

Manuscript Details

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Abstract

There is no shortage of concepts that aim to show how our economy can become more resource- efficient such as eco-innovation, cradle to cradle, etc. We analysed a long list of concepts using three dimensions: scope of change, ambition with regard to the (paradigmatic) degree of change, and the existence of plausible drivers and pathways of change. Reviewed literature on governance and transitions suggests that the more extensive and radical the scope and ambition of change are, the higher systemic and institutional resistance to change will be. From roughly 30 concepts reviewed, none gave a credible answer on how to overcome this dilemma. Resource scarcity is not (yet) a clear driver for change. Where in the field of climate change policy starts to respond to compelling scientific evidence of danger, in the field of resources only win-win policies are seriously considered. Advocates of radical resource efficiency must find credible pathways that allow it to be pursued at scale in practice or hope that incremental change will open up space for more radical options, in order to avoid the significant economic and social disruption from supply-demand imbalances that some now fear.

Keywords	resource efficiency; circular economy; sustainability concepts; drivers for change
Manuscript category	Analysis
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Submission Files Included in this PDF

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Journal: Ecological Economics

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We look forward to receiving your revised manuscript as soon as possible.

Kind regards,

Anne Aitken

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Dear Editor,

Thanks for the reviews. The initial reviews and your editorial decision asked for a minor revision, whereas several late reviews were more critical. We nevertheless took all comments on board where reasonable.

Please find our reaction to reviews attached.

Arnold Tukker, on behalf of the authors

R1 Comment	Reply
<p>In a nutshell: This is without any doubt an excellent paper and my comments refer just to technical details or items of discussion. Too many concepts toward resource-efficiency remain a collection of wishful thinking without consideration of real change management. The authors improve the level of discussion significantly by introducing the aspect of "realisation" or "plausibility of change".</p>	<p>Thanks!</p>
<p>p 1: Just for clarification and a better understanding: Do the authors consider it helpful to define the notion on "resource" in the context of this paper? Obviously reference is mainly made to (geogenic) raw materials, although sometimes fuels and energy resources are considered as well. The paper questions real salient shortages, so are we talking about resources or reserves (McKelvey)?</p>	<p>We have clarified that we define 'resources' in strict sense, i.e. extraction of biotic and abiotic materials from Nature.</p>
<p>p 5: As bottlenecks not only may occur on the supply side (availability) or input into the ecosystem, lack of output-resources, i.e. the capacity of soil, water, air, climate, or society to accept and properly deal with the by-products, wastes, or contaminants from resource consumption, can in fact set limits to the use of resources.</p>	<p>In relation to the above, emissions and waste are not seen as part of the resource-efficiency agenda. Often, emission problems are not inherently caused by resource use and can be mitigated (carbon a clear exception).</p>
<p>p 16: I understand the thorough approach and yet the still "personal" nature of the mapping results. However, it surprises that #4 EPR shows only -1 paradigmatic change with (at least in the EU) mandatory recycling/recovery targets beyond any market equilibrium and thus beyond "market-based solutions". The same question occurs with respect to #23 Circular Economy. Bearing in mind the high visibility and priority of CE in the EU since (at least) 2014, the description and analysis in 2.22 should reach beyond Ellen MacArthur Foundation (is this a reliable source?) and address the 2015 EU Circular Economy Package. This will imo probably lead to a different score due to the fundamental regulations foreseen (landfill ban, mandatory quotas, Action Plan).</p>	<p>Environmental Producer Responsibility will not by nature give a radical change. It is about better taking care of hazards and waste related to products sold. Not by necessity reducing drastically resource use.</p> <p>In a similar way, the current EU circularity package mainly focuses on waste management. Landfill bans are commonplace in advanced countries like Germany and the Netherlands and these are still far from circularity. We refer now to the EU policy document.</p>
<p>#3 (2.3) Waste prevention: The reference to art 4 EU WFD should be complemented by a further reference to the often forgotten art 4 (2): The hierarchy in art 4 (1) is not cast in stone. Four of</p>	<p>Description of art 4(2) added.</p> <p>Rationale for score added</p>

<p>the priority waste streams mentioned here had been addressed by EPR regulation together with recycling/recovery targets (not so much waste prevention) and should be dealt with under this paradigm (2.4). By the way, the (far more recent) EU Circular Economy Packaging sets new priority waste streams in the Action Plan (Plastics, food waste, construction waste, critical raw materials, and biobased wastes). Compared to more practical approaches as EPR or CE, waste minimization as a concept seems far more fuzzy. So how did it score +1 in plausibility of change?</p>	<p><i>While waste prevention can be seen as more fuzzy in nature as other approaches, there is a clear history in some EU member states of voluntary agreements or otherwise that have supported a reduction of waste (e.g. the waste prevention policies in the Netherlands in the 1990). We hence score viability and plausibility on +1</i></p>
<p>p 10: "the lever" "the level" of transformation? p 11: Numbers in fig. 3.4 (1-6) do not relate to those in the table above (1-5). p11: GWS (2013). p 14: "For" or "In" the analysis... p 20 "Tukker (2x) 2.10: Leopold Kohr</p>	<p>Typo's improved</p>

R2 Comment	Reply
. The selection of included concepts is, however, not very transparent. What is missing is a reasoning for the selection of approaches. A consistent explanation how the considered concepts have been selected and by which criteria this has been done is lacking; it is also not always clear how the literature to characterize the concepts has been selected (what was the guiding principle here)?	See addition and response to remark on page 14
In the main text the concepts are described somewhat inconsistently as approaches to reach “circularity”; to improve “resource efficiency” or “popular sustainability concepts”.	Now mainly rephrases as resource efficiency
The referencing is sometimes a bit weak in the main text and also in the description of the approaches in the SI.	Referencing improved, added some 15 new refs
Page 3: Referencing is not clear: References are only provided for the multi-level concept, but not for multi-actor, multi-phase concept (which appear as different concepts here). Please provide references or make clear that these are related concepts and that the references provided in the beginning refer to all of them..; Provide references for transition theory.	This is a misunderstanding – the following references combine all 3 concepts (e.g. Geels, 2005; Elzen et al., 2004; Rotmans et al, 2001)- Elzen et al., 2004; see also Geels, 2002 and 2005 and Kemp, 2008 are references to transition theory
Page 4 (right below heading 2.2):in our case the circular economy: Circular economy (one of the evaluated concepts?) is not at all mentioned in this sections. Delete!	Revised into ‘resource efficient’
Page 4 (bottom): Sentence: Rather than creating big programs... sentence is to long and unclear – please rephrase.	Sentence deleted
Page 5: Provide references for scenarios by Shell and IEA!	Included
Page 6: The term “resource” seems to play a prominent role for the analysis presented in this paper but it remains unclear how it is used. On page 6 four main material groups (as captured by material flow accounting) are discussed; in Table 2.1. also water and land are included....	Introduction explains now the focus on resources. The list now explains biotic resource extraction is strongly related to land use and water use.
Page 6: Building and construction materials: Rather focus on non-metallic minerals for construction here; metals are also addressed in the group metal ores and industrial minerals.	Changed to non metallic minerals
Page 6: Limitations of biotic materials: The focus on efficient use of land and water ignores that	Text adjusted. <i>The extraction of biotic materials is mainly limited by water and land use constraints in</i>

<p>biomass demand is likely to grow due to population growth and changing diets and maybe also due to the increasing demand for first or second generation biofuels, while at the same time possibilities expansion and intensity of land use are limited and land use and agriculture still contribute considerably to climate change. Climate change impacts on agricultural production are another factor that may limit future biomass availability.</p>	<p><i>relation to biodiversity impacts. Population growth, diet changes and the use of biofuels all are likely to lead to the need for a higher production of biomass in future. Without efficiency improvements, this will lead to pressure on land use, biodiversity loss, and a water shortage of 30% by 2030 (e.g. Water Resources Group, 2009; Nature, 2010). These sources however also suggest such problems can be overcome by a Factor 2 improvement of resource-efficiency by 2050. While this certainly is a challenge, it is probably one that can be realised by incremental rather than radical innovations and changes.</i></p>
<p>Table 2.1: Land and water: what does p.m. mean? Why are land and water not discussed in the text?</p>	<p>Was discussed in the text, but table now aligned with text</p>
<p>Page 11 and Figure 3.4: The text only lists the five intervention points shown in Figure 3.4 (with some inconsistencies). This duplicates information and could be shortened or should be rephrased.</p>	<p>Inconsistencies removed. It is 6 intervention points. In my view, having the list and figure is useful since the text explains where the figure maps on 2 axes.</p>
<p>Page 11 and Figure 3.5: The GWS concept and the meaning of Figure 5 remains largely unclear. Provide a bit more explanation; Figure 3.5 is of limited use; could probably also be deleted.</p>	<p>Figure deleted.</p>
<p>Page 13: Provide a reference for “Buddhist Economies”?</p>	<p>Added, EF Schumacher</p>
<p>Page 13, bottom: The first category in drivers and pathways: The concept ignores important factors that make the proposed change unnecessary. Unclear how this is meant, please explain.</p>	<p>Changed into • <i>The concept ignores important factors that make the proposed change difficult or impossible to achieve;</i></p>
<p>Page 14: There should be a section that discusses the selection of the 30 evaluated approaches. How approaches were identified, which criteria were applied to select them? Other prominent approaches (e.g. decoupling, smart cities, ecosystem services and their valuation) are missing. Overall, the manuscript is not very clear, what the common denominator of these approaches is:</p>	<p>An explanation of the limitations in selection is added: <i>“For the purpose of this study, an inventory was made of around 30 widely used sustainability concepts that include a more efficient use of resources in their scope. The ambition was to cover a large sample of widely used concepts, rather than to be fully comprehensive. We based ourselves amongst others on listings in the literature from the former section from which we derived the dimensions on which the concepts should be evaluated (e.g. Hopwood et al. (2005), OECD (2009) Lombardi et al. (2011), Eco-innovation observatory (2013) and GWS (2013)). The list was reviewed and complemented by 5-6 members of the study team from 5 different institutes in 4 different countries. While the final list inevitably is somewhat arbitrary, this procedure ensures it does contain a large number of the most used concepts.</i></p>

<p>Several keywords are mentioned in the text in an inconsistent way: circular economy (p.4); resource efficiency (title), popular sustainability concepts (p17).</p>	<p>Adjusted to resource efficiency</p>
<p>Table 4.3: What is EPR? Avoid acronyms!</p>	<p>Extended producer responsibility, adjusted</p>
<p>Page 19: Last sentence is long and complicated. Please rephrase!</p>	<p>Adjusted: <i>The resource-efficiency agenda is hence on a crossroads. In the domain of climate policy, policy makers increasingly reject outcome 4 in favor of some combination of outcomes 1 and 2, in view of compelling scientific evidence of dangerous outcomes in a business as usual scenario (outcome 3). Attitudes to policy making on resource efficiency are still largely based on outcome 4. This leaves only the hope that such attempts at outcomes 1 and 2 as actually occur may make more radical approaches more acceptable before outcome 3 causes the significant economic and social disruption that some now fear.</i></p>

R3 Comment	Reply
<p>- significant revision necessary; and - restructuring of the article necessary, which seems so far as quick compilation of project report(s).</p>	<p>Revisions as suggested in the annotated PDF included</p> <p>Major restructuring of introduction and conclusions</p> <p>Some specific reactions below. Copying all comments in the paper to this reply is a bit too much, reviewer is asked a next time to comment in the regular way as others did.</p>
<p>In 2.3 the authors are totally neglecting that it is widely understood that it is not the availability of resources rather the impacts of its use which exert pressure and induce policy responses including for more circularity and resource savings.</p>	<p>That is not the point. Resource scarcity is an unavoidable driver for change. A high level of resource use is not inevitably creating emissions/impacts. And even so, they do not exert policy pressure (see the climate debate). EMF for instance mainly uses resource scarcity or market volatility as the reason for change.</p> <p>Adjusted in the intro:</p> <p><i>But looking at the past, in many cases higher levels of resource use have been realized while society managed to reduce the environmental pressures related to that resource use – air quality and water quality in Europe, for instance, has been drastically improved in Europe in the last decades (REF). Even in cases where higher resource use almost inevitably leads to higher environmental pressures, such as in the case of climate change in relation to fossil fuel use, policy legitimization and action took decades to develop. It is hence questionable that pointing at the impacts of resource use will provide sufficient policy legitimization to embark on a resource efficiency policy that is radical and may hurt interests of the current mainstream actors. The case for resource-efficiency policies is mainly made by suggesting businesses or society as a whole win money in resource-efficiency scenarios, or that resource-efficiency and circularity are an answer to resource scarcity and price volatility of resources (e.g. EMF, 2013; TNO, 2013; WBCSD, 2016)</i></p> <p><i>Our position is that only such scarcity arguments will provide sufficient critical mass and</i></p>

	<i>legitimization for radical resource-efficiency policies that go beyond stimulating win-wins.</i>
- the insights are not new;	<p>That is not the issue – we know of course that radical change always encounters resistance. What is important, is, as indicated by reviewer #1, <i>This is without any doubt an excellent paper and my comments refer just to technical details or items of discussion. Too many concepts toward resource-efficiency remain a collection of wishful thinking without consideration of real change management. The authors improve the level of discussion significantly by introducing the aspect of "realisation" or 'plausibility of change'.</i></p> <p>We specified this as the main contribution to literature in our conclusions</p> <p><i>This finding is consistent with literature on transitions and system innovations. Radical and paradigmatic changes move away from existing socio-economic regimes and the related infrastructure, sunk costs and routines, and the dominant parties maintaining such regimes. Resistance to far-reaching change is hence usually significant since existing regime players often have no, or a different position in a radically changed future. Our contribution is hence mainly that we show all researched concepts fail to provide an answer to this crucial implementation question (or do not need to answer it, since the concept only aims at incremental change), Solid research into via which pathways radical changes to resource-efficiency can be fostered is hence essential. Creating yet another appealing concept that fails to explain how to overcome powers that resist that concept is useless.</i></p>
- the compilation of the concepts in the SI may be helpful to newcomers, but are also relying on subjective selection of references;- important references are lacking;	<p>There is indeed always a level of subjectivity in the selection, as noted by other reviewers. We explained the selection process in more detail. Our aim was not completeness, but to select a significant sample of concepts to perform our analysis on.</p>

Concepts fostering resource efficiency: a trade-off between ambitions and viability

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Abstract

There is no shortage of concepts that aim to show how our economy can become more resource-efficient such as eco-innovation, cradle to cradle, etc. We analysed a long list of concepts using three dimensions: scope of change, ambition with regard to the (paradigmatic) degree of change, and the existence of plausible drivers and pathways of change. Reviewed literature on governance and transitions suggests that the more extensive and radical the scope and ambition of change are, the higher systemic and institutional resistance to change will be. From roughly 30 concepts reviewed, none gave a credible answer on how to overcome this dilemma. Resource scarcity is not (yet) a clear driver for change. Where in the field of climate change policy starts to respond to compelling scientific evidence of danger, in the field of resources only win-win policies are seriously considered. Advocates of radical resource efficiency must find credible pathways that allow it to be pursued at scale in practice or hope that incremental change will open up space for more radical options, in order to avoid the significant economic and social disruption from supply-demand imbalances that some now fear.

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There is no shortage of concepts that aim to show how our economy can become more resource-efficient such as eco-innovation, cradle to cradle, etc. We analysed a long list of concepts using three dimensions: scope of change, ambition with regard to the (paradigmatic) degree of change, and the existence of plausible drivers and pathways of change. Reviewed literature on governance and transitions suggests that the more extensive and radical the scope and ambition of change are, the higher systemic and institutional resistance to change will be. From roughly 30 concepts reviewed, none gave a credible answer on how to overcome this dilemma. Resource scarcity is not (yet) a clear driver for change. Where in the field of climate change policy starts to respond to compelling scientific evidence of danger, in the field of resources only win-win policies are seriously considered. Advocates of radical resource efficiency must find credible pathways that allow it to be pursued at scale in practice or hope that incremental change will open up space for more radical options, in order to avoid the significant economic and social disruption from supply-demand imbalances that some now fear.

1 Introduction

In the last decade, resource efficiency and the related ambition of creating a circular economy has become a prominent topic on the sustainability agendas of particularly the EU (EC, 2014a), China (State Council, 2013) and Japan (MoE, 2006). More recently, this agenda received support from important societal stakeholders, such as the Ellen MacArthur Foundation (EMF, 2012, 2015) and the World Economic Forum (WEF; 2014). The ambition and scope of such a resource-efficiency and circularity agenda can be defined in different ways. Some interpretations of resource-efficiency go as far as to include the ability of nature to absorb pollution and waste, expanding this agenda to a wide range of environmental problems (EU, 2005). For the purpose of this paper, we focus on the efficient use of resources per se. We include both biotic and abiotic resources (cf. EMF, 2012). In this context, resource efficiency is usually defined as the useful material output related to (life cycle) material input (e.g. Dahlstrom and Ekins, 2005), or the monetary value of product/service output related to (life cycle) material input (e.g. EU, 2011). While the planetary boundaries for resource extraction still need refinement (cf. Rockstrom et al, 2009; Steffen et al, 2015), authors such as EMF (2012) and UNEP (2011) suggest that drastic improvements in resource efficiency are required to enable future economic growth, and/or that absolute reductions of resource use should be pursued. EMF (2012, 2015) calls this a 'resource revolution'.

In the last decades, many concepts in the field of sustainability have been proposed that (amongst others) aim to show how economies can become more resource-efficient. Examples include industrial ecology, eco-innovation, cradle to cradle, transition management, beyond GDP, eco-efficiency, and a couple of dozen others. Some of these concepts, especially the more radical ones such as de-growth, go beyond resource efficiency in their scale of envisaged change, but for all of

them increased resource efficiency is a major objective, and therefore the term is used in this paper to include these concepts as well. One concept, which is more or less synonymous with resource efficiency, is decoupling, which, in the formulation of UNEP (2011, 2014a) signifies that resource use and/or environmental impacts are increasing less fast than GDP (relative decoupling) or actually declining while GDP continues to grow (absolute decoupling). It can be seen that decoupling is a necessary characteristic of increased resource efficiency as defined in the previous paragraph, so that in the categorisation that follows increased resource efficiency and decoupling are treated together.

This paper evaluates the potential of these concepts to guide how to achieve radical resource-efficiency improvements. For this, the concept must address broad areas of society, be radical in nature, but, most importantly, also offer clear guidance as to how incentives for change can be implemented. Yet, as will be seen, the literature on governance and transitions suggests that the more extensive and radical the scope and ambition of change are, the greater will be the systemic and institutional resistance to change. The evaluation is done via the following steps

- Section 2 analyses as background how the literature discusses how momentum for change towards resource-efficiency may be brought about
- Section 3 reviews a number of existing classifications of concepts related to eco-efficiency, sustainability and resource efficiency (including these terms themselves), and derives the analytical framework used in this paper
- Section 4 scores some 30 concepts on the dimensions of this framework
- Section 5 provides a discussion and conclusions.

2 Changes to circularity and resource efficiency– what factors create momentum?

2.1 Factors creating resistance to change

Changes to resource efficiency and circularity require incentives for the change to take place. Scholars in the field of innovation and transition management in this context commonly make a distinction between incremental changes and radical changes. Incremental changes usually marginally affect the overall system and are related to relatively limited gains. The potential for cost reduction by using resources more efficiently often is the main driver. Such changes however are unlikely to create radical reductions of resource use in society, nor bring about the overall transition to a circular economy.

The theory of transition management offers a helpful perspective to understand what helps and hinders more radical change processes in society, such as a radical improvement of resource efficiency and the transition to a circular economy (see e.g. the contributions in Elzen et al., 2004; see also Geels, 2002 and 2005 and Kemp, 2008). Such transition processes can be evolutionary, where the outcome is not planned in a significant way, or co-evolutionary and goal-oriented, where some vision of the end-state is guiding decision makers or orienting strategic decisions. Most authors analyzing such transition processes propose to use a multi-level, multi-actor, and multi-phase concept to describe the process of change or transition (e.g. Rotmans et al, 2001, Elzen et al., 2004; Geels, 2005; Kemp et al., 2007, Loorbach, 2014) .

The multi-level concept divides societal systems in three main levels.

- a macro- or landscape level, which is to be taken for granted on short- and medium term. It contains very or fairly stable factors such as geopolitical realities, widely held values, and stable megatrends (e.g. in the area of demography). It poses boundary conditions for the next level

(the regime) to evolve, and is hence normally a source of stability (with the exceptions when disruptive shocks at this level occur, such as wars and natural disasters)

- a regime level. The regime itself is an interdependent and co-evolving set of technologies, symbolic meanings, services, consumer practices, rules, financial relations and expectations. It is difficult to change one part without the rest. This dynamic equilibrium changes usually only incrementally. A simple example: you cannot put a hydrogen car on the road without hydrogen gas stations, new safety rules, maybe even new driving licence standards, etc.
- niches, where innovators can try out new consumption and production practices. It is however often difficult for niches to become mainstream, due to the stabilizing effects at regime and landscape level.

The multi-actor concept metaphorically points at the fact that systems have to be seen as socio-technical regimes: interrelations of existing technologies, knowledge, skill sets, routines, regulatory demands, policy preferences, available infrastructures, and prevailing cultural and symbolic meanings that usually cannot be changed independently, but must co-evolve.

The multi-phase concept stipulates that transitions go through distinct phases: a pre-development phase in which new practices are tested in niches, a take-off phase in which elements of the new regime challenge the old regime and start to break through, a (relatively short) acceleration phase in which the old regime starts to break down, and a stabilization phase in which the new regime has taken over. The take-off phase is crucial for the success of the transition or regime change, and needs a 'green light' at all levels: availability of promising elements of a new regime in niches, instability in the existing regime, and a growing incompatibility between regime and landscape.

Transition theory explains why intentional radical socio-technical change is so difficult. Both the landscape and regime levels guide developments. This dynamic equilibrium changes usually only incrementally. But the theory can also help to find tensions or 'cracks' in the system that can make stimulating changes easier. Such 'cracks' can be: internal tensions in the production-consumption regime, or misfit between regime and landscape, and can have a normative and operational dimension. Examples include a production structure evidently based on labor exploitations in the South (misfit with ethical meta-values), or a sector practising agriculture in greenhouses, that due to rising energy prices becomes too expensive (operational misfit).

When promising niches are available that have matured (deepened) and got connected (broadened), and at the same time 'cracks' develop or 'shocks' in the landscape occur, pressure on the regime may become so high that rapid change may become possible (niches 'scaling up'). The regime breaks down, and niches plus the remnants of the existing regime will develop new structures, which eventually will stabilise and form a new regime (cf. Geels, 2005; Kemp and van den Bosch, 2006).

2.2 Options for intentionally guiding change

We can roughly identify three approaches by which transitions can be stimulated – in our case the one to a resource efficient economy¹.

First, one can rely largely on market based instruments. The World Business Council for Sustainable Development (WBCSD), probably the most powerful and influential industry think tank on sustainability, even has a slogan that reflects this: 'Sustainability through the market' (WBCSD,

¹ As discussed by Tukker and Butter (2007), these approaches reflect the so-called individualist, hierarchist and egalitarian perspectives in Cultural Theory, see e.g. Thompson et al. (1990), and further discussion in Tukker et al. 2013

1999). The idea is that once perverse subsidies are abolished and the undesirable side-effects of our current production and consumption systems are internalized into the market prices, the market mechanisms will direct innovations in the correct, sustainable direction. This approach, using mainly market-based instruments is useful if one knows which changes to the market incentive system will change the behaviour of actors in the direction of more sustainability. The exact means or roadmap to the sustainability goal can in principle still be uncertain. This approach has the following limitations:

- Since this option implies that changes in the rules of the (market) game must be implemented, most importantly internalizing external costs, a party must have the power or legitimacy to make them.
- If there are strong impediments to change that cannot be overcome by financial incentives, this approach will not be effective.

The second approach relies heavily on top-down government. This type of approach to transition management is probably supported by those who call for a 'master plan' or 'Apollo-program' for saving the environment. It should consist of an all-encompassing effort with a lead role for the government in various fields to realize the necessary system innovations. In more moderate forms, the goals and planning are more indicative and the assessment of which means to use more participatory, but there is still a powerful central actor which can when necessary enforce progress of the process of change. The US space program launched by President Kennedy is one example. And though at terrible human costs, both the Soviet Union and China transformed themselves from mainly agricultural countries into industrial nations via a number of strong centrally organized 5-year plans, changing the structure and culture of their society in the process (Kennedy, 1988). This approach can be applied under the following conditions.

- First, there must be a party in the system that has the power or legitimacy to apply a hierarchist governance model.
- Second, it must be fairly clear which transition goals must be reached and which means are the most appropriate to do so. Under these conditions, a top-down planning approach can be an effective and efficient way to realize a transition.

The third approach relies more on bottom-up activities in society of front-runner companies, civil society, and progressive governments. Scholars representing this view try to understand how fundamental change can be fostered via 'radical incrementalism', 'variety and selection', 'connecting long term visions and goals to short-term implementation activities', and fostering 'coalitions of the willing' (e.g., Ostrom, 1990; Rotmans et al., 2001; Hajer, 2011). The idea is that bottom-up initiatives will experiment with socio-technical innovations in a domain where a transition is desired, creating niches of change. Over time, this may lead to a situation where niches are capable to outcompete mainstream systems via the market based mechanisms of the first approach, or that gradually more critical mass for policy support for change is created, which then allows to apply the more top-down approaches from the second approach (Tukker and Butter, 2007). Noteworthy initiatives include the World Economic Forum, with various agenda councils related to climate change, water and urban sustainability, the Global Compact, and initiatives such as Transition Towns and the Dutch action organization Urgenda. The real question is how these largely bottom-up initiatives can ultimately be channeled and consolidated into lasting change. Otherwise, these noteworthy initiatives will end up being little more than repetitive meetings where good ideas are presented, ideas that, in the absence of institutional adjustments, cannot compete with the mainstream way of doing things and, hence, remain in their niches.²

² Even those who claim that we should build less on top-down agreements and foster and trust the 'energetic society' more (Hajer, 2011) acknowledge that there is a role for authorities: 'Authorities should give clarity (...). Then investors will dare to invest. Offer them certainty. Create new green accounting rules. Abolish subsidies that prevent innovation and keep us in the 20th century'. Maarten Hajer, column based on a presentation

2.3 Reflection: can a resource revolution be realized without absolute scarcity as an incentive?

Section 2.2 indicates that creating a trajectory of radical change to a resource-efficient society is no easy matter. Market-based and top-down approaches both require a government that is legitimized to enforce change – either in the form of creating market-based instruments and incentives or regulation. Bottom-up initiatives either must become winners in a market via a more or less autonomous innovation process, or at some point get enough policy support to enforce implementation, to avoid dying out in their niches. Creating such levels of policy support is difficult and time consuming – interests diverge (Nelkin, 1984), beliefs about what is desirable or not differ (Sabatier, 1987), and some discourses are more dominant than others (Hajer, 1995). Powers between actor coalitions that represent these interests, beliefs and discourses are unevenly distributed (Sabatier and Jenkins-Smith, 1993). All this hampers sustainability transitions in general, including that to a radically more resource efficient society. In the resources domain, the case for resource efficiency is still mainly made to point at possible economic win-wins (saving resources saves money), or that resource-efficiency and circularity are an answer to resource scarcity and price volatility of resources (e.g. EMF, 2012; Bastein et al., 2013; WBCSD, 2016).

It is however questionable whether the resource scarcity argument will drive a radical change to resource-efficiency in the near future³. Table 2.1, based on an evaluation of Tukker (2013), suggests the following:

- a) Fossil energy materials. Given the climate challenge there is in principle a need for a radical reduction in their use, or, rather, the impacts of their use, with around a factor 10 reduction in carbon emissions required by 2050. This radical reduction however will only take place if enough political will materialises to really embark on strong and radical climate policies (IEA, , Shell, 2016). Even despite the COP21 in Paris it is questionable if this will happen. It is further unlikely that absolute scarcity of fossil energy will become a bottleneck in the next few decades, significant amounts of coal, oil and (shale) gas being still available (McGlade and Ekins 2015).
- b) Building and construction materials. Apart from materials that during their production create significant emissions of carbon (e.g. cement, steel, aluminium), there is no clear sign that resource or emission constraints will lead to a need to limit their use. Localised problems in e.g. densely populated areas apart, they are abundant⁴. Any pressure on the use of materials such as cement, steel and aluminium seems most likely to come from climate policies, rather than from a greater desire for resource efficiency.
- c) Metal ores and industrial minerals. Here we encounter a very mixed situation, where some materials may indeed see absolute scarcity in the next decades, but where in most cases supply disruptions are caused by geopolitical factors or market instabilities rather than real scarcity⁵. In

during the meeting 'Rio aan de Maas' (Rio on the Meuse'), 'Rio as global fair', 30 May 2012, as published on <http://www.pbl.nl/node/55684> (accessed 14 August 2012).

³ One reviewer suggested that impacts of resource use would create the driver for radical changes to resource efficiency. We question this argument. In Europe for instance, resource use has grown significantly in the last decades, while apart from carbon emissions most environmental pressures were reduced (EEA, 2015). Even in cases where higher resource use almost inevitably leads to higher environmental pressures, such as in the case of climate change in relation to fossil fuel use, policy legitimation and action took decades to develop. It is hence questionable that pointing at the impacts of resource use will provide sufficient policy legitimation to embark on a resource efficiency policy that is radical and may hurt interests of the current mainstream actors.

⁴ But see UNEP 2014b for early signs that sand may be starting to be scarce in some places

⁵ A clear example of this is provided by Rare Earth Elements. In 2002 low prices of Chinese mines next to environmental problems led to closure of the only Western mine left, the US Mountain Pass mine, that had dominated supply for decades. The total value of REE materials mined annually was less than 1 billion US\$ at the time. Although demand was expected to rise, the level to which was uncertain, and the (minor) mining

such cases, simply learning better how to manage a market characterised by uncertainties in future demand and long lead times for opening mines, and dealing with geopolitical factors, can reduce many of the problems that exist today.

- d) Biotic materials, in relation to land and water use. The extraction of biotic materials is mainly limited by water and land use constraints in relation to biodiversity impacts. Population growth, diet changes and the use of biofuels all are likely to lead to the need for a higher production of biomass in future. Without efficiency improvements, this will lead to pressure on land use, biodiversity loss, and a water shortage of 30% by 2030 (e.g. Water Resources Group, 2009; Nature, 2010). These sources however also suggest such problems can be overcome by a Factor 2 improvement of land and water-efficiency by 2050, or 2% per year. While this certainly is a challenge, it is probably one that can be realised by incremental rather than radical innovations and changes.

Although there are obviously linkages between these resource categories, such as that a more productive agriculture may require more energy input (Graedel and van der Voet, 2010), the overall picture is that in the next decades scarcity will not be a transition driver. Yet, since transitions take a long time, and resources on Earth are indeed finite and may become scarce in the long term, it may be useful to start working immediately on a transition to radically more efficient resource use and a circular economy. A key question, however, is how to do this when for many resources there seems still ample scope to enhance production, and a critical mass and legitimisation of government for interventions other than in support of cost reduction and enhanced competitiveness is lacking.

companies in the West simply could not take the risk nor attract the capital to anticipate this new demand by opening new mines. Around 2007, China foresaw that it needed most of the nationally mined REE for its own industry, and started to reduce exports which led subsequently to a supply crisis in the West – high price volatility, price hikes. etc. Only then the West scrambled to see if new mines could be opened on the shortest possible notice – which given the long lead time to open mines would still take years. Given the fact that proven reserves of REE that can be mined economically are 800 times annual use, this crisis clearly has nothing to do with scarcity (Tukker, 2014).

Table 2.1: Potential resource constraints by material category usually discerned in economy wide Material Flow Analysis (elaborated from Tukker, 2013)

Type of resource	Fraction of global resource extraction	Basis for planetary limits	Potential limit	Reference
Fossil fuels	20%	Absolute scarcity CO ₂ emission targets	EU greenhouse gas (GHG) targets (20-20-20 or 30% reduction by 2020) Scientific targets (>80% reduction by 2050)	IPCC (2007; 2013), Meinshausen et al. (2009).
Metal ores and industrial minerals	10%	Absolute scarcity (varies by metal). Most metal ores need high levels of energy to be transformed, implying a 'linkage' to CO ₂ emission targets and energy constraints	Focus on 14 critical raw materials identified in the Raw Materials Initiative. Changes in energy and mobility infrastructure (solar cells, batteries) determine future criticality	EC (2014b). For linkages with energy use, see Graedel and Van der Voet (2010).
Non-metallic minerals (mainly building materials)	40%	With the possible exception of sand, absolute scarcity seems irrelevant, except in densely populated areas where space for mining for these minerals is limited.	Implicit targets for non-metallic minerals that need high levels of energy in their production (e.g., cement, ceramics) and linkages to land use targets (e.g. soil sealing)	For linkages: e.g. Hanle et al. (2006) at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf (accessed 21 May 2017)
Biomass, in relation to land and water use	30%	Maximum human appropriation of net primary production of biomass (HANPP), the available bioproductive land taking into account reservation for nature areas, and the renewable supply of water by region	Currently, 30%-35% of available biomass is extracted by humans. Target may be stabilization or minor growth. As for land use which is dominated by agriculture, there is conflicting information whether efficiency growth in agriculture will avoid land shortage in future. For water, a global 'water gap' of 30% is expected in 2030	Vitusek et al. (1986), Haberl et al. (2007). Erb et al. (2009), OECD/FAO (2009), Nature (2010); Hoekstra and Chapagain (2007), Water resources group/McKinsey (2009).

3 Dimensions for analyzing sustainability and resource-efficiency concepts

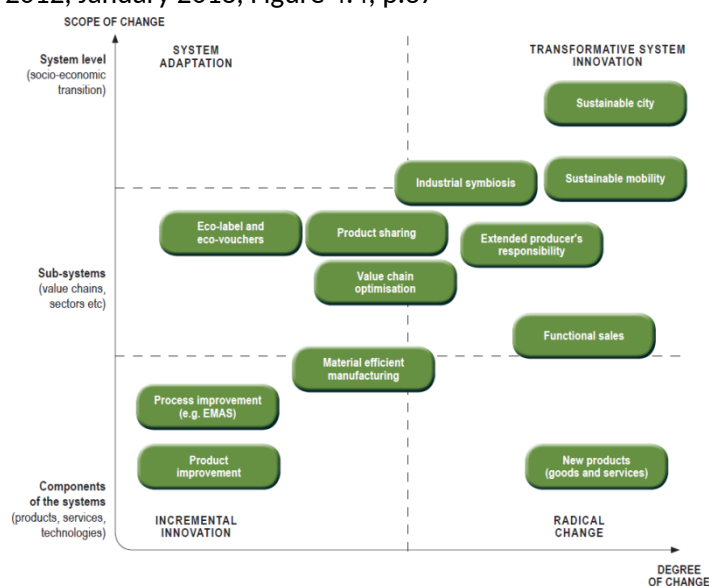
3.1 Introduction

In the past, various authors have reviewed strategies that can guide a transition of our economic system of production and consumption towards a higher level of eco-efficiency, resource efficiency and/or sustainability. In doing so, they have proposed various key dimensions that can characterize such strategies. This section reviews a number of such classifications, most notably from the EU Eco-Innovation Observatory (Eco-Innovation Observatory, 2013), the OECD’s work on eco-innovation (OECD, 2009), work of GWS on ‘Green growth’ strategies (GWS, 2013) and others (Hopwood et al, 2005; Tukker and Tischner, 2006). In this analysis, we did not strive for a comprehensive review of all classifications that may have been developed in the past. We did however use the classifications that have been developed under assignments of dominant policy actors, such as the German government, the EU and the OECD, which we think is an appropriate sample to build our own classification upon. We review these classifications in section 3.2 and on this basis, develop our own classification in section 3.3.

3.2 Dimensions used in earlier studies

The first conceptualization we show is one developed by the European Eco-Innovation Observatory (2013). They use this to classify eco-innovation concepts such as industrial symbiosis, product improvements, and extended producer responsibility. This conceptualisation discerns two dimensions: the degree of change (system adaptation, or systems transformation), and the scope of the system that is changed (system components such as individual technologies or products; sub-systems such as value chains; or transformations of major parts of society, such as the energy system, the urban system, etc.). This then leads to a classification as in Figure 3.1, discerning four quadrants: incremental innovation, radical change, system adaptation and transformative system innovation.

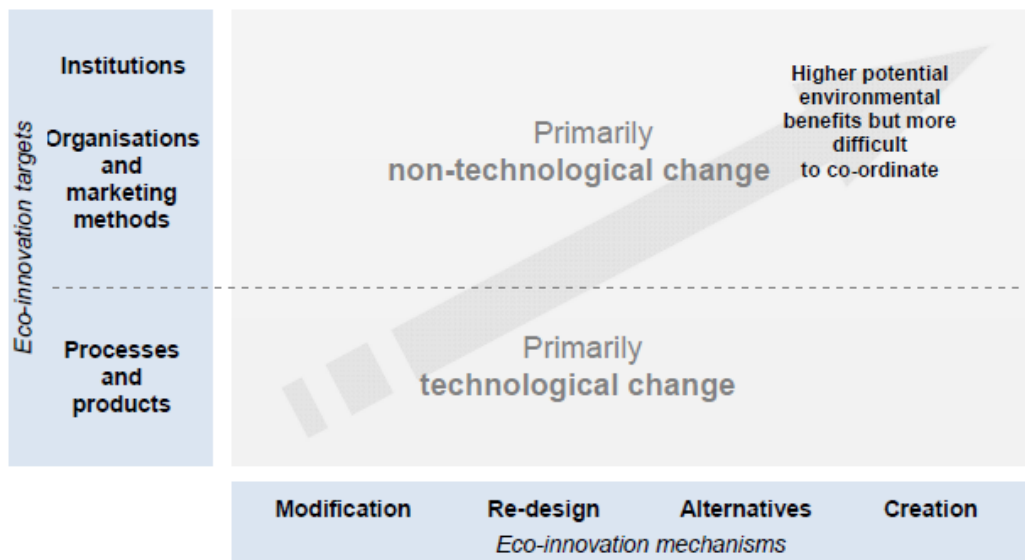
Figure 3.1: Classification of eco-innovations from the EU Eco-innovation observatory; Annual Report 2012, January 2013, Figure 4.4, p.37 ⁶



⁶ See: http://www.eco-innovation.eu/index.php?option=com_content&view=article&id=629:europa-in-transition&catid=80:annual-reports&Itemid=293, accessed 25 May 2017

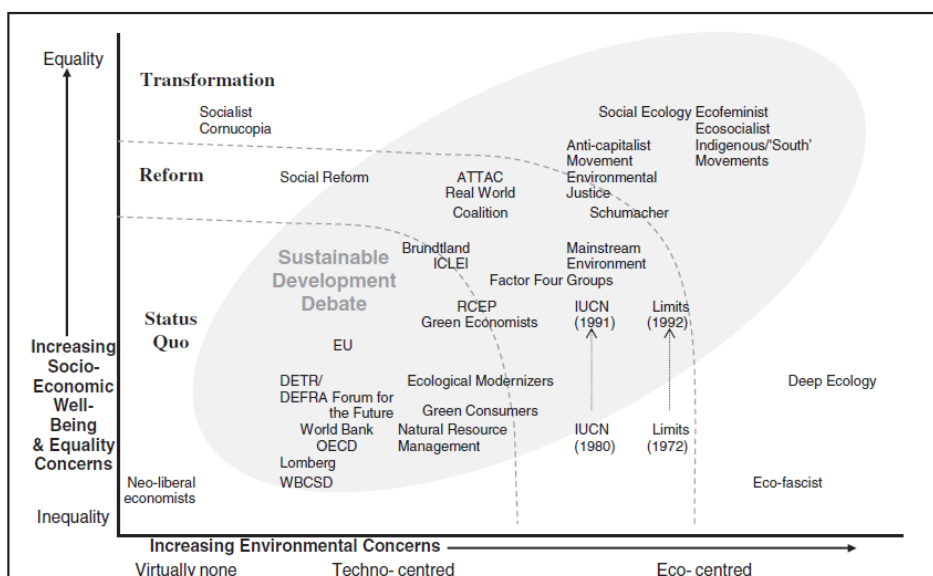
A second classification of eco-innovations is given by the OECD (2009) in its Sustainable Manufacturing and Eco-Innovation Synthesis Report (see Figure 3.2). The x-axis resembles very much a parameter that is also used by the EU Eco-innovation observatory: modification of existing systems or creation of fully new systems. The y-axis however looks at elements of the system that is targeted, rather than the scope of change of the system: products and processes, organisation and marketing methods, or institutions. The OECD uses this to identify if change is mainly of a technical or non-technical nature.

3.2: A typology of eco-innovations (Figure 4, p.13, OECD, 2009)



Lombardi et al. (2011) use a classification of Hopwood et al. (2005) to organise various views on sustainable development. Again, the x-axis gives the level of transformation required, but focuses on the environmental aspect of sustainability only. The y-axis covers the level of importance given to human well-being and equality, and is hence clearly of a socio-economic nature.

Figure 3.3 Mapping of views on sustainable development from Hopwood et al. (2005, figure 1, p.41)

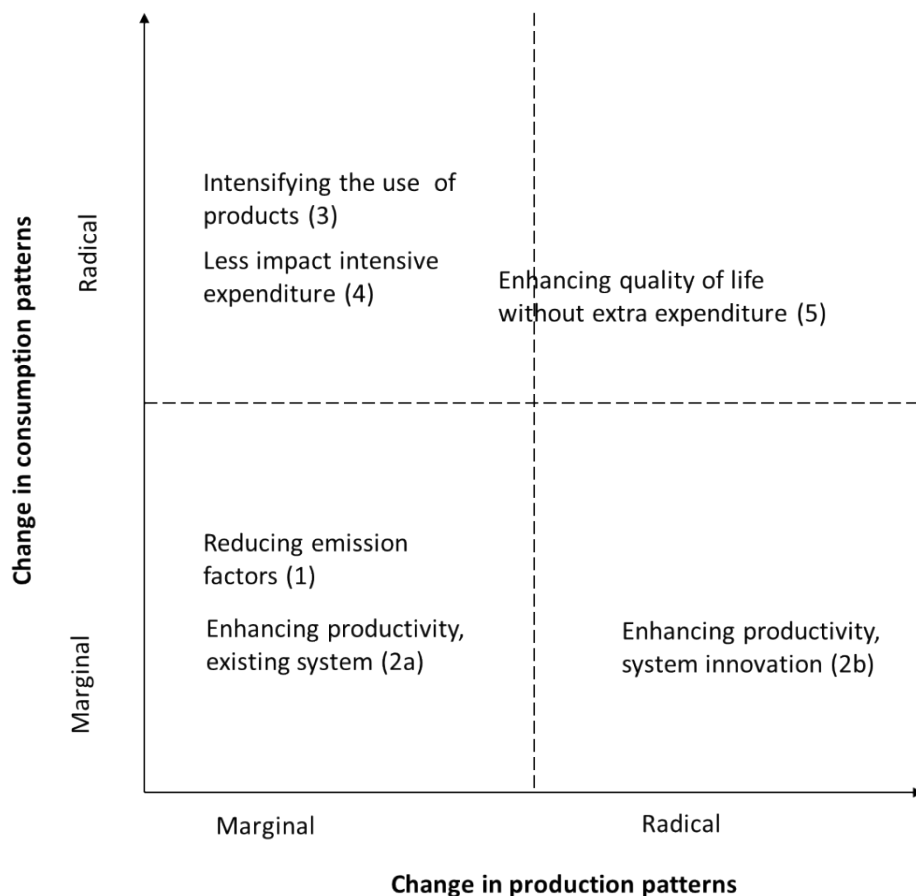


Tukker and Tischner (2006) identify five main intervention points along the production-consumption chain that each can improve the environmental performance of our economic system. In short it concerns (cf Tukker et al, 2010)

- 1: End of pipe / reducing emission factors
- 2a: Enhancing productivity of existing systems - greening production processes and products
- 2b: Enhancing productivity via system innovations – similar to 2a, but creating ‘Factor X’ improvements via system innovation of products and processes;
- 3: Intensifying the use of products, e.g. via product-service systems
- 4: Enhancing immaterial consumption / less impact intensive expenditure;
- 5: Enhancing quality of life without additional expenditure.

These improvement strategies now can be plotted on two axes: whether they address production or consumption and whether they are radical or incremental (see Figure 3.4)

Figure 3.4: Level of change in production and consumption patterns in relation to different decoupling strategies (Tukker and Tischner, 2006)



Finally, GWS (2013) developed a classification of about two dozen ‘Green Growth’ strategies. They used about 16 guiding questions related to (a) environmental, economic and social impacts, (b) possible structural economic change, (c) underestimated future welfare impacts and (d) supportive institutional foundations and political constellations. The answers on these questions allowed them to map each concept in a three dimensional framework that discerns an economic, environmental, and social axis, reflecting the extent to which each concept emphasises economic growth, the viability of ecosystems, and the social quality of societies.

3.3 Evaluation dimensions used in this paper

When comparing the evaluative frameworks discussed in the former section, the following can be observed. The Eco-Innovation Observatory uses as dimensions the Scope of change (system components or systems) and the Degree of change (in terms of incremental and radical). The OECD again uses Scope of change but then different system elements as targets. Tukker and Tischner also use the Scope of change as parameter, distinguishing between production and consumption, next to the Degree of change (incremental and radical). Hopwood et al. use a social and environmental dimension in combination with Degree of change. The GWS classification is somewhat more complex, with the Degree of change along each of the environmental, social and economic dimensions.

As the GWS study indicates it is not difficult to end up with dozens of criteria in respect of which new concepts with regard to resource efficiency can be evaluated. A drawback of using many criteria is that one easily loses oversight. We hence prefer to reduce the number of criteria or parameters to a maximum of three. On the basis of the above we decided that for the analysis in this paper at least the following dimensions are relevant, and propose to use a 3-point scale to define positions on these dimensions:

Scope of change. This plays a role in virtually all classification systems discussed in section 3.2, and seems also relevant given the long list of concepts mentioned in the introduction. Some concepts focus on parts of the value chain, such as responsible mining. Others aim at transforming whole systems. We propose to classify initiatives in one of the following three categories, which we will later use as ranked levels in the evaluation:

- Scope is a specific industry sector (e.g. mining)
- Scope is a value chain
- Scope is societal system or large (sub)-systems thereof (e.g. food, energy, mobility)

Ambition with regard to the (paradigmatic) degree of change. This resembles the degree of change found in many of the classification systems listed above, but deliberately adds the adjective 'paradigmatic' to it. Currently the sustainability discussion in general and the resource efficiency discussion in particular is often still framed in the utilitarian, economic rationality that has dominated Western society since enlightenment and the industrial revolution. Many concepts simply still adhere to this existing paradigm. Other concepts however see the existing paradigm as a root cause of the sustainability problem, and hence argue that an upheaval in values, institutions, etc. is essential, towards a direction that some have dubbed a 'Buddhist Economics' that is focused on human development, economic processes at a smaller and more regional scale, etc. (Schumacher, 1973). This goes significantly further than the differentiation between incremental and radical change, which is often just focused on technical aspects. We see further that within the existing paradigm of utilitarian, economic rationality of use of nature there is a differentiation between approaches that emphasise predominantly the business opportunities and benefits for being resource efficient - the role of authorities then simply is to remove market failures - and approaches that see also a threat to public goods - with authorities then having a role of protecting them. This leads then to the following three categories which we will later use as ranked levels in the evaluation:

- No paradigmatic change, focus on market-based solutions
- Intermediate paradigmatic change in the sense that there is a recognition of the 'public good' character of resource-related problems that need government intervention
- Fundamental paradigmatic change, the concept clearly calls for a revolution in our economic system, related values, institutions, etc.

Explicit attention to the plausibility of pathways of change. This dimension is in fact fully absent from most of the classifications reviewed in section 3.2 – only the GWS guiding questions include topics like the potential of institutions and political constellations. Our discussion in chapter 2 shows it is essential to have an understanding how far-reaching, radical changes can be actively fostered. Major historical changes like a ‘resource revolution’ do not happen automatically. Particularly with regard to radical, paradigmatic changes, Kuhn (1962) already noted that these are not frequent and only happen when the existing paradigm is about to become untenable. Concepts that respond to specified driving forces, or provide a clear pathway or formula as to how change must come about hence have value over concepts that don’t. Factors that may help or hinder shaping a ‘resource revolution’ include a proven (physical or geopolitical) scarcity of resources; technological momentum, social momentum, and institutional momentum. We would propose the following three categories to classify concepts on this dimension which we will later use as ranked levels in the evaluation:

- The concept ignores important factors that make the proposed change difficult or impossible to achieve, or is fully silent on the pathway of change;
- The concept only shows vaguely why change is needed or via what mechanisms it could occur
- The concept is clear in identifying pathways for change

4 Assessment of sustainability and resource-efficiency concepts

4.1 Materials and methods

For the purpose of this study, an inventory was made of around 30 widely used sustainability concepts that include a more efficient use of resources in their scope. The ambition was to cover a large sample of widely used concepts, rather than to be fully comprehensive. We based ourselves amongst others on listings in the literature from the former section from which we derived the dimensions on which the concepts should be evaluated (e.g. Hopwood et al. (2005), OECD (2009) Lombardi et al. (2011), Eco-Innovation Observatory (2013) and GWS (2013)). The list was reviewed and complemented by 5-6 members of the study team from 5 different institutes in 4 different countries. While the final list inevitably is somewhat arbitrary, this procedure ensures it does contain a large number of the most used concepts.

For each concept reviewed, a short literature analysis was done, resulting in a one-to-two- page description of the concept on the following aspects:

1. The concept in brief: main aim, origins/authors, and history/impact
2. Scope of change
3. Ambition of change
4. Pathway of change
5. Actors addressed and if it mainly focuses on environmental, social and/or economic aspects

Each concept was assessed on the three dimensions discussed in the former section: scope of change, paradigmatic degree of change, and plausibility of pathways of change. For this, a simple scoring table was developed as depicted in Table 4.1., simply using the three levels defined in section 3.3, giving a -1 in case of a low score, a 0 in case of a medium score, and a + 1 in case of a high score.

The descriptions are provided as supplementary information (SI) to this paper. Each description ends with a scoring table in which the cells in Figure 4.1 reflecting the score for the reviewed concept were made grey. For the analysis, the mapping was performed and cross-checked by again the 5-6

aforementioned people in the study team. Differences in opinion on mappings were circulated and discussed in a phone meeting, in which a consensus mapping was reached. One can always debate if such qualitative scoring approaches using expert panels are sufficiently robust. However, it may be noted that the panel used comprised scientists with rather different scientific and cultural backgrounds, and the consensus mapping was concluded without disagreement. While acknowledging that assessment procedures like the one applied always have some residual level of subjectivity, the results are in our view sufficiently robust to be used in the analysis performed.

Table 4.1: Classification dimensions and scoring criteria

	Low (-1)	Medium (0)	High (+1)
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change difficult/does not discuss change	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

4.2 Results of the assessment

The results of the scoring procedure are summarized in Table 4.2. Of course for realising real radical changes towards for resource-efficiency one would like to see concepts that score high (+1) on all aspects. Radical changes towards resource-efficiency must after all

- a) Address societal sub-systems rather than single value chains or an individual industry; the volume of change otherwise simply will be too low;
- b) Have a high level of paradigmatic degree of change;
- c) Have a high plausibility of pathways of change, since otherwise the concept gives no clue as to how change will happen.

Against this background, we presented the results in two other tables, i.e. one that lists all concepts scoring +1 on paradigmatic degree of change (all but one of which score +1 on the scope of change as well), and one that lists all concepts that score +1 on plausibility of pathways of change. Tables 4.2-4.4 lead to the following, somewhat sobering findings:

- a) There is not any concept scoring +1 on all aspects. Or, in other words, there is not any concept that aims at changes at societal level, that is radical and paradigmatic, and that at the same time provides a clear and plausible pathway of change.
- b) We see further that by far the most concepts that have a credible/plausible pathway of change in fact do not aim at a high level of paradigmatic change. Indeed, most concepts (extended producer responsibility, supply chain management, green growth, cleaner production, pollution prevention pays and eco-efficiency) simply assume that changes will be driven by win-win concepts, while it is well-known that changes based on such drivers tend to be incremental.
- c) Conversely, we see that concepts aiming at a high level of paradigmatic change at best have a conceptual explanation of factors that might bring this change about.

It therefore seems that all the concepts analysed in fact just managed to be convincing on one or two of the three aspects relevant for far-reaching change.

4.3 Implications

While as discussed there may be dispute about the individual scores in the tables provided, this overall finding is in fact very much in line with a message system innovation and transition scholars have conveyed for decades. Radical and paradigmatic change implies a shift away from existing socio-economic trajectories, the related infrastructure and sunk costs, routines, and hence also a shift to new parties dominating the system. Resistance to such change is hence significant, as exemplified by e.g. the almost continuous failure of sustainability summits like Rio+20 (2012), the COPs in Copenhagen (2009), Durban (2011), etc. 'New concepts' like Degrowth, Ecological economics and Small is beautiful hence may point at new ideas for organising society in a sustainable or resource-efficient manner, but simply having an appealing idea - even if embraced by various groups in society - is nothing like sufficient to foster revolutions that can overcome the resisting powers mentioned earlier. This suggests that, in line with insights from the transition management approach, the existing system and parties with power in it must already be under significant pressure before they 'crack' and a real revolution becomes possible.

Table 4.2: Mapping of concepts

No		Scope of change	Paradigmatic degree	Plausibility of paths
1	Industrial Ecology	1	-1	0
2	Industrial Symbiosis	0	-1	0
3	Waste Prevention	0	0	1
4	Extended Producer Responsibility (EPR)	0	-1	1
5	Supply chain management	0	-1	1
6	Leasing society	1	1	-1
7	Ecological economics	1	1	0
8	Natural step	1	1	0
9	Weak sustainability	1	-1	1
10	Strong sustainability	1	0	1
11	Small is beautiful	1	1	0
12	Eco Innovation	1	0	1
13	Transition management	1	0	0
14	Green growth	1	-1	1
15	Green economy	1	0	1
16	Beyond GDP	1	-1	0
17	Cleaner production	0	-1	1
18	Eco-efficiency	0	-1	1
19	Decoupling/(Increased) resource efficiency	0	0	0
20	Pollution prevention pays	0	-1	1
21	Sustainable consumption and production	1	0	0
22	Product service systems	1	1	0
23	Circular Economy	1	-1	0
24	3Rs (reduce, re-use, recycle)	1	-1	0
25	De-growth	1	1	0
26	Resilience, safe operating space	1	1	0
27	Hannover principles	-1	1	-1
28	BoP ⁷ business models	0	-1	0
29	Leapfrogging	0	0	0
30	Slow food, transition towns	1	1	0

⁷ Base of the Pyramid (BoP) business models focus on transforming the informal dysfunctional markets, and therefore the whole economic system, of the poorest socio-economic group.

Table 4.3: Concepts with a high plausibility of pathways of change

	Scope of change	Paradigmatic degree	Plausibility of paths
Waste Prevention	0	0	1
Extended producer responsibility	0	-1	1
Supply chain management	0	-1	1
Weak sustainability	1	-1	1
Strong sustainability	1	0	1
Eco Innovation	1	0	1
Green growth	1	-1	1
Green economy	1	0	1
Cleaner production	0	-1	1
Eco-efficiency	0	-1	1
Pollution prevention pays	0	-1	1

Table 4.4: Concepts with a high paradigmatic degree of change

	Scope of change	Paradigmatic degree	Plausibility of paths
Ecological economics	1	1	0
Natural step	1	1	0
Small is beautiful	1	1	0
Product-service systems	1	1	0
De-growth	1	1	0
Resilience, Safe Operating Space	1	1	0
Slow food, transition towns	1	1	0
Leasing society	1	1	-1
Hannover principles	-1	1	-1

5 Discussion and conclusions

This paper evaluated about 30 concepts supportive of the resource efficiency agenda, such as degrowth, the circular economy, green growth, and cleaner production. For each concept our study analysed whether it addressed a small or main part of society, whether the proposed change would be incremental or radical, and whether it provided a credible pathway for pursuing this change. Our research found that concepts either provide

- a vision of far-reaching change, but fail to provide a plausible and credible pathway of how to realise this change, or
- a credible, win-win pathway for change, that upon a closer look is likely to result in incremental change rather than radical change.

This finding is consistent with literature on transitions and system innovations. Radical and paradigmatic changes move away from existing socio-economic regimes and the related infrastructure, sunk costs and routines, and the dominant parties maintaining such regimes. Resistance to far-reaching change is hence usually significant since existing regime players often have no, or a different position in a radically changed future. And, as analysed in chapter 2 (table 2.1), autonomous developments are unlikely to force such actors to embark on a 'resource revolution'. Drastic reduction of the use of fossil energy carriers will rely on strong climate policies. To meet the growing need for biomass without a rise of land and water use the challenge is an efficiency improvement of about 2% per year until 2050. For non-metallic minerals and metals the situation is differentiated - if they are on criticality lists, in most cases this is due to supply concentration problems rather than absolute scarcity (EC, 2014b). A business as usual scenario for resource use will have plenty of challenges including balancing resource supply and demand, managing volatility, and managing emission and waste problems related to resource extraction, but it is unclear if this will provide sufficient legitimacy for radical resource reduction policies.

Our contribution is hence mainly that we show all researched concepts fail to provide an answer to this crucial implementation question (or do not need to answer it, since the concept only aims at incremental change), Solid research into via which pathways radical changes to resource-efficiency can be fostered in the absence of scarcity or inherent unbearable pollution as a driving factor is hence essential. Creating yet another appealing concept that fails to explain how to overcome powers that resist radical change is useless.

Of course this is not at all to say that resource efficiency policies are pointless. UNEP (2016, 2017) shows that there are many opportunities for both economic and environmental benefits from the intelligent implementation of such policies. Moreover, resource efficiency policies can complement other environmental policies, such as those that reduce carbon emissions. For instance, UNEP 2016 (p.33) shows that a strong policy on resource efficiency could reduce global resource use by 17%, and increase global GDP by 1.6%, by 2050 compared to current trends. A combination of a strong climate policy with a strong resource efficiency policy could reduce global carbon emissions by 63% from 2015 levels, and those in G7 countries by 74% from 2015 levels - sufficient to meet the 2°C global average temperature target endorsed by the Paris Agreement at COP21 in December 2015. It is also uncontested that on the longer term, humanity is probably better off when moving towards a resource-efficient and circular economy. The Earth and its resources are finite. Continuing economic growth on a time span of over a century or more seems only viable by designing societal systems in such a way that resources are kept in closed loops (as long as this does not need significant energy or other resource inputs), or that they are based on massively abundant materials. Furthermore, as discussed the UNEP (2016, 2017) report shows that if policies for radical increases in resource efficiency could be implemented, they would generate greater environmental improvements at lower, and perhaps no, net cost for society as a whole.

The problem lies in the fact that to make this happen without directly present scarcity drivers, on the short term such change becomes a matter of societal and/or political will. The example of the climate issue shows us that such political will, even in the face of convincing scientific evidence of the urgent need for change, is anything but easy to generate, although the Paris Agreement at COP21 provides some evidence that policy makers may at last be taking the scientific evidence seriously. But in the absence of comparable evidence for the immediate need for radical increases in resource efficiency, and despite the evidence that many such increases could be economically and environmentally beneficial for society now, none of the concepts that have been created to promote resource efficiency seem to have the transformative power to significantly increase its rate of take-up. The uncertainties, policy makers' lack of willingness to intervene strongly in markets, and

resistance lobbying from those who themselves as likely to be losers from attempts to promote resource efficiency, have to date been enough to prevent serious progress on this issue.

There are four possible outcomes to this situation, expressed here in terms of the analytical framework described earlier.

The first is that those advocating radical increases in resource efficiency (for example, those in Table 4.4) will be able to postulate a credible and plausible pathway for its achievement that allows it to be pursued at scale in practice. The second is that incremental changes (for example, those in Table 4.3) will be implemented in a way that opens up economic, social, political or technological space for such changes to be pursued more radically, or for more radical changes to be adopted. The third possible outcome is that real physical resource scarcity or scarcities, currently largely unforeseen, will arise, that will enforce radical increases in resource efficiency. A variant of this outcome is that, notwithstanding current successes in decoupling such impacts from resource use to some extent, the socio-environmental impacts of continuation of current trends in resource use (e.g. conflicts about mining and waste disposal; conflicts about water and land use etc.) become more and more unbearable, also leading to radical increases in resource efficiency. A fourth possible outcome is that approaches based largely on 'business-as-usual' will allow such scarcities as arise to be addressed within the current paradigm, such that radical change proves to be unnecessary.

The resource efficiency agenda is hence at a crossroads. In the domain of climate policy, policy makers increasingly reject outcome 4 in favor of some combination of outcomes 1 and 2, in view of compelling scientific evidence of dangerous outcomes in a business as usual scenario (outcome 3). Attitudes to policy making on resource efficiency are still largely based on outcome 4. This leaves only the hope that such attempts at outcomes 1 and 2 as actually occur may make more radical approaches more acceptable before outcome 3 causes the significant economic and social disruption that some now fear.

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1 Concepts, classification and mapping of strategies

Within the project, a long list of concepts has been developed by UCL and WI, which was complemented by the other project partners. This list includes:

- industrial ecology,
- industrial symbiosis,
- waste prevention,
- priority waste streams,
- eco-innovation,
- transition management,
- green growth,
- green economy,
- ecosystem goods and services,
- capital approach: natural capital, inclusive sustainable growth
- novel approaches to multi-level (micro/meso/macro) governance.
- 'Beyond GDP'
- 'extended producer responsibility'
- supply chain management,
- cleaner production
- eco-efficiency,
- resource-efficiency aimed at reducing the impacts of industrial processes
- Pollution Prevention Pays
- Sustainable Consumption and Production
- Product-service systems
- circular economy
- lease society
- 3Rs
- de-growth
- resilience & safe operating space
- ecological economics
- Natural Step
- Hannover principles
- weak, strong and sensible sustainability
- BoP business models
- leapfrogging
- slow food, Transition Towns
- small is beautiful / appropriate technology

2 Description and classification of concepts

2.1 Industrial Ecology

	Description
Main aim / origins /history	The concept of industrial ecology (IE) proposes a system-oriented view to analyse the interactions between human and natural systems. In an attempt to minimize the impact of production and consumption processes on natural systems, " <i>IE seeks to optimize the total industrial materials cycle from virgin materials to the finished product to ultimate disposal of waste</i> " (Graedel, 1994). Generally, the origins of the concept are attributed to Frosch and Gallopoulos (1989) that in their seminal paper Strategies for Manufacturing, allude to what has been later termed as the " <i>ecological metaphor</i> ", the idea that industrial systems should mirror the efficiently functioning of natural systems, where waste of process becomes a resource for another process or organism. In the same year, Ayres (1989) published a paper on Industrial Metabolism defining some of the key ideas and pillars of the field. IE proposes a profound restructuring of production and consumption systems from a mainly linear design where raw materials are extracted from natural systems, transformed and consumed and then released to the biosphere, to a circular, closed-loop system where resources are cascaded and recycled within the system, " <i>favouring an industrial metabolism that results in reduced extraction of virgin materials, reduced loss of waste materials, and increased recycling of useful ones</i> " (Ayres, 1989).
Scope of change	The scope of change proposed is thus high involving all parts of the supply chain and the manufacturing and consumption systems as a whole. However, most of the research in the field has focused on production systems and business actors, while the analysis of consumption systems and individual behaviour has been insufficiently explored.
Paradigmatic degree of change	IE suggests a change of paradigm in the way human systems function and are organised, moving towards a more holistic paradigm where human systems are restructured following the principles that govern biological systems. However, the policy agenda of industrial ecology is underdeveloped and still contains a profound utilitarian-rational pose. Alternatives are mainly based on win-win solutions, where improvements in the efficiency of the system leads to economic gains.
Plausibility of pathways of change	The concept offers some clear guidance with regard to the necessary changes in the technical/production spheres but there is limited discussion of the societal changes this would imply. There have been some attempts to introduce social considerations to the transformation of industrial systems proposed (Binder, 2007). However, aspects such as social justice or equity are rarely addressed. Main actors leading the change are industrial actors and technology. The role of policy makers is set back to defining the appropriate institutional framework to allow for the changes operated in production and consumption system.
Actors addressed (industry, government, civil society) environment/social/economic aspects	Main actors addressed are industry and businesses from different supply chains and to a lesser extend consumers. The role of government is generally secondary to define the general framework for industrial actors cooperation. Environmental and economic dimensions are the focus of the approach, with little attention to the societal dimension.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change unnecessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.2 Industrial Symbiosis

	Description
Main aim/origins/history	<p>Within the field of industrial ecology, industrial symbiosis (IS) is principally concerned with the “<i>cyclical flow of resources through networks of businesses as a means of cooperatively approaching ecologically sustainable industrial activity</i>” (Chertow, 2000). Therefore, the emphasis of industrial symbiosis is on the interfirm interface, focusing on ways of resource optimisation based on collaboration among different industries and activities. The approach aims to overcome the traditional boundary of the organisation to achieve better environmental collective performance offered by a more global approach to material and energy flows. A comprehensive definition of the concept is offered by Chertow (2000): “<i>Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchanges of materials, energy, water and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity</i>”.</p> <p>Kalundborg (www.symbiosis.dk) is generally portrayed as the model of industrial symbiosis. The IS system created in Kalundborg involves a number of public and private companies that exchange waste products and process residuals in a closed cycle. The residual streams traded include steam, gases, heat, slurry, Gypsum, sulphur fertiliser among others. Kalundborg has become an example of how waste material from one company can become a raw material for another, generating substantial economic and environmental benefits. A growing number of examples of both planned and spontaneous IS networks have emerged in the last years contributing to the empirical foundations of the approach. China has launched recently large scale IS networks and eco-industrial parks pilot programmes as part of their circular economy strategy (Geng et al., 2009).</p>
Scope of change	The scope of change proposed under this approach is incremental, affecting primarily the organisation of production systems. Linear production systems need to be transformed into closed loop systems by promoting the recirculation of resources within the system.
Paradigmatic degree of change	The approach maintains a basically utilitarian and rational economic approach to nature, where win-win solutions drive the change towards more closed-loop systems of production and consumption. The paradigmatic degree of change can be thus considered as low, where business solutions are preferred though there is recognition of the basic dependence of production systems from the natural systems where they are embedded.
Plausibility of pathway of change	As in the field of industrial ecology, the plausibility of pathways of change is explored for production and technological systems but uncertainty persists regarding necessarily societal changes.
Actors addressed (industry, government, civil society) Environment / social / economic aspects	Industry and businesses are the main focus of the approach. The role of government, as in industrial ecology, is generally secondary, limited to define the general conditions for industrial actors cooperation. Environmental and economic dimensions are the focus of the approach, with little attention to the societal dimension.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change unnecessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.3 Waste prevention / priority waste streams

	Description
Main aim/origins/history	<p>Waste prevention alludes to the reduction in the volume of waste generated at source and its hazardous content and thus the minimization of the impact of waste on the environment. Waste prevention strategy is considered the highest priority of the waste management policy according to the “waste hierarchy” defined in the EU Waste Framework Directive (article 4). This hierarchy is however not cast in stone and informed deviations are possible if the environmental impacts are clearly lower. There is a direct connection between waste prevention and resource efficiency, as improving the efficiency with which resources are used should lead to reduction in the amount of waste generated. More than a normative concept, waste prevention is largely a legal-policy construct. Waste prevention, understood as waste reduction per capita, is one of the aspirational targets included in the <i>Roadmap to a resource efficient Europe</i>. Also, according to the revised Waste Framework Directive, member states should establish waste prevention plans by December 2013. Connected with waste prevention and, as part of the waste management policy, both EU and members states have defined a number of priority waste streams. Priority waste streams are selected according to their potential damage to the environment when they are disposed of or the potential energy and material savings associated with their reuse and recycling. Priority waste streams identified by the European Commission include: packaging waste, end-of-life vehicles, batteries, electrical and electronic waste, construction and demolition waste, waste oils and bio-waste. These waste streams are regulated by EU Directives (WFD and Extended Producer Responsibility schemes_ see definition) that establish requirements for their collection, reuse, recycling and disposal. The Circular Economy package of the EU (EC, 2015) sets new priority waste streams in the Action Plan (Plastics, food waste, construction waste, critical raw materials, and biobased wastes).</p>
Scope of change	<p>To be successful, any waste prevention strategy should be pursued at all levels of the supply chain and life cycle of a product or service from its initial design, manufacturing and production, distribution, consumption and final disposal. Strategies such as designing out waste and reuse of products and materials are mainly targeted at waste prevention. Although waste prevention implies changes in manufacturing processes and consumption patterns towards greener products, with less packaging, this strategy rarely implies a profound change or restructuring of manufacturing and consumption systems and thus the scope of change can be considered medium.</p>
Paradigmatic degree of change	<p>The paradigmatic degree of change of waste prevention strategies could be considered medium as well, as although there is an implicit recognition of the right of the governments to act to protect environmental goods and services, they do not provide an alternative to the predominant utilitarian and rational economic approach. Indeed, a combination of market based instruments and bans, targets and prohibitions constitute the bulk of the waste prevention legislative framework.</p>
Plausibility of pathway of change	<p>As an eminently practical approach, waste prevention explicitly identifies specific instruments to incentivise behavioural change by actors (industry, consumers) to influence their choices and promote waste reduction at source both qualitatively and quantitatively. These changes or mechanisms of change, however, do not generally involve paradigmatic changes of values and practices or explicit pathways of societal change but rather incremental changes to behavioural practices. While waste prevention can be seen as more fuzzy in nature as other approaches, there is a clear history in some EU member states of voluntary agreements or otherwise that have supported a reduction of waste (e.g. the waste prevention policies in the Netherlands in the 1990). We hence score viability and plausibility on +1</p>
Actors addressed (industry, government, civil society) Environment/social/economic aspects	<p>Main actors addressed by the approach include industry, consumers and governments. The role of government is to define the framework conditions and create the necessary incentives to waste prevention. Economic and environmental dimensions are the focus of the approach with less attention paid to societal aspects.</p>

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change unnecessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.4 Extended Producer Responsibility

	Description
Main aim/origins/history	<p>The concept of extended producer responsibility (EPR) involves a “<i>shift in the responsibility of the end of life management of products to producers</i>” (Lifset et al., 2013). A widely used definition of EPR is the one provided by the Organization for Economic Cooperation and Development (OECD, 2001), which refers to it as “<i>an environmental policy approach in which a producer’s responsibility for a product is extended to the post-consumer stage of a product’s life cycle</i>”. From the policy point of view, EPR schemes generally involve two related features (OECD, 2001): “(1) <i>the shifting of responsibility (physically and/or economically; fully or partially) upstream toward the producer and away from municipalities, and (2) (...) the incentives to producers to incorporate environmental considerations in the design of their products</i>”. The origins of EPR concept can be found in the early policy developments in Sweden and Germany in the early 1990s of EPR schemes that aimed at providing an integrated strategy to tackle eco-design of products and to internalize the economic costs of end-of-life management, shifting its financial burden from public authorities to producers and consumers. Although in most cases concrete policy manifestations of the EPR schemes have fallen short of the initial aims of the strategy to focus on the expansion and funding of post-consumer recycling, EPR should in principle contribute to advance towards closing the loop of materials and resources and thus to enhance resource efficiency. Currently, the EU has introduced EPR schemes covering the following waste streams: batteries (Batteries Directive 2006/66/EC), packaging (Packaging Directive 94/62/EC), vehicles (end-of-life Vehicles Directive 2000/53/EC), electrical and electronic equipment (WEEE Directive 2002/96/EC). The recast of the waste framework directive (2008/98/EC) also includes a general provision to support the “design and production of goods which take into full account and facilitate the efficient use of resources during their whole life-cycle including their repair, re-use, disassembly and recycling”. Article 8 from chapter II (General Requirements) specifically encourages Member States (MSs) to take legislative or non-legislative measures to ensure that producers of products have extended producer responsibility, including measures to accept returned products at the end of their use life and the waste associated with them. Producers should also have the financial responsibility associated with those activities. The directive also encourage MSs to take measures to ensure that design of products incorporate principles of environmental impact and waste minimisation and that, where possible, they are suitable for multiple uses and durable and suitable for proper and safe recovery at the end of their useful life.</p>
Scope of change	<p>EPR schemes, by creating a link between the products and the producers at the end of their use life, introduce significant changes to various parts of the supply chain, including, in some cases, reverse logistics and take back systems, to revert to the manufacturer the product at the end of its use-life. The scope of change can thus be considered medium.</p>
Paradigmatic degree of change	<p>Regarding the paradigmatic degree of change, even though it could be argued that different manifestations of EPR could lead to significantly divergent results in terms of paradigmatic changes operated at the core of the manufacturing system, the concept does primarily rely on the predominant utilitarian and rational paradigm in most of its current manifestations with a focus on internalizing the costs of end-of-life management. Moreover, the way schemes have been implemented at present are too fragmented to achieve a profound widespread effect on the manufacturing system.</p>
Plausibility of pathway of change	<p>The concept addresses real-life driving forces, such as resource scarcity, and provide clear pathways of change through the introduction of reduction targets, materials bans and market-based instruments to improve end-of-life management of products. Different initiatives and schemes tackling a variety of waste streams (batteries, vehicles, electronic waste) exist both at the EU and at the international level (Canada), which demonstrate the practical dimension of the concept. The drivers to introduce changes in the responsibility of end of life management are explicitly specified by EPR schemes. Also as a policy instrument, EPR contains prescriptive measures</p>

	to bring about the change required, detailing aspects of the end-of-life collection, reuse and recycling and disposal. Some schemes also incorporate prescriptive measures upstream at the design stage, such as prohibition to use certain substance or materials or percentage of recycle content. However, as a technical instrument, EPR does not address societal pathways of change.
Actors addressed (industry, government, civil society) Environment / social / economic aspects	Main actors addressed by the concept include industry, end consumers and government. The role of the government is generally to define the framework conditions in which EPR schemes work, while industry and end consumers have a more active role in defining the operation of those systems.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change unnecessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.5 Supply chain management

	Description
Main aim/origins/history	The increasing complexity of supply chains and global scale of sourcing, purchasing, manufacturing and distribution activities explain the growing corporate, academic and policy interest in sustainable supply chain management. According to Handfield and Nichols (1999), <i>“the supply chain encompasses all activities associated with the flow and transformation of goods from raw materials stage (extraction), through to the end user, as well as the associated information flows. Material and information flow both up and down the supply chain”</i> . Consequently, supply chain management (SCM) can be defined as <i>“the integration of these activities through improved supply chain relationships to achieve a sustainable competitive advantage”</i> (Handfield and Nichols, 1999). Increasing pressure to control and enhance the social and environmental dimensions along supply chains have led in recent years to the concept of green or sustainable supply chain management. Sustainable supply management can be defined as the <i>“management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements”</i> (Seuring and Mueller, 2008).
Scope of change	As an integrative approach to supply chain management, the concept addresses all stages of the supply chain from the sourcing of the materials to the distribution and sale of the final product/ service. The scope of change can thus be considered medium.
Paradigmatic degree of change	Although, there may be an implicit recognition of the public good character of environmental goods and services that need to be protected and preserved along the supply chain through closer cooperation and interconnection among primarily business actors, the approach relies on the predominant utilitarian and rational paradigm to nature and resources, where win-win solutions drive the change to existing practices.
Plausibility of pathway of change	Pathways of change and drivers are identified and play a significant role in introducing practical improvements in the management of supply chains incorporating principles of environmental protection and safeguarding and social justice and equity, as the stakeholders' pressure increases.
Actors addressed (industry, government, civil society) Environment /social /economic aspects	The concept thus implies a proactive role of all actors involved in the supply chain, mainly industry, but also consumers and stakeholders as a whole. Economic competitiveness is at the basis of the approach, but environmental and social issues are increasingly being accounted for in the management of the supply chain.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change unnecessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.6 Leasing society

	Description
Main aim/origins/history	One of the important elements of a circular economy is changing the relationships between producers and consumers and the introduction of new business models that rely on fundamental changes to the traditional approaches to ownership and product responsibility in an attempt to move towards more closed loop production and consumption systems. Under this approach, the idea of the leasing society has gained momentum as a way to move towards a more service-oriented economy where resources and products are used efficiently, preserving their value along its use life and where materials are recovered to the the system in a cyclical way. The vision of the leasing society implies a novel way to fulfil consumer needs that puts the emphasises in the production of services rather than products, reducing the environmental impact associated with products disposal at the end of their use life and providing more resource efficient product design, durability and easier disassemble and remanufacturing to optimise resource use and minimize environmental impact over the life-cycle of the product. It has been argued that the concept of the leasing society may contribute to a more resource efficient Europe (see, Marsden, 2012 or Merkies, 2012).
Scope of change	The vision of the leasing society proposes substantial changes in the way manufacturing and consuming systems are organised and structured. The scope of change is thus potentially high, leading to new way of production and consumption based on the fulfilment of the need rather than the acquisition of a material product.
Paradigmatic degree of change	Although emerging from a utilitarian approach to nature, the concept of the leasing society proposes a radical change in the way societies are organised and to some extent a paradigmatic change of values and behaviours associated with production and consumption activities.
Plausibility of pathway of change	Even though the concept is not entirely new and have links to early developments of the concept product-service, there is uncertainty and openness regarding the ways this may operate in the practice and the drivers and factors that may make change possible at present. Further development of the concept is needed to specify possible pathways of change and drivers and barriers to it.
Actors addressed (industry, government, civil society) environment/social/economic aspects	Main actors addressed by the approach include producers and consumers; Government is assigned the role of defining the framework conditions in which the leasing society operates. Environmental and economic aspects are the focus of the approach with less attention paid to societal issues.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change unnecessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.7 Ecological Economics

	Description
Main aim/origins/history	Ecological economics is a transdisciplinary approach that focuses on the interface between natural, social and economic systems and incorporates elements from the natural and social sciences. Although its roots can be traced back to Malthus or Stuart Mill (Martinez Alier, 1990), it is in the last decades of the 20 th century when the discipline developed as a response to the acute environmental problems that modern societies were facing and the lack or inadequacy of the responses provided by the mainstream or neoclassical economics, that pointed to prices and perfect functioning markets as the solutions to environmental degradation. The limits to growth (Meadows et al., 1972) and the steady-state economics (Daly, 1977) set the basis and main principles of the discipline. Aspects such as scale of human-economic systems with respect to the natural systems they are embedded in, allocation and distribution of resources have been addressed in the discipline. This approach rejects some of the neoclassical principles such as the perfect substitution between different capital forms (natural, labour and man-made) or perfect allocation of resources and introduces aspects such as minimum threshold levels and life supporting environmental services.
Scope of change	Ecological economics is a holistic approach to the understanding of the functioning of environmental and social-economic systems and thus proposes a restructuring of social systems as a whole to adapt to the constraints and operating principles of the natural systems. The scope of change thus involves the societal systems as a whole.
Paradigmatic degree of change	Ecological economics incorporate aspects of moral justice and reject the positivist, rational utility-maximizing approach that is on the basis of traditional neoclassic approaches. Aspects such as intra- and inter-generational equity or the intrinsic value of nature and natural systems are recognised in the discipline.
Plausibility of pathway of change	Explicit pathways of change and alternative instruments and policies are proposed in the discipline to deal with some of the environmental and social problems faced by modern societies and to substitute existing predominant decision-making structures based on a utility-maximizing approach, which fails to recognise the intrinsic value and operating rules of natural systems. However, the discipline has an eminently theoretical approach and limited empirical basis exist to demonstrate the practicality of the approach.
Actors addressed (industry, government, civil society) environment/ social/ economic aspects	The approach addresses all societal actors including industry, consumers, citizens, NGO's and governments. Environmental, economic and societal dimensions are all considered in an integrative and co-evolutionary way.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change unnecessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.8 Natural step

	Description										
Main aim/origins/history	<p>The natural step is a framework to sustainability developed by a non-profit organisation founded by Karl-Henrik Robert in 1989. It proposes a number of system conditions that need to be fulfilled to lead to a sustainable society. The first three conditions are based on the thermodynamic laws, adding a fourth condition that focuses on the socio-economic interface. Regarding the fourth condition, the concept of needs is based on the approach proposed by Max-Neef (www.max-neef.cl), which identifies nine fundamental human needs: subsistence, protection, affection, understanding, participation, leisure, creation, identity and freedom.</p> <p>The system conditions can be redefined as sustainability principles, as shown in the table below:</p> <table border="1" data-bbox="359 577 1212 1108"> <thead> <tr> <th data-bbox="359 577 718 607">SYSTEM CONDITIONS</th> <th data-bbox="718 577 1212 607">SUSTAINABILITY PRINCIPLES</th> </tr> </thead> <tbody> <tr> <td data-bbox="359 607 718 779"> 1. Nature is not subject to systematically increasing concentrations of substances extracted from the earth's crust (heavy metals, fossil fuels, etc). </td> <td data-bbox="718 607 1212 779"> 1. A sustainable society must contribute to eliminate the systematic increase of concentrations of substances extracted from the earth's crust </td> </tr> <tr> <td data-bbox="359 779 718 891"> 2. Nature is not subject to systematically increasing concentrations of substances produced by society </td> <td data-bbox="718 779 1212 891"> 2. A sustainable society must contribute to eliminate the systematic increase of concentrations of substances produced by society (dioxins, PCBs, DDT, etc) </td> </tr> <tr> <td data-bbox="359 891 718 1003"> 3. Nature is not subject to systematically increasing degradation by physical means </td> <td data-bbox="718 891 1212 1003"> 3. A sustainable society must contribute to eliminate the systematic physical degradation of nature and natural processes </td> </tr> <tr> <td data-bbox="359 1003 718 1108"> 4. People are not subject to conditions that systematically undermine their capacity to meet their needs </td> <td data-bbox="718 1003 1212 1108"> 4. A sustainable society must contribute to eliminate the conditions that systematically undermine people's capacity to meet their basic human needs </td> </tr> </tbody> </table> <p>Source: www.naturalstep.org</p> <p>The framework uses a combination of backcasting and creative visioning as instruments of change towards more sustainable scenarios. The principles provide the framework conditions a sustainability society must comply with and the backcasting method of planning attempts to identify steps and bridges towards that vision (www.naturalstep.org).</p>	SYSTEM CONDITIONS	SUSTAINABILITY PRINCIPLES	1. Nature is not subject to systematically increasing concentrations of substances extracted from the earth's crust (heavy metals, fossil fuels, etc).	1. A sustainable society must contribute to eliminate the systematic increase of concentrations of substances extracted from the earth's crust	2. Nature is not subject to systematically increasing concentrations of substances produced by society	2. A sustainable society must contribute to eliminate the systematic increase of concentrations of substances produced by society (dioxins, PCBs, DDT, etc)	3. Nature is not subject to systematically increasing degradation by physical means	3. A sustainable society must contribute to eliminate the systematic physical degradation of nature and natural processes	4. People are not subject to conditions that systematically undermine their capacity to meet their needs	4. A sustainable society must contribute to eliminate the conditions that systematically undermine people's capacity to meet their basic human needs
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4. People are not subject to conditions that systematically undermine their capacity to meet their needs	4. A sustainable society must contribute to eliminate the conditions that systematically undermine people's capacity to meet their basic human needs										
Scope of change	<p>The scope of change is high as the concept implies radical changes in the way societal systems operate. The approach proposes a set of limitations derived from planetary constraints that should be on the basis of the operation of social and economic systems.</p>										
Paradigmatic degree of change	<p>The paradigmatic degree of change is also high as the approach moves away from the utility maximizing models to a society organised around the limitations derived from the ecosystems carrying capacity. Elements of moral justice are also recognised in the fourth of the sustainability principles proposed.</p>										
Plausibility of pathway of change	<p>Although the approach aims at providing practical principles for achieving a sustainable society, and a number of guidelines have been developed for household, planners or municipal decision-making, the specific mechanisms to initiate and manage the transition and discussion of adequate pathways of change need further development.</p>										
Actors addressed (industry, government, civil society) environment/ social/ economic aspects	<p>All societal actors are addressed by the approach, including industry, consumers and citizens. Governments and NGO's, relying on participatory methods, play a very active role in defining the steps to move towards a sustainable society. Environmental, economic and social aspects are all seen in an integrative way.</p>										

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change unnecessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.9/2.10 Weak, strong and sensible sustainability

	Description
<p>Main aim/origins/history</p>	<p>Although the concept of sustainable development can be traced back to the 1980s, it was the publication of the Brundtland report in 1987 (WCED, 1987), what which contributed to its popularisation and policy resonance, by providing reconciliation between growth and environmental protection. According to the report, sustainable development is a: <i>'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'</i>. At a global level, the sustainable development concept and associated goals and principles have been refined over time during the United Nations Conference on Environment and Development at Rio in 1992 and the World Summit on Sustainable Development in Johannesburg in 2002. Most of the concepts suggest an environmental, economic and social dimension. The ambiguity contained in the term has given rise to different interpretations or "plethora of paradigms" (e.g. Fowke and Prasad, 1996; Fischer-Kowalski et al., 1994; WRR, 1994; Gallopín, 2003). Sustainable development has been conceived as a desirable goal for some and as a paradigm shift for others (Downs, 2000), ranging from maintenance of the status quo with small changes, to major structural changes in the way societal and economic system are organised, becoming an umbrella term for a multiplicity of approaches. The range of interpretations of sustainability has been captured in two contrasting views: weak sustainability vs. strong sustainability. These two perspectives have concentrated the academic debate on the assumptions made about the degree of substitutability between natural and manmade or manufactured capital (Ayres and Ayres, 2002).</p> <p>The perspective of weak sustainability assumes that there is a perfect (or quasi-perfect) substitutability between man-made and natural capital (Pearce and Turner, 1990). Therefore, a sustainable society, from this point of view, should aim at maintaining or increasing the total stock of capital over the years. The process of environmental degradation (or diminishing of natural capital) is not critical as long as it is compensated with an increase of manufactured capital, including human capital. This position fits within the neoclassic economics of utility maximisation models, where welfare is equivalent to utility, measured as aggregated consumption.</p> <p>From the perspective of strong sustainability, it is assumed that minimum amounts of different types of capital (technology, human capital, natural capital) are essential for the productivity of the other factors. Therefore, different types of capital can only be substituted to a certain degree, beyond which they become complementary. Natural critical capital refers to this minimum amount of natural capital that needs to be secured to guarantee the production of the other types of capital. Moreover, some forms of natural capital are subjected to irreversible processes of environmental degradation and cannot be substituted by manmade artefacts or systems. The levels of substitutability and complementarity vary according to different authors, as well as the determination of the levels of natural critical natural capital. The right of existence of nature, independently of its "utility" to human societies is also recognised from the point of view of the Deep Ecology (Ayres and Ayres, 1998).</p>
<p>Scope of change</p>	<p>The scope of change both in its weak and strong versions can be considered high, as it involves a restructuring of all societal subsystems by operating a fundamental change in the way social, economic and environmental systems operate, recognising the linkages and inter-dependence between the systems.</p>
<p>Paradigmatic degree of change</p>	<p>The concept of sustainable development strives to overcome the traditional trade-off between economic and social development and environmental protection, looking at ways in which the systems can operate in a mutually supportive way. The paradigmatic degree of change can be considered low in the case of the weak perspective on sustainability that relies primarily on the utility-maximizing paradigm, where market solutions are preferred, and substitutability between different types of capital is assumed. The perspective on strong sustainability though involves a radical change in existing values and institutions and the way in which environmental systems are considered and accounted for. Critical environmental system services and thresholds are key for the maintenance of economic and social systems. Also, aspects such as</p>

	justice and equity, understood as intra- and inter-generational equity are at the centre of the approach.
Plausibility of pathway of change	The concept has materialised in ever-growing number of policy strategies and programmes around the world. From the Agenda 21, proposed at the UN Conference on Environment and Development in Rio 1992, there has been innumerable initiatives and programmes to pursue sustainable development at the global, supranational (EU sustainable Development Strategy), national (see, for example, Sustainable Development Strategy of Canada), regional, sectorial (see, for example, German Sustainability code or the cement sustainability initiative) and local level (see, for example, Local Agenda 21). Although the content and level of ambition of these initiatives varies considerably, they provide specific measures and instruments to move towards a more sustainable path of development.
Actors addressed (industry, government, civil society) environment/ social/ economic aspects	As a holistic approach, all societal actors are addressed, including industry, consumers, citizens, NGO's and Governments. A key pillar of the approach is the interconnection between economic, social and environmental dimensions.

Weak sustainability

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change unnecessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

Strong sustainability

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change unnecessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.11 *Small is beautiful / appropriate technology*

	Description
Main aim/origins/history	<p>Small is beautiful proposes an alternative approach to mainstream economics, which criticizes the focus on output and technology while ignoring the limited capacity of natural systems and their irreplaceable role in sustaining society. Although the phrase came from Leopold Kohr, author of the <i>Breakdown of Nations</i> (1957), where he rooted the cause of social misery in the concept of “bigness”, it was a collection of essays by economist F.E. Schumacher entitled <i>Small is Beautiful: a study of economics as if people mattered</i> (1973) that championed the idea of small, appropriate technology. Schumacher argues that the modern way of production is unsustainable, generating tensions both in the social and natural systems. This approach challenges the idea that big is better or that growth is good and proposes a new perspective on economics, that he termed Buddhist economics, that tries to overcome the materialist focus and where small, local, decentralised models of work and production are preferred.</p> <p>This approach entails a fundamental restructuring of all societal systems and the values behind them and proposes a vision of development that transcends materialistic realm to focus on the ethical maturity of human beings (Payutto, 1992). Pathways of societal change are rooted in a redefinition of the nature of human labour and the scale and modes of production. The local sphere gains relevance and the idea of maximising profits is substituted by that of minimizing suffering and non-violence to all living and non-living beings. Thus, resource management should focus on a very careful, planned use of resources, avoiding overexploitation of natural resources that is a form of violence that opposes the Buddhist principle of non-violence. Production needs to be locally adapted and where possible self-sufficient. Maximizing consumption is not a true measure of human happiness and thus it advocates for different measures of wealth such as the Gross National Happiness (www.grossnationalhappiness.com).</p>
Scope of change	The scope of change is thus high, calling for an upheaval and restructuring of all societal sub systems and the basic principles of organising society.
Paradigmatic degree of change	The paradigmatic degree of change is also high as the concept seeks an alternative way of organising society and production, moving away from a materialistic focus, to a human-oriented approach, that redefines the nature of human labour and its connection with human dignity and the scale and mode of production, based on local, decentralised systems.
Plausibility of pathway of change	Pathways of change are discussed conceptually, pointing to possible avenues of social change, building around local alternatives of work organisation focused on self-subsistence and sustainability. These small-scale practical initiatives scattered around the world though are of a too limited scale to demonstrate the practicability of the approach at a wider context.
Actors addressed (industry, government, civil society) environment/ social/ economic aspects	The approach addresses all societal actors, including industry, citizens and governments. Decentralized and participatory models of government are though proposed. Environmental, social and environmental issues are considered intrinsically intertwined.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change unnecessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.12 Eco-innovation

	Description
Main aim / origins /history	Traditionally, eco-innovation was understood mostly as a solution to minimise or fix negative environmental impacts from production and consumption activities. These end-of-pipe solutions allowed for the 'cleaning-up' of polluted water and soils, and for reducing harmful emissions. One of the first appearances of the concept of eco-innovation in the literature is in the book by Claude Fussler and Peter James (1996). It is increasingly evident today, however, that the key challenges of the 21 st century are not only about reducing pollution, but also about getting a handle on the over-consumption of natural resources (e.g. Rockström et al. 2009, EEA 2010). The understanding of eco-innovation has thus broadened to include a focus on resource and energy efficiency taking into account a full life-cycle perspective. In contrast to innovations in general it brings both environmental and economic benefits. The EIO Report 2010 published by the European Commission defines eco-innovation as "the introduction of any new or significantly improved product (good or service), process, organisational change or marketing solution that reduces the use of natural resources (including materials, energy, water, and land) and decreases the release of harmful substances across the life-cycle".
Scope of change	The scope of change ranges from incremental to disruptive. It is assessed as high, as it addresses all parts of the value chain. As such, the concept tries to achieve a "systemic change" in the economy, which represents one of the societal sub-systems.
Paradigmatic degree of change	While eco-innovation traditionally focused on market-based solutions and emphasizes the business opportunities and benefits for being sustainable and resource efficient, the recent Annual EIO Report 2012 "Europe in transition" points out that "the importance of new technologies goes beyond displacing established products; it can also be a powerful means for enlarging and broadening markets and providing new functionality". The argument is that, from a historical perspective "waves of innovation" have been accompanied by shifts in behaviour, shifts in policy, and shifts in structure that converge with the occurrence of technological innovation. Thus, the paradigmatic degree of change is considered medium, since the extent of paradigm change differs according to the perspectives of different actor groups.
Plausibility of pathways of change	Analyses "discontinuities" of trends, tries to overcome the risks (Horizon Scanning and Foresight Reports) and thus responds to real-life driving forces. The concept is explicit and plausible in identifying pathways of change. The EC has launched an Eco-Innovation Action Plan in 2011 (EcoAP) defining measures that have to be taken in order to promote the further development and use of environmental technologies in the EU. However, most political advocates of eco-innovation in the EU are still focusing on making the concept attractive for the businesses. Thus, the concept is implemented rather incrementally, not taking into account the radical innovations needed to bring the EU on the track of strong sustainable development. According to this analysis, the concept's plausibility of pathways ranges between medium and high, depending on the viewpoint from which it is evaluated.
Actors addressed (industry, government, civil society) environment/social/economic aspects	Actors addressed by the eco-innovation concept are mainly business and government. It focuses on environmental and economic aspects of sustainability, by arguing that "when business meets environment" win-win-solutions are created, and views social benefits as a by-product.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.13 Transition management

	Description
Main aim / origins /history	<p>“Transition management has rapidly emerged over the past few years as a new approach dealing with complex societal problems and the governance of these problems. In the Netherlands, UK and Belgium, serious efforts have been and are being undertaken to develop transition policies in areas such as energy, building, health care, mobility and water management. This is the result of a much broader scientific development of transition research as an interdisciplinary field of study in which innovation studies, history, ecology and modelling are combined with sociology, political and governance studies and psychology. Because of the focus on integrated sustainability problems and the applied nature of transition research, the natural interaction between science and policy has led to a continuously coevolving theory and practice of transition management, following the tradition of post-normal and sustainability science”. (Wittmayer et al. 2011)</p> <p>“The importance of social actors for achieving sustainability and the critical role of innovation are at the core of transition management. More specifically, all the transition management tools include both stakeholder and community engagement elements (e.g., participation as the way for vision-building, knowledge-creation and scenario-drawing) and innovation-stimuli elements” (Frantzeskaki et al, 2012). Transition management as a governance approach can facilitate programmes and policies that have a direct link to resource efficiency. Since the underlying rationale of the management approach and the design of the transition management instruments follow the basic principles of sustainable development (integration, plurality of interests, intergenerational justice, and importance of scale), it is well suited to support socially-rooted and thus successful transition processes to a resource efficient Europe. For example, between 2004 and 2006, a transition arena and network were developed in Flanders, Belgium (Loorbach and van de Lindt, 2007). A main objective was to apply the transition management approach to sustainable living and housing. The transition arena defined criteria for a sustainable living and housing that included closed material cycles and an integrated policy approach thus demonstrating the relevance of this approach for resource efficiency.</p> <p>“Numerous transition experiments have been initiated in the fields of sustainable agriculture, mobility, construction, energy, spatial planning, and health care. The interest in transition processes is growing, e.g., in the UK, Germany, Austria, Finland, and—most concretely—Belgium, where two transition processes are being attempted at the national level, one on waste management and one on sustainable housing and construction in Flanders” Fischer-Kowalski and Rotmans (2009)...”Studies about transitions and its main drivers have been done regarding resource and land scarcity, climatic variations, or specific colonial and trade relations” (Fischer-Kowalski and Rotmans, 2009).</p>
Scope of change	The concept focuses on persistent problems of unsustainability and aims at transforming whole sub-systems (institutions, regulations, physical, infrastructures, financial infrastructures, etc.). As such its scope of change can be considered high.
Paradigmatic degree of change	The concept clearly calls for a revolution in the economic system, related values, institutions, etc. and as such initiates a fundamental paradigmatic change. The goal of this concept is to reframe existing societal issues at the various levels of the societal sub-systems in terms of their underlying problems to go beyond obvious and partial problems. The premise is that sustainability transitions require a new way of thinking and acting, which are intertwined. While the ambition of transition management is to achieve systemic change, the experience so far generally does not meet this goal, so the paradigmatic change is ranked as medium.
Plausibility of pathways of change	An explicit part of the transition management process (see Wittmayer et al. 2011) is backcasting from a vision to develop pathways. These pathways are then implemented through measures decided by the participants in the transition process, accompanied by monitoring and evaluation. Although, the plausibility is grounded in the process design, there are only few real life examples for how transition management can be put into practice successfully, initiating change towards sustainable development
Actors addressed (industry, government, civil society) environment/soc	<p>The concept acknowledges the integrated nature of sustainability problems. It thus it tries to integrate various societal actors, such as the civil society, scientific community, government and industry, and engage them into joint-learning processes.</p> <p>Transition Management takes into account the environmental, social and economic dimension of sustainability.</p>

ial/economic aspects	
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	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.14 Green growth

	Description
Main aim / origins /history	<p>Green Growth describes an alternative path to growth in contrast to the conventional paradigm of economic growth. The idea is that the environmentally necessary restructuring of the economy to include greater energy and resource efficiency and better management of natural capital can be a strong driver for growth. The thesis suggests that the inclusion of new green markets, the development of eco-innovations and the management of ecosystem services create both improved competitiveness and new business opportunities. The concept of green growth was coined in Asia and the Pacific. In 2005, at the Fifth Ministerial Conference on Environment and Development in Seoul, 52 Governments and other stakeholders from the region agreed In a Ministerial declaration to pursue a path of "green growth". They also adopted an implementation plan. This provided the starting point for the UNESCAP vision of green growth as a regional initiative to achieving sustainable development and the Millennium Development Goals (United Nations Department of Economic and Social Affairs).</p> <p>The Green Growth concept is also anchored in the OECD. The OECD (2011) defines Green Growth as "fostering economic growth and development, while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies". In 2009, government ministers from 34 countries signed a Green Growth Declaration and thus gave the OECD a political mandate to develop a Green Growth strategy. The strategy was published in 2011 under the title "Towards Green Growth" as the starting point for a long-term Green Growth Agenda.</p> <p>The World Bank (2012) defines green growth as "growth that is efficient in its use of natural resources, clean in that it accounts for natural hazards and the role of environmental management and natural capital in preventing physical disasters. "</p> <p>Each institution places a different emphasis on the green economy. For example, the World Bank places an emphasis on the role that nature plays in preventing physical disasters, and emphasises the role of resource use efficiency while the OECD places importance on the role of sustainability of natural resources as the basis of existence.</p>
Scope of change	high, because it covers not only the economic sub-system, but the whole society.
Paradigmatic degree of change	The concept's degree of paradigmatic change is low, since it is still framed in the conventional economic paradigm. It provides market-based solutions that adhere to the existing utilitarian economic rationality. Rather than initiating radical change and an upheaval in existing values and institutions, the Green Growth concept provides solutions to the crisis and demonstrates a commitment to the belief that growth and environmental protection can go hand in hand.
Plausibility of pathways of change	<p>The concept addresses real life driving forces, such as resource scarcity and provides clear pathways for change e.g. through measures in the areas of education, research, innovation and ICT. The fact that many initiatives (OECD, UNEP, World Bank*) already exist, demonstrate the concept's high level of practicability.</p> <p>*http://www.unep.org/greeneconomy/Portals/88/documents/partnerships/GGKP%20Moving%20towards%20a%20Common%20Approach%20on%20Green%20Growth%20Indicators.pdf</p>
Actors addressed (industry, government, civil society) environment/social/economic aspects	Green Growth centers around environmental aspects, but always in the economic context: environment should be used sustainably in order to create win-win-situations. As such it does to feature full commitment to social and environmental sustainability.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.15 Green economy

	Description
Main aim / origins /history	<p>The Green Economy is a concept that UNEP has taken the lead in promoting. UNEP sees the Green Economy as an economic approach that "results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2011). To implement this vision, UNEP created the Green Economy Initiative, the first results of which were published in the report Towards a Green Economy in 2011. The initiative aims to support decision makers in moving towards a more resource efficient, low carbon and socially inclusive economy in practice.</p> <p>The Green Economy was one of the two key themes forming the focus of UN Conference on Sustainable Development Rio+20 in Rio de Janeiro.</p> <p>While the concept of a green economy has human development at its center, the concept of green growth is often seen as one that is more profoundly economics oriented. Its paradigm does not imply the necessity of growth in all economies but recognizes that there is growth potential in greening economies.</p>
Scope of change	high, because it covers not only the economic sub-system, but the whole society.
Paradigmatic degree of change	The concept's degree of paradigmatic change is medium. While it is still framed in the conventional economic paradigm and provides market-based solutions that adhere to the existing utilitarian economic rationality, the Green Economy Initiative of UNEP has the ambition to develop a green economy in which growth in income and employment is driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services. It is recognized that these investments will require policy reforms and regulation changes.
Plausibility of pathways of change	<p>The concepts addresses real life driving forces, such as resource scarcity, climate change or social exclusion and provides clear pathways by bringing together and analysing best practice examples from all around the world, to illustrate the positive impacts of green investments and policies.</p> <p>Ultimately, this involves embedding individual measures, based on robust economic research and policy analysis, in a coordinated way within a comprehensive strategy, in order to make quick progress towards the goal of a green economy.</p>
Actors addressed (industry, government, civil society) environment/social/economic aspects	<p>The green economy concept focuses on the industry and the government as the main driving forces behind sustainable development.</p> <p>Thus the societal benefit is rather viewed as a by-product of the synergy that results from increasing the economic and environmental dimension of sustainability.</p>

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.16 'Beyond GDP'

	Description
Main aim / origins /history	<p>The aim of this initiative developed by the European Commission (2009) is to identify which indicators are best suited to measure societal progress. Usually societal progress is measured and compared using GDP, but it has been increasingly recognized that GDP does not capture whether well-being or prosperity (assets over and above financial assets such as health, social capital and security) has improved (see, for example, Jackson (2009)). Further the initiative identifies pathways for integrating these indicators into decision-making processes and public debate. The second key milestone after the Beyond GDP conference that took place at the end of 2007 is the communication entitled GDP and Beyond from August 2009. The communication sets out a concrete roadmap in the form of five key actions for the development of a new set of indicators for progress that can be used alongside GDP.</p> <p>The Sofia Memorandum on Measuring progress, well-being and sustainable development (2010), adopted at the 96th conference of the Directors General of the National Statistical Institutes considers that sustainable development and well-being are fundamental objectives of the "Treaty on European Union"(Article 3) (Directors General of the National Statistical Institutes, 2010). While there is growing demand by societal actors and policy makers to measure progress towards well-being and sustainable development in a more comprehensive way the European Commission Communication "GDP and Beyond: Measuring progress in a changing world" (2009) can be seen as a commitment to pursue the further development of measurements in this areas. The "Europe 2020" strategy adopted by the heads of EU States and Governments includes measurable targets for several indicators that go beyond GDP.</p>
Scope of change	This initiative only indirectly aims at changing the existing societal sub-systems by driving a fundamental change in the way in which societal well-being and progress towards sustainable development is measured and reported. As an awareness-raising tool for indicating that progress cannot be measured by GDP alone and that prosperity does not just depend on money, its potential for stimulating systemic change is high.
Paradigmatic degree of change	This concept clearly strives for an upheaval in existing values, institutions, etc. It tries to overcome the current paradigm of evaluating societal progress according to economic growth and material prosperity. To go beyond this traditional paradigm of measuring progress, the concept proposes the inclusion of environmental and social parameters.
Plausibility of pathways of change	Since the concept works indirectly through awareness raising, it does not provide concrete pathways of change but the process of developing new indicators recognizes the need for change.
Actors addressed (industry, government, civil society) environment/social/economic aspects	<p>The Beyond GDP concept mainly addresses governments and their willingness to measure progress with alternative indicators.</p> <p>However, Beyond GDP indicators take into consideration environmental, social and economic progress towards sustainable development.</p>

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.17 Cleaner production

	Description
Main aim / origins /history	<p>“The continuous application of an integrated preventive environmental strategy to processes, goods, and services to increase overall efficiency, and reduce risks to humans and the environment. Cleaner Production can be applied to the processes used in any industry, to goods themselves, and to various services provided in society” (UNEP 2013).</p> <p>Cleaner Production is seen as a tool that can contribute to the sustainable forms of economic development, as endorsed in Agenda 21 adopted by the United Nations Conference on Environment and Development (UNIDO 2002). This holistic approach of Cleaner Production aims to:</p> <ul style="list-style-type: none"> • “Increase productivity by ensuring a more efficient use of raw materials, energy and water • Promote better environmental performance through reduction at source of waste and emissions • Reduce the environmental impact of products throughout their life cycle by the design of environmentally friendly but cost-effective products” (UNIDO 2002). <p>Cleaner production does not only relate to costly technologies but identifies a range of measures to achieve the above objective.</p>
Scope of change	<p>The scope of change of this concept can be considered medium, as it is only targeted at one part of the value chain, namely the production. Cleaner production centres in about 40 countries supported by governments and UNIDO and UNEP have been supporting a wide range of industries on the transformation of production processes. The approach has moved from end of pipe to a more input oriented approach but does not look at the whole economic system and consumption side.</p>
Paradigmatic degree of change	<p>ambition to initiate a paradigmatic change is low, since it predominantly stresses the business opportunities and benefits of sustainability for producers.</p>
Plausibility of pathways of change	<p>UNIDO (no date) already identified a range of concrete measures to reach the objective of a cleaner production without the need to make huge investments in new technologies. Amongst these are for example:</p> <ul style="list-style-type: none"> • On-Site Recovery/Reuse: the reuse of the wasted materials in the same process or for another useful application within the company; • Production of Useful By-Products: the transformation of previously discarded wastes into materials that can be reused or recycled for another application outside the company; or • Product Modification: the modification of product characteristics in order to minimize the environmental impacts of the product during or after its use (disposal) or to minimize the environmental impacts of its production. (UNIDO no date)
Actors addressed (industry, government, civil society) environment/social/economic aspects	<p>The concept only addresses governments and the industry as major the actors supposed to drive the change to more sustainable and “clean” production processes.</p> <p>Since it is structured around the business opportunities of resource efficiency, the cleaner production mainly addresses the economic and environmental dimension of sustainability. Benefits for the society come as a side effect.</p>

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.18 Eco-efficiency

	Description
Main aim / origins /history	<p>“Eco-efficiency is a management philosophy that encourages business to search for environmental improvements that yield parallel economic benefits. It focuses on business opportunities and allows companies to become more environmentally responsible and more profitable. It is a key business contribution to sustainable societies. Eco-efficiency is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth’s estimated carrying capacity.” (UNEP 2010)</p> <p>The term was coined by Stephan Schmidheiny, founder of the World Business Council for Sustainable Development (WBCSD), in his 1992 publication “Changing Course”. Further, at the 1992 Earth Summit, eco-efficiency was endorsed as a new business model and means for companies to implement Agenda 21 (UN 1992) in the private sector.</p>
Scope of change	Eco-efficiency is a concept that is targeted at changing various parts of the value chain to become more environmentally responsible. However, it does not aim at transforming the whole economic system. Therefore, its scope of change is medium.
Paradigmatic degree of change	The concept mainly focuses on business opportunities and related economic benefits and thus adheres to the existing paradigm. Rather than escaping from the utilitarian, economic rationality that is currently dominating our Western society, it reproduces them by providing market-based solutions to sustainable development.
Plausibility of pathways of change	The concept has managed to show why becoming eco-efficient is economically profitable, but failed to provide a clear pathway for radical change to social and environmental sustainability. However, it can be argued that the concept presents plausible pathways within the current economic paradigm. Thus it can be rated high.
Actors addressed (industry, government, civil society) environment/social/economic aspects	<p>Business is the only actor addressed by the concept.</p> <p>Hence, it is primarily tailored to meet the economic challenges of sustainability, rather than the environmental or social ones.</p>

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of ‘public goods’ and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.19 Decoupling/(Increased) resource efficiency

	Description
Main aim / origins /history	<p>Resource efficiency is defined by Dahlstrom and Ekins (2005) as a basic ratio of two resource variables of the same kind, that is, the ratio is dimensionless. For example, material efficiency is measured as a ratio between useful material output, Mo, and material input, Mi, such as useful material output per total material input:</p> $Mo/Mi = \text{material efficiency}$ <p>And energy efficiency is useful energy output, Eo, per input of energy, Ei:</p> $Eo/Ei = \text{energy efficiency}$ <p>These definitions of resource efficiency are therefore consistent with the definition of efficiency used in engineering. It is also consistent with the economic concept of efficiency, which relates to economic outputs and inputs, Yo/Yi, although one difference is that engineering efficiencies are always less than 1 (e.g. $Mo < Mi$), whereas for a profitable company $Yo/Yi > 1$.</p> <p>Other definitions are given by:</p> <ul style="list-style-type: none"> • Wuppertal Institute: Resource efficiency means in general the relation of a desired output of a process to the related resource requirement or -input. If the output is an economic measure, e.g. value added or GDP, we speak in the context of whole economies of “resource productivity”. Resource efficiency of processes, however, can also refer to physical relations, e.g. the relation of used raw material extraction to the total extraction of primary materials. • EU DG ENV (2011): Increasing resource efficiency means producing more value using less material and consuming differently, to limit the risks linked with scarcity and for less environmental impacts, within our planet’s natural limits. It concerns the sustainable management and use of resources throughout their life cycle - from extraction, transport, transformation, consumption to the disposal of waste. Resources include all material and natural resources, from food, timber, and biodiversity in the widest sense, to energy, metals, soil, water, minerals, our atmosphere and land. • UNEP (2011, 2014): Decoupling, as used by UNEP’s International Resource Panel is synonymous with increased resource efficiency, so that ththe two terms may be used interchangeably
Scope of change	The scope of change of this concept can be considered medium, as it is targeted at various parts of the value chain in industrial processes, yet does not look at the economic system as a whole.
Paradigmatic degree of change	The concept sees an unsustainable development path not only a threat to economic profitability, but also to public goods. As such it can be argued that it drives an intermediate paradigmatic change, in the way that it recognizes the need for government intervention in order to safeguard also social interests.
Plausibility of pathways of change	The concept responds to real life driving forces such as poverty, environmental degradation and resource scarcity. UNEP (2010) envisages strengthening the scientific knowledge base, building capacity for government interventions by developing national and local policies and stimulating demand by providing market incentives. Thus, the concept identifies clear pathways of change. However, it can be argued that in reality the decoupling concept has not been implemented very successfully and thus has not driven any real life change towards sustainable development so far.
Actors addressed (industry, government, civil society) environment/social/economic aspects	<p>UNEP (2010) addresses governments, businesses and the scientific community as the major actors that should be driving the change. However it also gives attention to the importance of changing lifestyles.</p> <p>As such, it addresses all three pillars of sustainability.</p>

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.20 Pollution prevention pays

	Description
Main aim / origins /history	Pollution prevention focuses on the source reduction of pollution and environmental impact. Waste is eliminated and reduced within the process and not end-of-pipe. Therefore waste treatment is not part of the concept. Pollution prevention pays addresses those pollution prevention which additionally saves money through avoidance of pollution and reduction of operating costs. The concept was first introduced in the US by the 3M company in their pollution prevention pays (3P) programme in 1975. Nowadays the terms pollution prevention, cleaner production and resource efficiency are often used synonymously while pollution prevention is more common in North America (UNEP 2013).
Scope of change	Pollution prevention focuses on parts of value chain: reducing waste within the process/at the source, not over the whole lifecycle. waste treatment is not part of the concept because it doesn't prevent the creation of waste.
Paradigmatic degree of change	Pollution prevention focuses on market based solutions. Depending on the country context the concept is applied voluntarily or on a legal basis. It also focuses on business opportunities to reduce cost while reducing harmful or wasteful inputs.
Plausibility of pathways of change	The plausibility of pathways is high, as governmental laws have been adopted in many countries on pollution prevention, yet the definition and adoption of laws regarding harmful chemicals lags behind the ever new appearance of chemicals on the market. However, leading companies such as 3M have adopted Life Cycle Management reviews with the aim of systematically and holistically address the environmental, health and safety (EHS) and energy opportunities and issues from each stage of their product's and more concretely to reduce or eliminate toxic emissions during manufacturing, reduce or eliminate toxic releases for the customer, or introduce a new product that has no toxic releases.
Actors addressed (industry, government, civil society) environment/social/economic aspects	Pollution prevention is mainly targeted at industrial and commercial business and covers less less social aspects apart from health and safety issues. It predominantly addresses the economic dimension of sustainability.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.21 Sustainable Consumption and Production

	Description
Main aim / origins /history	<p>The most widely accepted definition of SCP, as developed at the multi-stakeholder workshop hosted by the Norwegian Ministry of Environment at the Oslo Symposium on Sustainable Consumption in 1994, is “the use of services and related products, which respond to basic needs and bring a better quality of life while minimising the use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardise the needs of future generations” (UNEP 2010).</p> <p>However, global recognition of the need for sustainable consumption and production (SCP) dates back to the United Nations Conference on Environment and Development (UNCED) held 1992 in Rio de Janeiro. Agenda 21, the action plan for sustainable development adopted at the summit, called for “action to promote patterns of consumption and production that reduce environmental stress and will meet the basic needs of humanity” (UN 1992). Ten years later, the World Summit on Sustainable Development (WSSD 2003) in Johannesburg reaffirmed at the highest political level in the Johannesburg Plan of Implementation (JPOI) that “poverty eradication, changing unsustainable patterns of production and consumption and protecting and managing the natural resource base of economic and social development are overarching objectives of, and essential requirements for, sustainable development”. In order to accelerate the shift to SCP, the WSSD encouraged the development of a 10-Year Framework of Programmes on SCP. The multistakeholder Marrakech Process, launched in 2003, has supported the implementation of SCP and provides inputs for the development of the 10-Year Framework (UNEP, 2012b). The 10 YFP on SCP was finally adopted at Rio+20.</p>
Scope of change	The scope of change of this concept can be considered high. While it is targeted at parts of the value chain (consumption and production), its implementation through product services and other measures would have system-wide implications.
Paradigmatic degree of change	Sustainable consumption and production aims at maximizing business' potential to transform environmental challenges into economic opportunities and provide a better deal for consumers. Since it addresses both consumers and producers, and views resources as public goods, the paradigmatic degree of change is medium.
Plausibility of pathways of change	The EC has outlined a Sustainable Consumption and Production Action Plan (2008), proposing the introduction or expansion of a range of policies at EU and national level that are targeted at resource efficient and eco-friendly products and raise consumer awareness. However, the pathways proposed by the EC have not been far-reaching enough to trigger considerable change towards sustainable development in real life. Thus plausibility can be rated medium.
Actors addressed (industry, government, civil society) environment/social/economic aspects	<p>The concept addresses the importance of government- as well as industry actors and the civil society likewise. It clearly states that, only by viewing sustainability as an integrated phenomenon the multiple challenges resulting from our currently unsustainable development path can be met.</p> <p>Hence sustainable consumption and production takes into consideration all three dimensions of sustainability.</p>

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of ‘public goods’ and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.22 Product-service systems

	Description
Main aim / origins /history	<p>Product-service systems are a company related approach. The idea is to sell the service of a product rather than the product itself (Jasch et al. 2006). Consumers are interested in the comfortable warmth and not in the technical heating system. The concept has been developed in academic circles and some initiatives tried to transfer the PSS concept to industry but it is still not implemented widely.</p> <p>A product-service system represents the change from a focus on producing and consuming products to consumption approach, where the service components are increasingly replacing the more traditional material intensive ways of product manifestation (Jasch et al. 2006). A focus on service provides individuals and organisations with the possibility to fulfil needs through the provision of more dematerialised system solutions (Mont, 2000). Baines et al. (2007) explains that a product-service system proposes to extend the traditional functionality of a product by incorporating additional services. Here the emphasis is on the “sale of use” rather than the ‘sale of product’. The customer pays for using an asset, rather than its purchase.</p> <p>The definition of product-service system reflects the development of the production systems in the society. The society went from focusing on products to discovering the surrounding factors of a product and its production system e.g. other products and services, drivers, stakeholders, factors that influence a product's performance, friendliness to the customer and environment, price, reparability, and all other parameters of the product's life cycle. The concept of product-service system indicates that society buys services instead of products, and that the service plays a very important role in customer satisfaction and again in product performance (Mont 2000).</p>
Scope of change	The scope of change resulting from the increasing importance of product-service system can be considered high, as it significantly drives dematerialization and the change to a more service oriented economy.
Paradigmatic degree of change	The PSS concept is much related to the vision of a leasing society, in which people have acquired a new mind set. This society takes a different approach to consumption. Instead of satisfying human needs through material goods and services, they are now met by “functions”. As such, PSSs call for a paradigmatic change of our values and behaviours that are currently rooted in the material foundation of our economy. It seems appropriate to argue that the idea of a service oriented economy calls for a revolution of the basic parameters that our economic system is built upon.
Plausibility of pathways of change	The PSS concept is conceptually valuable and there is an substantial amount of literature (e.g. Jasch et al 2006) providing companies with pathways for how to put theory into practice, however, despite several singular initiatives, PSS have still not been implemented widely. Possible reasons for this failure to disseminate the concept are (a) the lack of inappropriate supporting methods and tools for the companies and (b) the lack of acceptance of consumers. Ownership is an important factor for consumers and there appears to be a psychological barrier which prevents consumers from turning away from possessing things towards their common use (Hrauda 1999, 4).
Actors addressed (industry, government, civil society) environmental/social/economic aspects	<p>This concept addresses business actors and their consumers. It leaves sustainability up to market-forces.</p> <p>However, due to its far reaching implications PSSs address all dimensions of sustainability likewise.</p>

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.23 Circular economy

	Description
Main aim / origins /history	<p>“A Circular Economy is an economy that balances economic development with environmental and resource conservation. It puts emphasis on environmental protection and the most efficient use of and recycling of resources. A Circular Economy features low consumption of energy, low emission of pollutants and high efficiency. It involves applying Cleaner Production in companies, eco-industrial park development and integrated resource-based planning for development in industry, agriculture and urban areas. The Circular Economy was adopted by the Chinese Government in the last five year plan (2001-2005) as the development model for China to follow” (UNEP 2010).</p> <p>The Ellen Macarthur Foundation defines the circular economy referring to an industrial economy that is restorative by intention. It aims to rely on renewable energy; minimises, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design. The concept of the circular economy is grounded in the study of non-linear systems, particularly living ones. It involves a careful management of materials flows, which, in the circular economy, are of two types as described by McDonough and Braungart (quoted by Ellen Macarthur Foundation 2013): “biological nutrients, designed to re-enter the biosphere safely and build natural capital, and technical nutrients, which are designed to circulate at high quality without entering the biosphere”.</p> <p>A core principle of the circular economy is the concept of 3Rs (reduce, reuse and recycling), which is used for defining the waste management hierarchy. Essentially, the circular economy defines an ecological economy that follows the principles of ‘reducing resource use, reusing, and recycling’, with the objectives of reducing the resources that enter the production process, effecting multiple use of the same resources in different ways, and reusing waste from one facility as a resource for other facilities.</p>
Scope of change	The scope of change intended by the circular economy is high. It proposes a fundamental transformation of the whole economic system from a linear model to a circular one.
Paradigmatic degree of change	circular economy (e.g. EU, McKinsey) predominantly emphasize the business opportunities and economic benefits entailed in this concept. With a focus only on economic aspects, the degree of paradigmatic change is low.
Plausibility of pathways of change	The concept responds to real life driving forces like environmental pollution and resource scarcity and brings up plausible pathways to deal with these challenges. China for example was the first country to implementing the Circular Economy at an Industrial level, with the development of 30 Eco-Industrial Parks based on circular economy principles. Also the EU has developed policies based on the concept of transforming the economy into a circular model (UNEP 2010). Since the experiences with implementation of a circular economy have shown deficits in the pathways, the plausibility is ranked medium.
Actors addressed (industry, government, civil society) environment/social/economic aspects	<p>This concept mainly addresses industry-actors, but also governments, since they are supposed to incentivise industries to become circular.</p> <p>It emphasizes the economic and environmental dimension of sustainability, while viewing social benefits as positive side-effects.</p>

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.24 3R

	Description
Main aim / origins /history	<p>The 3R concept is a core principle of the circular economy. It aims at promoting the “3 Rs” (reduce, reuse and recycle) globally so as to build a sound-material-cycle society through the effective use of resources and materials. Agreed upon at the G8 Sea Island Summit in June 2004, it was formally launched at a ministerial meeting in Japan in the spring of 2005 (UNEP 2010).</p> <p>Reducing means choosing to use things with care to reduce the amount of waste generated. Reusing involves the repeated use of items or parts of items which still have usable aspects. Recycling means the use of waste itself as resources.</p> <p>Waste minimisation can be achieved in an efficient way by focusing primarily on the first of the 3Rs, “reduce,” followed by “reuse” and then “recycle” (UNEP 2010).</p> <p>Japan has embarked on continuous development of a legislative structure geared towards 3Rs, with the emphasis moving to the “front of pipe” or preventative, rather than “end of pipe” solutions to its waste problem. The development of a “Recycling Oriented Economic System” has created new policies and legislation aimed at overcoming the country’s severe landfill shortage. Japan is revising from a sole focus on hazardous substances management to new phases of greening, especially in the home appliance and electronic sectors. The 3R Project is to be completed in three phases:</p> <ul style="list-style-type: none"> • Phase 1: Elimination of hazardous chemical substances • Phase 2: Recycling • Phase 3: Green new product development
Scope of change	The 3R concept aims at transforming the economic system as a whole, initiating fundamental changes in other societal subsystems. Thus, its scope of change is considered high.
Paradigmatic degree of change	The focus is on business opportunities and economic benefits, so the degree of paradigmatic change is low.
Plausibility of pathways of change	enactment or amendment of various laws relating to waste management and recycling. Experience with this approach suggests that the pathways do not always address central issues, so the plausibility is ranked medium.
Actors addressed (industry, government, civil society) environment/social/economic aspects	The 3R concept addresses mainly businesses, consumers and governments. Its systemic approach makes the 3R concept consider all three pillars of sustainability.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of ‘public goods’ and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.25 De-growth

	Description
Main aim / origins /history	<p>De-growth denotes economic downsizing. The vision of a degrowth society comprises a relocalisation of the economy, a fairer distribution of income and resources, new and more democratic institutions, sufficiency, and social and technical innovations that support a convivial and frugal way of life. Nicholas Georgescu-Roegen, who published numerous essays on economics and degrowth in the 1970s, is viewed by proponents of the degrowth movement as one of the leading pioneers of the concept. The Club of Rome Report “Limits to Growth” and E.F. Schumacher’s book “Small is Beautiful” are also seen as early calls for degrowth. Nonetheless, it is only in recent years that the movement has obtained momentum. The first international conference in Paris in 2008 marked the beginning of the academic debate and civil society movement that exist today. Since then, two further international conferences have taken place: 2010 in Barcelona and 2012 in Venice (Pirgmaier 2012).</p> <p>Continuous environmental and economic crises compounded by a growing disjuncture between the real economy (in which the value of natural capital is seldom recognised) and the fictitious paper economy of finance have provoked renewed calls to depart from the promethean economic growth paradigm and to embrace a vision of sustainable de-growth. De-growth proponents recognize that the natural limits to growth have already been surpassed and we are now entering an overshoot phase which may not be but a transition leading to a more or less prolonged period of decline. The concept of sustainable de-growth is understood as an equitable and democratic transition to a smaller economy with less production and consumption. Such a system, in the eyes of its proponents, would allow a prosperous way down or at least a soft landing rather than a crash due to environmental collapse (Martínez-Alier et al. 2009).</p>
Scope of change	The de-growth concepts foresees the necessity to change the economic system and accept a no growth policy as its basis. This idea transcends all societal systems and therefore, its scope of change can be considered high.
Paradigmatic degree of change	The degrowth idea arises from the debate surrounding critiques of growth. Economic growth is characterised as a problem and not as a solution for social and ecological problems. Technological innovations and greater resource and energy efficiency are not enough in themselves because rebound effects occur that increase production and consumption and thus lead to yet more environmental consumption. In its critique of neoliberal economic theory and practice, degrowth stands in opposition to the concept of sustainable development. Any form of additional economic growth, whether it be sustainable, green, or social, is seen as legitimising the continuation of the status quo and as a distraction from the contradiction that GDP growth and renaturation on a sustainable level are mutually incompatible. For degrowth adherents, the necessity for degrowth—as soon and in as democratic a form as possible—is the logical conclusion of critiques of orthodox economic systems and the awareness of social and ecological problems (Pirgmaier 2012). Therefore de-growth calls for a fundamental paradigmatic change – a revolution in our economic system, related values and institutions.
Plausibility of pathways of change	<p>The discussion on degrowth has engaged with possible pathways. For example, Paech (2009) discusses 5 pathways of change. The Barcelona Degrowth Conference in 2012 developed concrete proposals for future actions, for example introduction of local currencies, co-housing and a guaranteed basic income.</p> <p>plausible pathways for political action that can be taken in order to strive towards downsizing the economy do not fit with this concept, which is based on a bottom-up approach that is not primarily driven by policy. Plausible pathways are therefore available but are not policy-driven, so the plausibility is ranked medium.</p>
Actors addressed (industry, government, civil society) environment/social/economic aspects	<p>Supporters of degrowth come from diverse fields, although most are scientists or activists. They pursue very different strategies in promoting the idea of degrowth. Some constitute protest movements against new large-scale infrastructure projects (e. g. motorways, nuclear power stations), others attempt to promote alternative infrastructures (e. g. solar energy, cycle transport); some focus on individual actions (e. g. —voluntary simplicity), others on collective measures (e. g. cohousing); some wish to replace existing institutions, while others wish to see their adaptation; some work in research fields, whereas others insist that action at local level is of primary importance. It mainly addresses consumers, civil society and scientists, viewing businesses and governments as barriers to change, which have to be overcome</p> <p>Degrowth pose the question of how the upcoming degrowth can be managed in order to avoid social and ecological collapse. As such it addresses all three pillars of sustainability.</p>

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.26 Resilience & safe operating space

	Description
Main aim / origins /history	<p>Resilience is often described as the ability of systems to adapt to unforeseen changes. The concept is used in different disciplines, first in psychology, later in ecology and economics. The resilience approach focuses on the dynamic interplay between periods of gradual and sudden change and how to adapt to and shape change (www.stockholmresilience.org)</p> <p>Rockström and colleagues introduced the term “safe operating space” in 2009. It identifies biophysical thresholds which shouldn’t be crossed in order to prevent “eroding the resilience of major components of Earth-system functioning.” Several of the thresholds (e.g. freshwater, chemical pollution, phosphorous) deal directly with resources and their use, others deal indirectly with resource use (e.g. climate change and stratospheric ozone depletion).</p>
Scope of change	<p>If humanity seriously decided to live within the so-called planetary boundaries the scope of change would be system wide, since it would mean drastic reductions of emissions, new agricultural practices, reducing chemical pollution etc.</p> <p>Shaping change for a resilient system is carried out using an adaptive management approach that has similarities to the transition management approach discussed above. See also http://www.wachstumimwandel.at/wp-content/uploads/Policy-Paper-Resilienz-_makro_final.pdf</p>
Paradigmatic degree of change	<p>The adaptive management approach is a major paradigmatic change, since it adopts a participatory and experimental process.</p> <p>Planetary boundaries represent a paradigmatic change, acknowledging that the Earth System is complex and abrupt, non-linear regime shifts are possible and should be avoided.</p> <p>The paradigm change is largely within the scientific community and not really considered within the policy arena.</p>
Plausibility of pathways of change	<p>The pathways of change are not defined for planetary boundaries. The adaptive management approach does not define pathways, it relies strongly on processes of experimentation and learning. Thus, the plausibility can be rated medium.</p>
Actors addressed (industry, government, civil society) environment/social/economic aspects	<p>“Safe Operating Space” and “resilience” are becoming widely used in the scientific community and were introduced in UNEP’s Global Environmental Outlook (UNEP 2012a), which addresses policy-makers. Governments were addressed by the Stockholm Memorandum in 2012 and many case studies on resilience have involved a broad range of societal actors.</p>

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of ‘public goods’ and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.27 Hannover principles

	Description
Main aim / origins /history	<p>The Hannover Principles are design principles for sustainable buildings and objects. They were formulated by William McDonough and Michael Braungart (1992) as principles for the design competition for the EXPO 2000 in order to guarantee design and construction in the understanding of sustainability.</p> <p>McDonough and Braungart propose that “designing for sustainability requires awareness of the full short and long-term consequences of any transformation of the environment. Sustainable design is the conception and realization of environmentally sensitive and responsible expression as a part of the evolving matrix of nature”. The nine principles are:</p> <ol style="list-style-type: none"> 1. Insist on rights of humanity and nature to co-exist in a healthy, supportive, diverse and sustainable condition. 2. Recognize interdependence. The elements of human design interact with and depend upon the natural world, with broad and diverse implications at every scale. Expand design considerations to recognizing even distant effects. 3. Respect relationships between spirit and matter. Consider all aspects of human settlement including community, dwelling, industry and trade in terms of existing and evolving connections between spiritual and material consciousness. 4. Accept responsibility for the consequences of design decisions upon human well-being, the viability of natural systems and their right to co-exist. 5. Create safe objects of long-term value. Do not burden future generations with requirements for maintenance or vigilant administration of potential danger due to the careless creation of products, processes or standards. 6. Eliminate the concept of waste. Evaluate and optimize the full life-cycle of products and processes, to approach the state of natural systems, in which there is no waste. 7. Rely on natural energy flows. Human designs should, like the living world, derive their creative forces from perpetual solar income. Incorporate this energy efficiently and safely for responsible use. 8. Understand the limitations of design. No human creation lasts forever and design does not solve all problems. Those who create and plan should practice humility in the face of nature. Treat nature as a model and mentor, not as an inconvenience to be evaded or controlled. 9. Seek constant improvement by the sharing of knowledge. Encourage direct and open communication between colleagues, patrons, manufacturers and users to link long term sustainable considerations with ethical responsibility, and re-establish the integral relationship between natural processes and human activity (McDonough 1992). <p>http://www.c2c-centre.com/sites/default/files/The%20Hannover%20Principles_1.pdf</p> <p>http://www.mcdonough.com/speaking-writing/the-hannover-principles-design-for-sustainability/</p>
Scope of change	The Hannover Principles are only targeted at one specific industry, namely design and construction. Considering that the principles focus only on design and construction, the scope of change is low.
Paradigmatic degree of change	The paradigmatic degree of change seems to be high. The principles are based on a holistic concept, where humanity as well as nature has the right to live in a healthy, sustainable condition. Besides, inter-generational aspects are considered (create safe objects of long-term value) .
Plausibility of pathways of change	The concept has so far failed to provide clear pathways of change such as new legislations providing incentives for the design and construction industry to incorporate the Hannover Principles to their core business-activities.
Actors addressed (industry, government,	<p>The Principles are to be considered by designers, planners, government officials and all involved in setting priorities for the built environment.</p> <p>They mainly focus on the environmental aspect: the rights for nature and interdependencies</p>

civil society) environment/social/economic aspects	between human design and nature. However also the social and the environmental dimension of sustainability is incorporated in the 9 Hannover Principles.
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	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.28 *BoP business models*

	Description
Main aim / origins /history	BoP business models aim at reducing poverty through profitable business opportunities. The base of the Economic Pyramid (BoP) is the largest but also poorest socio-economic group. However, together they have significant purchasing power. The idea is to use this potential. Private firms explicitly address the needs of the bottom of the economic pyramid and improve the quality of life of these people (WRI no date).
Scope of change	The BoP business models scope is focused on transforming the system of informal dysfunctional markets of the poorest socio-economic group. As such it aims at transforming an entire system.
Paradigmatic degree of change	The BoP model stays within the logic of the market. It develops business strategies and adopts a market based approach to poverty reduction. It is a pro-growth concept which considers that there is a market of 4 billion people yet unaddressed. The meeting of their needs and the involved business-models entail growth.
Plausibility of pathways of change	The BoP model is based on the awareness that some business models work, others not. Hence, there are concrete strategies for successful business models (e.g. Gollakota et al. 2010) providing plausible pathways for change. However, there is not much evidence that these strategies have been implemented successfully in real life and shown the potential to trigger radical change towards sustainable development. Thus, the plausibility of pathways is rated medium.
Actors addressed (industry, government, civil society) environment/social/economic aspects	It addresses business showing opportunities for addressing people with lowest income and enabling them to become consumers. It focuses on social and economic issues of sustainability, in the sense of allowing consumption for the poorest socio-economic groups. In the BoP model, environmental issues are of minor importance.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.29 Leapfrogging

	Description
Main aim / origins /history	Leapfrogging is a term used to describe the possibility for developing countries to bypass inefficient, polluting, and ultimately costly phases of development by jumping straight towards sustainable human development and a better quality of life. In other words, is the concept demonstrates an opportunity to avoid the inefficient and polluting phases of development that industrialised countries have gone through. The term “leapfrogging” describes the rapid change made by a society or a company to a higher level of development without going through the intermediate stages observed in other cases. This connects with the idea that economic resources for unsustainable, outdated and polluting technologies can be saved and instead invested directly in a sustainable future. Ecological leapfrogging can be an alternative to development-as-catching up. It provides strategies to directly enter the phase of sustainability without going through the resource-intensive production and consumption models of industrial societies (UNEP 2010).
Scope of change	medium as it is often only related to specific industries in the developing world or certain parts of the value chain. It does not focus on changing the societal system as a whole.
Paradigmatic degree of change	The concept ambition to initiate a paradigmatic change is medium. It adheres to the existing paradigm of utilitarian use of nature, yet acknowledges that nature is a public good. Hence, in the leapfrogging concept government intervention is an essential precondition for solving resource related problems.
Plausibility of pathways of change	There is a discussion about pathways to change in some industries, such as the promotion of ICTs in developing countries (e.g. Steinmueller 2001), however, the concept has not been implemented on a broader scale. Hence, there is no evidence that leapfrogging is a plausible concept for triggering radical change towards sustainable development so far. countries
Actors addressed (industry, government, civil society) environment/social/economic aspects	This concept addresses all societal actors including governments, businesses and international development and trade agencies as well as the civil society in developing countries. Leapfrogging takes into account all three dimensions of sustainability.

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of ‘public goods’ and related right of government to act in public interest	Seeks an alternative for the utilitarian and rational economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

2.30 Slow food, transition towns

	Description
Main aim / origins /history	<p>The transition movement comprises groups of committed citizens who join together in cities and smaller communities to respond to climate change and Peak Oil by minimising their carbon footprint and increase their resilience to supply deficits triggered by oil shortages (Pirgmaier 2012).</p> <p>In the search for responses to climate change and Peak Oil, Transition Communities aim to actively manage the transition to a resilient, self-sustaining society. Their goal is to free themselves from a dependency on fossil energy carriers and to practice a low carbon lifestyle. They view themselves as a form of "social experiment" and as being on a learning path. The term —Transition Movement originated in Ireland and Great Britain, where the idea of transition as the further development of the permaculture concept was born. The first Transition Towns were established in Kinsale (Ireland) und Totnes (England) in 2005, at the initiative of Rob Hopkins. In 2008, Hopkins published the Transition Handbook as a 12-step guide to support further Transition Initiatives. Supported by the Transition Network founded in 2007, the movement spread throughout the world. As of November 2011, a total of 406 local communities had officially joined, mostly in Europe, North America, and Australia, with a few participants elsewhere (Pirgmaier 2012).</p> <p>Slow Food is an international grassroots movement as alternative to fast food chains and industrial agriculture. Its aim is to preserve regional cuisine and culture as well as the environment and biodiversity. It was founded by Carlo Petrini in Italy in 1986 and expanded from a gastronomic association to a social and political movement. "Slow Food believes that everyone has a fundamental right to the pleasure of good food and consequently the responsibility to protect the heritage of biodiversity, culture and knowledge that make this pleasure possible" (Slow Food Website 2013).</p>
Scope of change	The scope of change is high, since transition towns aim to change from being energy-dependent to being locally-oriented and resilient communities. Likewise, the slow food movement brings a high scope of change, given the aim of shifting from large agro-industries to locally produced and consumed food.
Paradigmatic degree of change	At the local level these initiatives aim for a change of paradigm.
Plausibility of pathways of change	The Transition movement does not provide readymade answers. It sees itself as providing both the inspiration and catalyst for change. Concrete ideas and projects are developed at community level in open and creative consultation processes. The Transition Handbook of Rob Hopkins 2008 provides concrete pathways for change. Both types of initiatives depend on bottom-up processes of engagement, which means that explicit pathways cannot be defined in a top-down manner. The plausibility is therefore medium, since the initiatives do show how change can be supported (Pirgmaier 2012).
Actors addressed (industry, government, civil society) environment/social/economic aspects	<p>The transition movement comprises groups of committed citizens who join together in cities and smaller communities to respond to climate change and Peak Oil by minimising their carbon footprint and increase their resilience to supply deficits triggered by oil shortages (Pirgmaier 2012).</p> <p>Transition Towns mainly address environmental aspects of sustainability but also take into consideration the organisation of communities. Thus, it can be argued that also social aspects are covered.</p> <p>Slow Food believes that food is tied to many aspects of life, including culture, politics, agriculture and the environment. This is why we are an active player in a wide variety of areas, from education to agricultural policy. To work across this broad sphere, Slow Food defends biodiversity in our food supply, promotes food and taste education and connects sustainable producers to co-producers through events and building networks" (Slow Food Webpage 2013). This clearly indicates the holistic approach the slow food movement takes on sustainability.</p>

	Low	Medium	High
Scope of change	One specific industry	Various parts of value chains	Societal (sub) systems
Paradigmatic degree of change	Focus on market-based solutions	Recognition of 'public goods' and related right of	Seeks an alternative for the utilitarian and rational

		government to act in public interest	economic approach to life and nature
Plausibility of pathways of change	Ignores factors making change un-necessary	Explains at best conceptually factors supporting change	Explicit and plausible discussion of pathways of change

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