corporate leaders' (2009: 93) appears to be out of reach today.

In order to move forward in this stalemate situation we suggest applying a new conceptual framework for the analysis of different types of innovation that might provide us with a better vantage point to assess the requirements for *transformative innovation*. The framework of 'agentic operators' was developed to analyse agency in terms of its *impact* on social reality. It can be used to analyse and distinguish different modes of agency and to identify the modes of agency with the highest transformative capacity. The underlying assumption is that not all forms of change and not all modes of agency are equally effective in engendering a transformation of society and that a lot of 'energy' can be 'wasted' by investing in ineffective modes of agency. The framework introduced below is certainly not exhaustive but it provides a good starting point for analysing the transformative requirements for innovation policies.

4. 'Agentic operators' and transformative innovation

The framework developed in Hausknost (2012) analytically distinguishes three modes of agency or 'agentic operators'. We call them 'operators' because they do different things to reality, just like mathematical operators do different things to numbers. The idea is that just like *addition*, *subtraction*, *division* and *multiplication*, so *decision*, *choice*, and *solution* do fundamentally different things to the realities they are applied on. There are two distinctive criteria which define the characteristics of agentic operators and which separate them from each other. One is the question whether or not the operator *eliminates the options* that are not selected in the operation. The other is the question whether the operator *selects between incommensurable options* or not, that is, whether or not it involves the passage through the *field of undecidability*. Each operator combines different answers to these two questions and therefore constitutes a unique way of 'processing' reality. *Table 1* summarises the resulting typology.

Table 1. Typology of agentic operators

	Elimination of options	*Incommensurability (undecidability)*
decision	✓	✓
choice	–	✓
solution	✓	–

There are three logically distinct operators: decision, choice and solution. According to the two selection criteria identified, they cover all possible modes of agency.[4] Decisions introduce path dependency in that they eliminate the discarded options: if I decide for X, then Y and Z are eliminated as options. Any future development will have X as its point of departure. Importantly, however, a decision is only worth its name if it selects between options that are *incommensurable*, that is, between options that differ at least in one aspect for which there does not exist a common unit of measurement. In the field of ethics and politics, such factors are usually expressed in terms of values, ideologies and world-views. In ecological economics, the problem of incommensurability is well-known as the problem of *valuation*: what is the value of a tree? Is it the economic value of its timber and fruit? Is it its ecological value as habitat of many species? Is it its recreational value for people resting underneath? Is it its aesthetic value or even its spiritual value? Does it have an 'intrinsic value' as a living being? And how can these different values be made comparable? The answer is that they cannot. Prices are the only economic means of comparison, but they fail to recognise the incomparability of values. 'Prices are not worth much when it comes to the assessment of values', as Røpke (2005: 279) points out, meaning that the incommensurability of values is irreducible, although it is often violently ignored in the process of capitalist commodification (see Røpke 1999; Røpke 2005; Martínez-Alier 2002; Spash and Carter 2001). Sometimes, decisions between these incommensurable values or world-views must be taken. Therefore, 'decision situations should be illuminated with all their conflicts instead of suggesting simplified "solutions" (Røpke 2005: 279).

Decisions, then, are path-dependent selections between different ways to frame reality, which cannot be compared in objective terms of measurement or calculation. That is why Jacque Derrida (1990) defined decisions paradoxically as having to *pass the field of undecidability*. A decision that is *decidable* would not decide anything but reveal the *solution* to a calculable problem (Butler and Laclau 2004: 332).

Solutions, therefore, are defined as selections between *commensurable* options, that is, between options that can be assessed and compared within the same rational framework or paradigm. One of the options will be the *best* solution, others will be *less* ideal or even *wrong* – this ranking can be established unambiguously by applying a common unit of measurement or rationality. The selection a solution executes also eliminates the discarded options, just like in a decision: the wrong or second-best options will no longer play a role as soon as the best option is established. The path dependency of solutions, however, is severely restricted since the path is implicitly pre-selected by the common paradigm. The path is calculable on the basis of the common unit of measurement. Solutions only constitute different stages or steps of following this path.

Choices, finally, are marked by the peculiar trait that they do *not* eliminate the incommensurable options between which they select. Hence, while the options are

[4] For the sake of completeness, one would have to introduce a fourth operator that is negative on both counts (no elimination of options and no incommensurability). This operator is what I would call *routine*: it is the 'dark matter' of which perhaps ninety per cent of our daily actions and behaviour consists. Without routines, no social order could be sustained. However, routine is the background operation on the basis of which the other three operators work. Hence it is not an 'operator' like the others, since it does not intervene into reality, but reproduces it. For a discussion of routines see, for example, Schatzki 2008; Bourdieu 1977; 1998.

incommensurable like in decisions, the ones a choice discards are not eliminated from the pool of further selections. A choice can be repeated at will: this time, I select X, next time Y, and another time Z. This feature makes choice the genuine agentic operator of the market place: Today I select a *Milky Way* chocolate bar, tomorrow a muesli bar, and the next day an organic and fair-trade chocolate bar. The options are incommensurable in that they cannot be ordered according to a single rational framework: one day, my preference for the taste of *Milky Way* will prevail over my ambition to lead a healthy lifestyle and my desire to contribute to the creation of a 'better world'. Another day, the ranking may be reversed on the basis of different moods, cravings or manipulations by adverts.

While choice is the operator of the market place, solution is that of science and technology, for obvious reasons. Decision, finally, is the operator of politics proper, by virtue of politics being the name of the undecidability of the social: if society were a *decidable* structure, there would be no need for politics (Critchley 2004: 113) in the first place. The typology, it should be mentioned, presents *ideal types* in the sociological sense rather than clear-cut phenomena of social life. In reality, the boundaries are often somewhat blurry in that large investments in a market may take the form of decisions as they actually eliminate other options for an investor, or in that many 'solutions' are in fact highly political when their actual undecidability is (deliberately) disguised under the veil of scientific rationality. But this is precisely the terrain we enter when talking about 'innovations', and especially when talking about environmental innovations with an intentionally transformative impact on society at large. Let us therefore now apply this analytical framework to the field of innovation studies:

4.1 Socio-technical evolution as a matter of solutions and choices only?

As discussed above, the dominant approaches to innovation studies are all drawing from evolutionary economics as their common point of departure. The evolutionary economics approach to socio-technical change is well-suited to explain the co-evolution of economic, technical and socio-political subsystems *within* the industrial age, and that means, *within* the fossil energy regime, but, as noted above, it might be ill-equipped to design and prepare an exit strategy *out of* the fossil energy regime. Arguably, both tasks require different analytical and conceptual tools and the ones used to describe change *within* the fossil age might not help us very much to overcome that very age. The reason for this is that evolution does not follow any normative goals or objectives – it simply evolves. However, once *normative* objectives for societal development are defined, the mechanisms driving evolution will need to be adapted accordingly and purposively, and this means, according to the *normative* requirements of change.

The mechanisms driving evolutionary change are those of selection, variation and retention. While retention is important in an institutional sense to set the 'rules of the game' without which change would be chaotic, non-systemic and arbitrary and therefore lead the system to disintegrate, the mechanisms that account for change and its directionality are those of variation and selection. Now it may be argued that the conditions of variation (at least in socio-technical systems) depend on the mechanisms of selection in that variations that stand no chance of being selected will be discouraged and such that are commonly selected encouraged. For example, niches operating close to the market and developing products or services that stand a good chance of being commercially viable will attract more resources both in terms of financial and human capital than niches working on 'utopian' solutions for which no market currently exists.[5]

Hence, the mechanisms of *selection* can be said to be of the highest strategic importance when it comes to profound societal change. Variation to some extent follows selection, in that the modalities of selection create certain *patterns* and *directions* of variation. It thus makes sense for the study of sustainability transitions to focus on the mechanisms and indeed on the *regimes of selection* that are at work in our societies. The argument we want to put forward here is that in advanced industrial societies and, *a fortiori*, in advanced liberal democracies, the regime of selection is dominated by the agentic operators *choice* and *solution* and is therefore restrained in its directionality to a particular pattern of change that is unlikely to escape the developmental trajectory of the fossil energy regime.

Solution is the generic operator of the techno-scientific domain. Scientific disciplines and technologies both develop their own paradigmatic systems of reference within which 'problems' can be defined for which 'solutions' can be sought. As Carlota Perez (1983: 361) puts it, within each techno-economic paradigm 'managers and engineers will apply what becomes the "technical common sense" to make incremental improvements along the natural trajectories of the technologies in place […]'. Hence, every solution addresses a problem that was defined within a relatively coherent and closed cognitive framework or paradigm. Although it is often possible to translate *between* paradigms, it is impossible to apply a solution of one paradigm to a problem of another one *directly*. For example, the problem of climate change can be translated into the socio-technical paradigm of the automobile industry by defining the corresponding problem of fuel efficiency and searching for the respective technical solutions. But this translation obviously involves a change in the frame of reference that 'loses' the problem of climate change in its societal dimension. The translation between paradigms will thus always be partial.

Solutions are thus mechanisms of selection that apply the paradigm within which their corresponding problem is addressed as their frame of reference. Improvements in the aerodynamics of car design or in engine technology are solutions to the problem of fuel inefficiency. Whether solutions are successful in moving their paradigm forward is depending, to a large extent, on whether they satisfy the other relevant selection mechanism: *choice*. This means that a solution to a problem within a socio-technical paradigm must also be selected in the market place in that it addresses the private needs and preferences of consumers. The solution must be commercially viable.

Solution and choice are coupled as a double-mechanism of selection. This, however, binds the selection mechanism to the criteria of private utility and commercial viability,

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[5] Change often occurs as a result of an interaction of choices, solutions and decisions. Certain discourses for change emerge in the public sphere and are then reflected in (market) choices and (technical) solutions, but these stay at a niche level. It often needs an external event – a kind of rupture – which enables some of these niche developments to conquer the mainstream. Before smoking was banned in restaurants, a certain constellation of scientific findings and individual choices (lifestyle-changes) had to be in place in order for the discourse to 'tip' towards a ban. But in the end the 'universalisation' of these tendencies had to be achieved by a political decision to ban smoking in public places. This ban, then, enabled the consequent reduction of smokers as a percentage of population. For a more detailed discussion see Hausknost 2012.

since the market is the prime selection environment within which capitalist evolution takes place. The problem with this coupled selection mechanism, however, is that both solution and choice are relatively ineffective operators for achieving transformative change. Choice is good for social and technological experimentation in socio-technological niches, where practices, institutions, technologies and products can be developed and tested. But it is weak in diffusing innovations beyond the constraints of commercial viability. This is particularly true for environmental innovations as they are usually factor-saving and not quality-improving, which means that the usual market mechanisms of diffusion that rely on private utility and not on social benefit, are ineffective. Solutions are necessary and will continue to be so, but they suffer from the risk of technological lock-in when their frame of reference is set by the narrow bounds of their socio-technical domain and by the marketability of incremental improvements. Put differently, when the market alone is the relevant environment for science and technology to innovate for sustainability, then the incremental change of ecological modernisation is the best we will get.

4.2 *Towards transformative innovation policy*

We therefore suggest that for a sustainability transition to be successful the favoured selection mechanisms of capitalist evolution, namely solution and choice, would need to be complemented, if not replaced, by a *strategic* coupling of solution and decision as selection mechanisms in the politics of innovation. For only decisions are effective in addressing *normative* societal goals in an effective manner. *Table 1* summarises the advantages and disadvantages of the three agentic operators for environmental innovation.

Table 2. Advantages and Disadvantages of agentic operators for environmental innovation

Agentic Operator	*Advantages*	*Disadvantages*
Decision	Very effective operator for transformative and disruptive change	Conflictual; political risks; possible resistance to unpopular decisions even if democratically legitimised; accountability for short-term negative effects or failure of measure
Choice	Plurality of options; social and economic experimentation; politically risk-free	Ineffective operator to achieve disruptive change; slow and insufficient diffusion of innovation; environmentally effective innovations tend to stay in niches; problems of rebound and leakage
Solution	Technological and scientific innovation will remain indispensable to achieve sustainability	Ineffective operator to achieve disruptive change if not *enforced* by decisions; risk of technological lock-in (staying within the box), yields incremental change in most cases

The strategic coupling of solution and decision as selection mechanisms in socio-technical evolution means that while the market would remain an important field of experimentation and variation, it would no longer constitute the main selection environment. Instead, *political instruments* designed specifically to fulfil the *normative* requirements of steering a sustainability transition would become endowed with the power to make at least the strategically most important selections. For the extended period of transition, the market would remain an important sphere of social coordination, providing for a domain of societal 'normality' in which daily transactions take place, while transition itself would become a political domain. This, of course would lead to a new host of problems related to the antagonistic nature of the political which is rooted in the constitutive undecidability of the social (Mouffe 2005). Every decision chooses sides and creates winners and losers. Limiting the availability of cars or stopping investments in new road infrastructure means actively choosing (long-term) social benefit over (short-term) private utility and limiting some individuals' 'freedom to choose'. Making collective decisions necessarily means taking away some choices from the individual. This, of course, makes decisions so politically painful and risky. Liberal democracies, focussing on rule of law and individual choice as they do, are ill-prepared for transformative decision-making. Decisions that actively intervene into the social metabolism or into capitalist evolution are rare. The institutional framework of liberal democracies was instead designed some hundred years ago to manage and govern capitalist evolution, and thus to administrate the fossil energy regime. That means, however, that the institutions to actively and smoothly move society out of the fossil energy regime are lacking.

Our argument here is thus that any transformative innovation policy that seriously aims to tackle the challenge of a sustainability transition needs to focus on developing democratic mechanisms and institutions of decision-making that allow to tackle difficult, complex and conflict-laden issues concerning the social metabolism in a transformative perspective. Transformative innovation will arguably be more about inventing, testing and implementing new democratic institutions and procedures of decision-making than about developing new technologies. This does not mean that the technological dimension is to be neglected; but it means that without the institutions to decide for and implement the transformative technologies needed, these technologies will perhaps not even have a chance of being invented. As pointed out above, if the market remains the only powerful selection environment (with choice its selection mechanism) then only a certain type of technological innovation will flourish – and this may not be the type that is needed to overcome our current socio-metabolic regime.

The decisions required for a sustainability decision arguably do not only pertain to types of technology, but go much deeper into the structures of society. Decisions may be needed to change the way societies use time and organise work. As Schor (1991), Hayden (1999), Jackson and Victor (2011) and others have forcefully argued, a sustainable society may require that we work less and distribute the product of our work more evenly. This is, of course, a politically explosive proposal since it intervenes deeply into the very structures of capitalist accumulation and economic growth. Deep changes like these require fields of experimentation, spheres of discourse and institutions organising and preparing the changes ahead. Others argue that we need to leave the growth-path altogether and must start building a type of society that functions without the in-built need to expand its economy continuously (Victor 2008; Jackson 2009; Martinez-Alier et al. 2010; Kallis 2011; Deriu 2012). How to organise a democratic society that is not dependent on continuous economic growth is, however, an open question that requires institutional innovation on an unprecedented scale. Instituting a post-growth society would require confronting difficult issues of power-struggles and political stability that would have to be resolved. Investing into these types of innovation, however, might be an effective way of meeting the challenge of the sustainability transition.

The coupling of solutions and decisions in increasing the directionality of change can also be used to clear the market of products and services that constitute a 'dead end' in terms of sustainability, thereby pushing socio-technical innovation in directions that are more sustainable. The concept best known in this regard is 'choice-editing' and was developed by the UK Sustainable Development Council. It 'is about shifting the field of choice for mainstream consumers: cutting out unnecessarily damaging products and getting real sustainable choices on the shelves' (Sustainable Consumption Roundtable 2006). Choice editing is a practice that has been applied for decades by advanced bureaucracies around the world, when dangerous chemicals or unsafe food products are banned from the market, for example. But in the context of the sustainability transformation, more rigorous and comprehensive decisions are required to delete certain (categories of) products from the market place (and thus stimulating innovation for new, more sustainable ones). This could concern cars that emit more than 100g of CO_2 per km, non-organic meat products, virgin-fibre paper, electric appliances that do not conform to the category 'A' of energy efficiency, etc. With a determined political discourse preparing such a scheme, popular support could be secured. Questions of institutionalisation are crucial in this respect: perhaps, a deliberative panel could be established that consists of citizens who prepare a proposal on the basis of expert hearings every year, which is presented to parliament.

The need for decisions abounds when taking the concept of a sustainability transition and its normative nature seriously. The argument put forward here, however, is not to do away with choices and solutions, to neglect the market or the power of technology, but it is to recombine the agentic operators in a way that allows for directing societal change more actively in an intended direction. It is to take more control over socio-technical evolution by carefully designing selection mechanisms that are political by nature and thus capable of responding to collective, normative goals. The proposal is thus to integrate choices, solutions and decisions into a transformative innovation policy that is able to act more strategically and to take the political nature of the sustainability transition seriously. As pointed out above, this could be a painful experience for liberal democracies at first, as they are used to govern the socio-economic metabolism mainly by the 'soft' operators of individual market choice and technological solutions. Introducing powerful instruments of decision-making could be perceived as disruptive and unjustified by some. The old struggle between the two core values of modern democracy, popular sovereignty and individual liberty, would re-surface and would need to be settled by smart institutional innovations. Decisions that are not perceived as legitimate by a majority could be interpreted as autocratic or undemocratic. Hence, the institutions to be designed for transformative decision-making must put a strong emphasis on democratic legitimacy and inclusion. This is rather new terrain to liberal democracies, however. Hence our contention that the design of democratic institutions and mechanisms might be the most important field of innovation for a socio-ecological transition. The rationale here is that transformative solutions are highly dependent on transformative decisions: the technological solutions we need will not be invented let alone implemented without rigorous decisions that define the 'riverbed' into which technological innovation must be channelled in order to effectively respond to the SET.

It should be noted, however, that strengthening the role of decisions is of course no panacea. The decision is just a tool in a toolbox, and does not guarantee that the work it is applied to will be an overall success. For example, dramatically reducing the demand for fossil energy in Europe by choice editing and other transformative mechanisms might lead to the saved resources being used up in other world regions at a comparatively lower price (as the efforts of resource saving in Europe would depress the price of the resource). This effect is known as the 'green paradox' (Sinn 2012, van den Bergh 2012b) and can conceivably be dealt with only on a global level by introducing binding caps to tradable emissions. This, of course, requires *decisions* by the relevant parties to enter into an effective global climate agreement. Another way of responding to this argument, however, is to point at the leadership aspect and to the competitive advantages a successful reduction of demand for fossil energy and other non-renewable resources would create: even if some of the saved resources were used up elsewhere, Europe could guide the way to a low-carbon society and there should be no doubt that highly energy-dependent industrialised and industrialising countries (like China) around the world would be eager to follow that example.

But also within Europe, decisions are needed not only to restructure consumption patterns but also to reduce the overall level of consumption. One way of doing this would be to reduce average working hours, leading to lower spendable incomes but more available time (Victor 2010; Jackson and Victor 2011, Rosnick 2013). Reducing the overall levels of consumption is of course at odds with the expansive nature of capitalism, which means that further decisions (and democratic institutions) will be required to deal with the resulting contradictions (lower incomes and more time mean that societies will have to think about new mechanisms of social security and redistribution). This should come as no surprise, however, as a response to the socio-ecological transition of the scale required will inevitably change the very nature of capitalism or lead to societies that are no longer recognisable as capitalist (Haberl *et al.* 2011; Kallis 2011; Jackson 2009). Thus, the call for decisions alone does not suffice to tackle the complex problems of a socio-ecological transition. Decisions will often lead to new problems that require more decisions as well as technical solutions and individual choices. And all this will have to be done in a highly experimental mode, as no society has ever tried before to deliberately and dramatically reduce its social metabolism without collapsing.

5. European Response Strategies and innovation policy

In conclusion we shall attempt an assessment of the European Response Strategies as developed in the NEUJOBS report on socio-ecological transitions (Fischer-Kowalski *et al.* 2012) in regard of the analytical framework of innovation policy as developed here. As these response strategies are central to the analysis of socio-ecological transitions within the NEUJOBS project, it is important to relate the findings of our paper to these strategies. Different response strategies, we assume, will require different emphases and combinations of agentic operators in innovation policy.

Strategy 1 envisages 'no policy change' (ibid. 90) and is the business-as-usual strategy. This strategy focuses on economic growth by all means and orients its innovation policy accordingly. The market remains the prime selection environment and national innovation systems strive to compete with each other while the European innovation system strives to compete with the rest of the world. Solutions are sought primarily for economic problems and sustainability problems are perceived mainly as problems of resource scarcity that inhibit further growth. Choice and solution remain the dominant agentic operators in the innovation regime.

Strategy 2 is about 'ecological modernisation and eco-efficiency' (ibid. 91). Here, the socio-ecological crisis is recognised as a real-world problem but is addressed in terms of 'eco-efficient production reached through market-based instruments' (ibid.). The focus in the innovation regime is on the 'strategic' coupling of solution and choice. Whereas in *strategy 1* the focus is on choice, here the focus is on solution. This is the strategy in which approaches like Strategic Niche Management and Transition Management are developed further and where attempts are made to influence the socio-technical evolution of the capitalist market by strategically supporting certain niches and actors and by creating spaces for experimentation. Governments intervene by supporting and subsidising certain technologies but rely on markets to take up the favoured innovations. As pointed out in Fischer-Kowalski et al. 2012, this strategy may be successful in further increasing the resource-efficiency of the economy and in stimulating the development of more sustainable technologies and thus of 'sustainable growth', but it faces stubborn problems of rebound effects and technological lock-in. In other words, while it leads to the improvement of the socio-economic paradigm in terms of resource efficiency or even to the birth of a new general purpose technology that unleashes a new wave of economic growth, it does not manage to change the trajectory of societal development significantly: saved resources are used to fuel further growth and while carbon emissions can be slightly reduced, they do not drop at the rate required to avoid dangerous climate change.

Strategy 3, finally, is that of a 'sustainability transformation' and aims at a 'smart, lean and fair societal metabolism optimizing human welfare' (ibid. 92 f.). These ambitious normative aims, combined with the objective to stay within a 'safe operating space for humanity' (Rockström *et al.* 2009) requires an altogether different repertoire of political agency and innovation policy. Without a strong role for the agentic operator decision this strategy is bound to fail, since the changes required here extend far beyond the level of technology and efficiency. Change here is of a structural kind and affects the deepest structures of society and the economy. As discussed above, however, introducing decisions to the agentic repertoire of liberal democracies is not easily done. Hence, the type of innovation primarily needed for this response strategy is of an institutional and political kind. Resources, effort and ambition needs to be invested into developing the institutional spaces for experimentation and decision-making, for organising democratic conflict and discourse over socio-metabolic and socio-economic issues, and for making Europe socially resilient to the perturbations of the coming transition.

It is obvious that *response strategy 3* is the least likely to be realised. Too big are the political risks involved, too little is there to gain in the short term for policy makers, elites and indeed consumers. Economic growth and eco-efficiency will in all likelihood remain the main objectives of environmental and innovation policy alike. The reason we put our focus on the sustainability transition and on the need for decisions, however, is to point out the implications of taking the term 'socio-ecological transition' or its normative twin, 'sustainability transition' seriously. If that were to be our goal, really, strategy 3 had to be the answer. Becoming aware of the bewildering complications this would mean for our political and economic systems should be the first step of the transition itself. The alternative is to trust a socio-economic evolution that will continue to provide us with new technologies and more economic growth but will presumably leave us stranded on a hot planet once it runs out of energy.

6. Conclusion

The purpose of this working paper was to assess the role innovation and innovation policy can play in a socio-ecological transition (SET) of Europe. Our strategy was to start with defining what a SET entails and then to ask to what extent innovation can contribute to it and, most importantly, what type of innovation will be required for a successful sustainability transition. Importantly, we based our analysis on the robust assumption that the world faces a SET in any case – either as a sustainability transition that is the result of colossal societal efforts to change the current trajectory of development, or as a transition resulting from resource scarcity and environmental pressures that even could take the form of socio-economic collapse. Innovation can of course contribute to both scenarios (and it has so far dominantly been used to get us to the edge of the latter) and the real question is how to define and secure the conditions under which innovation is put at the service of the sustainability transition.

To this end we examined the three dominant approaches in innovation literature on a conceptual level and assessed whether they provide some answers to the many questions a sustainability transition raises. We analysed the multi-level perspective, the innovation systems approach and the neo-Schumpeterian theory of techno-economic paradigms or long waves. All three are ontologically based in evolutionary economic theory. While evolutionary theorising can be very helpful to understand processes of socio-technical co-evolution, the approaches we analysed all share a crucial shortcoming in that they build on the much narrower *economic* interpretation of evolutionary theory which defines the market as the most important selection environment for technological (and other) innovations. As the market cannot anticipate future external selection pressures resulting from resource scarcity and environmental degradation, however, it is an improper selection environment for the implementation of purposive changes that build on the mitigation and avoidance of future problems.

Conceptually our main result was therefore that technological innovation, as long as it is left to the market, will continue to be undirected and contribute at least as much to potential collapse (through rebound and leakage effects and other problems related to a growth-based economy) than to potential sustainability. What is required, then, we argued, is the internal representation of the external pressures in selection systems other than the market. In other words, we need powerful institutional mechanisms of selection that substitute the mechanisms of the market to some extent and where this is relevant in terms of sustainability considerations. Hence, perhaps the most important (and difficult to invent and implement) innovations in the years to come will have to be of an institutional type and concern purposive interventions into socio-technological systems.

In conceptualising the outlines of a transformative approach to innovation we used the analytical framework of 'agentic operators', as developed by one of the authors. The operators choice, decision and solution are analytically distinct modes of intervening into reality. Our analysis led to the conclusion that current innovation policy is dominated by the operators *choice* and *solution* and thus tied to market selection and incremental technological change. What is lacking are *decisions* that shift the entire terrain on which *solutions* are thought and that make purposive selections between alternative technological trajectories. Such *decisions* are rare because they are irreducibly political and face inherent legitimation problems. Nevertheless they will be needed in the future to provide the level of steering that is necessary to break out of our carbon economy. While *choices* will continue to dominate our everyday life as consumers and *solutions* will continue to be necessary to solve technological and other problems, we will need to rely much more on *decisions* to purposively navigate society onto a sustainable trajectory. The combination of solutions (technological and organisational) and decisions (political) will have to replace the dominant combination of choices (market) and solutions.

With regard to the European Response Strategies set out in the NEUJOBS State of the Art Report No. 6/D1.1., we came to the unambiguous conclusion that while the strategy of 'ecological modernisation' which relies heavily on the power of solutions within a market environment is the most likely to dominate Europe in years to come it is unlikely to lead to a sustainability transition. For this transition to occur, the power of decisions will have to be re-learnt by democratic institutions, and new institutions will have to be created to make decisions that are effective, relevant and legitimate.

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About NEUJOBS

"Creating and adapting jobs in Europe in the context of a socio-ecological transition"

NEUJOBS is a research project financed by the European Commission under the 7th Framework Programme. Its objective is to analyse likely future developments in the European labour market(s), in view of four major transitions that will impact employment - particularly certain sectors of the labour force and the economy - and European societies in general. What are these transitions? The first is the **socio-ecological transition:** a comprehensive change in the patterns of social organisation and culture, production and consumption that will drive humanity beyond the current industrial model towards a more sustainable future. The second is the **societal transition,** produced by a combination of population ageing, low fertility rates, changing family structures, urbanisation and growing female employment. The third transition concerns **new territorial dynamics** and the balance between agglomeration and dispersion forces. The fourth is **a skills (upgrading)** transition and and its likely consequences for employment and (in)equality.

Research Areas

NEUJOBS consists of 23 work packages organised in six groups:

- **Group 1** provides a conceptualisation of the **socio-ecological transition** that constitutes the basis for the other work-packages.
- **Group 2** considers in detail the main drivers for change and the resulting relevant policies. Regarding the drivers we analyse the discourse on **job quality**, **education**al needs, changes in the organisation of production and in the employment structure. Regarding relevant policies, research in this group assesses the impact of changes in **family composition**, the effect of **labour relations** and the issue of financing transition in an era of budget constraints. The regional dimension is taken into account, also in relation to **migration** flows.
- **Group 3** models economic and employment development on the basis of the inputs provided in the previous work packages.
- **Group 4** examines possible employment trends in key sectors of the economy in the light of the transition processes: energy, health care and goods/services for the **ageing** population, **care services**, housing and transport.
- **Group 5** focuses on impact groups, namely those vital for employment growth in the EU: **women**, the **elderly**, immigrants and **Roma**.
- **Group 6** is composed of transversal work packages: implications NEUJOBS findings for EU policy-making, dissemination, management and coordination.

For more information, visit: www.neujobs.eu

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