Transversal
International Journal for the Historiography of Science

Transversal: International Journal for the Historiography of Science 2020 (9): 1-20
ISSN 2526-2270
Belo Horizonte – MG / Brazil

Article

The Emerging Research Field of Sustainability Transitions: An Evolutionist Perspective on Scientific Advance

Victo José da Silva Neto[1]

Abstract:

The main goal of this article is to understand the process of formation of the sustainability transitions (ST) research field. The working hypothesis of this article states that the field arises through a process of speciation: gradual differentiation, from an older and already established research field (innovation studies). This exercise is useful both as a first approximation into the history of ST thought and as a means to assess the explanatory potential of different approaches towards scientific advance (epistemological discussion). Our proxy to investigate the evolution of the field is the ST language or scientific lexicus (concepts, terms and vocabulary) and how it came to be. The methodology to assess the evolution of this object is threefold: documental analysis (epistemic communities' newsletters); critical review of the literature (retrofitted concepts and proto-ideas) and bibliometric analysis (Scopus/Vantage Point). The documental analysis provides evidence that ST is, indeed, an emergent scientific field. A critical review of the literature points to connections and redetermination of pre-existent concepts and terms from the innovation studies area; bibliometric evidence points to a movement of distancing: after building its own lexicon coherent to its problem framing, ST research area is gradually leaving innovation studies terms and concepts behind. General results point to a process of speciation, reinforcing the explanatory potential of epistemological evolutionism.

Keywords: Language and Science; Epistemology; Epistemic Community; Sustainability; transitions

DOI: http://dx.doi.org/10.24117/2526-2270.2020.i9.04

Introduction

"This may sound like a matter of semantics only, and it may change little about the substance of the main arguments raised in this paper, but it suggests working on a new policy **vocabulary** that is better in line with most recent advances in innovation research" (Weber; Rohracher 2012, 1046, emphasis added). One of the last sentences of the article by Weber and Rohracher denotes the main point of this article: sometimes, science is a matter of

[1] Victo José da Silva Neto [https://orcid.com.br/0000-0002-9009-1203] is a PhD Candidate in the Science and Technology Policy Department at the State University of Campinas. Address: Rua Carlos Gomes, 250 – Zip code: 13083-855 - Campinas, SP (Brazil). E-mail: victont@gmail.com

grammar. I do not mean by that the usual grammar, though; rather, grammar as a set of vocabulary rules shared by a specific community that serves specific uses.

Also in that paper, the authors work hard to refurbish some concepts related to the old literature of innovation systems, so as to couple then to new issues raised by the new literature on sustainability transitions. The title of the article is straightforward: *Legitimizing research, technology and innovation policies for transformative change: combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework*. In other words, they are trying to create a bridge between the old and the new research fields, and this bridge is built using a specific grammar.[2]

It may seem strange to deal with scientific advancement through the concept of grammar, or vocabulary. This feeling of unease has a lot to do with the predomination, at least outside the core area of history of science and philosophy of science, of the *scientific paradigm* proposed by Thomas Kuhn, in 1962.[3] However, the paradigm is not the only possible conceptual device for focusing on and understanding the advancement of science. In fact, even it's ontological stance is not consensual. The paradigm is the bearer of a discontinuous view of scientific advancement. According to Condé, other authors such as Wittgenstein and Fleck provide different accounts of scientific advancement: one in which transformations are gradual, not revolutionary. Instead of paradigms, they talk of shared *codes of language*, *grammar*, *thought styles* and *thought collective*. Science unfolds then through processes of speciation that surmount the – so problematic – notion of incommensurability, so dear to the early Kuhn.

This article investigates the emergence of a research area *in flux*. This new research area, self-nominated *sustainability transitions* (Markard *et. al.* 2012), seems, at first sight, to corroborate the assumptions of the evolutionary epistemologists of scientific development. The effort to bridge concepts from a related old research area to the new one signs some sort of *commensurability* and gradualism. To verify to what extent does the emergence of this field matches the assumptions of the gradualist' scientific change, methodology proceeds in three steps: (i) to review the main concepts of the sustainability transitions research area; (ii) to collect bibliometric evidence regarding the citations among the most important articles of this emerging community; and finally (iii) to look for publication of manuals and/or handbooks, an indicative of a stabilized and shared minimum grammar. The first step looks for *proto-ideas*: speciation of older concepts, or refurbishing, into better suited new versions of the old concepts. The second step's main goal is to find out, through co-occurrences of key terms, the relatedness of the emerging research fields with other established research fields (such as innovation systems).

The underlying hypothesis takes this form: the scientific field of sustainability transitions has evolved from previous research fields and, gradually, developed a grammar of its own. We do not expect to find a steep paradigm shift whatsoever. Instead of that, we expect to find a process of **speciation**: a continuous improvement in the common language of the field, derived from previous related scientific fields.

[2] "In this paper we have worked out a set of guiding rationales for underpinning a broader approach to innovation policy that is geared towards inducing and realizing long-term processes of transformative change towards sustainability. With these rationales **we have tried to reconcile structure-oriented innovation system approaches with the multi-level perspective of socio-technical transitions**" (Weber; Rohracher 2012, 1045, emphasis added).

[3] Condé (2003, 128), who provides most of the theoretical assumptions mobilized in this article, argues that, despite its shortcomings, the simplicity and didatism of the kuhnian paradigm was responsible for its widespread adoption. The *paradigm* was such an appaling success that even Kuhn itself failed later on to overcome it, when trying to advace into more comprehensive frameworks to deal with scientific development (first introducing the *disciplinary matrix*; finally, the *lexicon*) (Condé 2003, 128).

Theoretical References

> In those years it comes to life and rapidly reaches full maturity a form of knowledge that reveals characteristics structurally different from other forms of culture, barely managing to create its own institutions and its own **specific languages.** (Rossi 2001, *premise*; own translation, emphasis added)

Modern science, according to Paolo Rossi, struggled to create its own institutions and language. Why was language so important? Because it mediates the reachable truth and human understanding. Even more than understanding nature, language defines the *shape* of the diffusion regarding that understanding. Pre-modern science, often intertwined with alchemy, had its own "ambiguous and elusive" language. The patterns of scientific language also reflect the ontology of science itself. Since pre-modern science regarded science / truth as partially concealed, hidden, except for those enlightened beings versed in the scrutiny of secrets, its language was structurally, purposely opaque, "full of semantic slips, of metaphors, of analogies and elusiveness" (Rossi 2001, 37).

That's why the language revolution of modern science is so important. The commom grammar, clear and direct, designed to reach the broader audience. The mertonian norm of communalism, which refers to the collective use of what is produced by science, excluding the secrecy and exclusiveness of the scientific universe. Yet science is not static, and the language that represents it can not be either. Its language, therefore, is dynamic, and is related to the scientific facts that emerge and to the social praxis that defines its meaning. But exactly how does this co-evolution of scientific facts and scientific language happens?

Condé (2005, 2012, 2016) mentions the basic elements to understand two distinct epistemological stances: the *epistemological catastrophism* sums up the idea that scientific practice depends on some sort of cognitive consensus that changes from time to time in a discontinuous fashion. This cognitive consensus is subsumed into the kuhnian scientific paradigm (1962). The alternative stance is called *epistemological evolutionism*, and regards scientific advancement as a gradual process, permanently happening, permanently reforming its consensus, often through processes of language displacement/replacement. Ludwik Fleck's notion of *thought style* and Wittgenstein's proposal of a pragmatic *grammar* (that gives meaning to scientific practice and at the same time is signified by scientific practice) synthesize this evolutionary stance towards the advancement of scientific knowledge (Condé, 2005, 2012).

Figure 1 - Scientific Knowledge's Epistemological Perspectives in Dispute (Based in Condé, 2005)

However, there are similarities in both perspectives. For instance, the perception that social elements influence the consolidation of both a paradigm or a thought style. The Wittgensteinian grammar seems even more connected to the social use of the scientific knowledge: "the rules that constitute the grammar are embedded in social practice. A rule can only constitute itself effectively as such by social *praxis*. Grammar is a social product" (Condé 2012, 92). Kuhn and Fleck, in their own ways, also promoted the "social aspects present in the production of scientific knowledge" (Condé 2013, 135, own translation) In this sense, both epistemological perspectives here analysed are externalists: they abide to the idea that the development of science is conditioned by non-scientific, social factors.

Still, their differences are also startling and, maybe, they rather account for a difference in the degree of change, than for a difference in the nature of change. Fleck and Wittgenstein reclaimed a progressive change in the cognition's frameworks that allowed for a specific "guided perception" of scientific problems and facts. Kuhn emphasized the radical change of paradigms: "ducks in the scientist world before the revolution, are rabbits afterwards" (Kuhn 1970 *apud* Condé 2013, 137). An important consequence of this approach is the commensurability issue. Since paradigms abruptly change, there is no room for the previous practices or *grammars* associated with the paradigm that was overcome – the *social conventions* and the meanings that *social praxis* used to attribute to concepts and words were revolutionized.

Box 1 – Key Concepts' Definitions

Grammar: a set of rules that is pragmatically (constructed through social praxis) open, (new rules can be added, old rules changed) and that governs the use of language (Condé 2012, 92). Another definition is "grammar is constituted as a set of rules that is formed from language-games" (Condé 2016, 53).

Tought Style (*Denkstil*): according to Condé, the thought style can be perceived as the *Grammar of Science*; it is "The set of language-games or semantic-pragmatic rules involved in the construction of scientific knowledge in a form of life" (Condé 2012, 91).

Gestalt: the stablished shape of a thought style, or the concrete interactions in the scientific community under the influence of a specific thought style

The impossibility of this bridge between the old and the new leads to a conundrum involving theory and history. History shows that scientific practices, grammars and "technical and literary styles", as mentioned by Fleck, do not disappear after a revolutionary episode. Rather, they evolve and change – they adapt to the new social praxis, they absorb elements of the past and resignification also happens. This process could, at least in theory, be captured by the evolution of a specific scientific community grammar: "Science is a grammar or a thought style among multiple and different languages and practices that emerge in society" (Condé 2012, 93). Kuhn's theory, in this case, is not a flawless construct.

Therefore, for our purposes, and imbricated in our hypothesis, epistemological evolutionism presents a higher potential for explaining the emergence of new research fields. Fleck, instead of using the notion of paradigms, explains the stability and cohesion of a thought style through the installation of a *Gestalt* – a specific, historically and socially conditioned pattern of shaping scientific knowledge – of bringing scientific problems to the world and the peers. Thus, the prevailing *Gestalt* specifies a well defined way of shaping "thought's visual fields". The altercation of *Gestalten*, however, is not a radical battle of "all or nothing"; assuming a *Gestalt* does not imply the same incommensurability present

between competing paradigms (Condé 2013) (for some thoughts on different criteria for intertheory concurrence see **Box 2**).

Following that definition, what changes? The circulation of scientific knowledge itself. If there is some indirect communication between different thought styles and their respective *Gestalten*, there is also a constant open-ended system that might evolve under new influences. This is the *circulation between collective thoughts*. We may even postulate that there are two steps of circulation and cross-fertilization between collective thoughts, or thought styles: one, is the inherited knowledge from previous existent proto-ideas and concepts; the second one is the speciation, or mutation of the thought style (Condé 2013, 140). New rules for "guided perception" emerge then, from fragments of past thought styles – and even competing ones.

BOX 2 – Incommensurability and Inter-theoretical rivalry

Along with the Kuhnian incommensurability, the problem of inter-theoretical competition arises. Before Kuhn, the traditional view of the philosophy of science had two criteria to assert when two theories were in a competitive state: (i) the *convergence criterion* required that both theories be devoted to the same object of study (and it is for this reason that the Copernican-Ptolemaic pair was understood as a competitor and the Copernican-Darwinian pair did not); (ii) the *criterion of divergence*, according to which some incompatibility of beliefs about that object should exist between theories. The thesis of incommensurability suspends the possibility of the first criterion being respected: there being no referential identity between theories separated by a scientific revolution, "the effective relation of the competition will perhaps not be destroyed, but the logical spine of the traditional notion will be broken: if one can not determine if they speak about the same entities, two inter-theoretical statements can not be said to be logically incompatible" (Oliveira 1991, 45). This same author claims that Kuhn never offered an alternative theory for inter-theoretical competition, although he did give a clue: Kuhn comments in some passages how, even with the passage from one theory to another, the use of the same **signs** persists, even if with different functions. The signs, therefore, would be a kind of identifier of a kinship relationship (descent) between theories – and the new would emerge from the old by recycling its signs. Thus, Oliveira's interpretation is very close to epistemological evolutionists: [4] "inter-theoretical rivalry would be thought of as an instance of the conflict of generations ..." (Oliveira 1991, 51)

This mutation implies no pre-defined chronological period. It may take centuries, or it may take years. There must be, however, enough time for the new thought style to conceive its own *Gestalt* – and the technical and literary style associated with it. Certainly, the closer the thought styles (their kinship relationship, as stated in **Box 2**), the less time needed for

[4] As stated by Condé: "there are connections – to a greater or lesser degree – not just between scientific thought and everyday life, but also between different scientific thought styles (Fleck, 1986, 81). In Wittgensteinian terms, there are family resemblances between these particular realities" (Condé 2012, 102). We can think of this open systems (thought styles and grammars) slowly evolving together with the social praxis, and in this process reprogramming the same signs/words/concepts (or inserting new ones) towards new meanings/functions. And perhaps, it is precisely this modest degree of commensurability between the old and the new that provides, through praxis, some creativity and fosters diversibility into the scientific disciplines, as theoretically explored by Fleck (1980, 144) *apud* Condé (2003, 140).

this mutation/adaptation. But there is no clue concerning practical, *i.e.* historical measures of that in the literature here discussed.

Finally, an observation becomes necessary. Wittgenstein's concept of *grammar* is not restricted to the literary style or concepts mobilized by a scientific community at any given time. It ties into a much broader set of issues – institutions, social rules, etc. – and resembles Fleck's concept of thought style. Our focus hereafter rests on literary style, keywords and key concepts, as a very narrow clipping within a huge set of codes and tacit rules that conform a *grammar* in the Wittgensteinian sense.

Methodology

To assess the evolution of the ST field, this article combines elements of bibliometric analysis (top papers, yearly publications, citations and co-citations) with content analysis (key-words and concepts). Those statistics are related to a set of articles that compose the ST field. To get to this *core set* of articles, I follow Markard *et al* (2012) research method. Their search string was "Title-Abs-Key ("strategic niche management" OR "technological innovation system" OR "technological system" OR "multi-level perspective" OR "transition management")" (Markard *et al.* 2012, 959). This search string led to a data set (in Scopus, as the original research preconized) of 3.867 documents, almost a 100% increase over the 1.950 documents found by them in 2012. Since this first search string goal is to establish the core papers of the field, I have followed Markard *et. al.* (2012) procedure and, based on the information provided by the titles and abstracts of the documents, deselected those unrelated to our subject. Finally, I have compared the top 20 documents those authors arrive at with the list provided by Scopus as a result of the new search and checked manually for documents that had not appeared in this new set of results. This procedure led to the manual insertion of 9 documents. The result is documented in **annex 1**. The second step, still reproducing Markard *et al* (2012) search, was to look up for all the documents citing one or more of the 20 documents comprising the sustainability transitions "core-set". The result was 7.312 documents. Then, the same key-word filter used in Markard *et al.* (2012) was applied,[5] resulting in a set of 2.140 documents.[6] They comprise what is here considered the research field of sustainability transitions – nearly fourfold the number Markard *et al.* (2012) had found six years ago. The core-set was then analyzed with the aid of *Vantage Point* software, especially for the identification/analysis of keywords and most recurrent terms in the abstracts, through the software's *natural language processing* tool.

Results

Main Concepts and Proto-ideas

There is some important meta-reflection on the field of sustainability transitions. Beyond Markard *et al.* (2012), Geels (2013a), Geels (2013b), Chapin and Ligtvoet (2014) and Sengers *et*

[5] TITLE-ABS-KEY ((sustainab* OR environmental* OR bio* OR renewable OR socio- technical) AND (transition OR transform* OR "system innovation" OR "radical innovation" OR shift OR change)). The authors justify this filter by arguing that "The first part of this string is intended to refer to sustainability-related characteristics, while the second part should refer to the fundamental nature of the change" (MARKARD *et. al.* 2012, 960). We also limited the search for articles only and excluded those publishing in 2019.

[6] In their original search, the authors did a third step after this one: they manually inserted documents from special issues. We have not reproduced this third step since many of the documents they manually inserted were already in the list after our second step, so we only assume the risk of incurring in minor data losses.

al. (2016), conducted their own bibliometric analysis. Nevertheless, in this sub-section, we focus on the core concepts of the field and their foundations. For that purpose, Geels (2004), Weber and Rohracher (2012), Smith *et al.* (2010) and Loorbach *et al.* (2017) offer good insights. They inquire about the theoretical origins of the research field and how and why it emerged as it did.

Before getting into the concepts, it is important to understand how the field evolved. Smith *et al.* (2010) excel at this exercise: they conceptualize the intersection of sustainability and innovation studies as an area undergoing changes for, at least, the last forty years (autonomous research fields take time to establish!). This long term view allows them to see a recurring pattern of broadening the scope, both of the (i) *problem framing* supposedly addressed by the field and its practitioners and of (ii) *analytical broadening*, the natural response of the analytical tools to the higher demands of new problems framed.

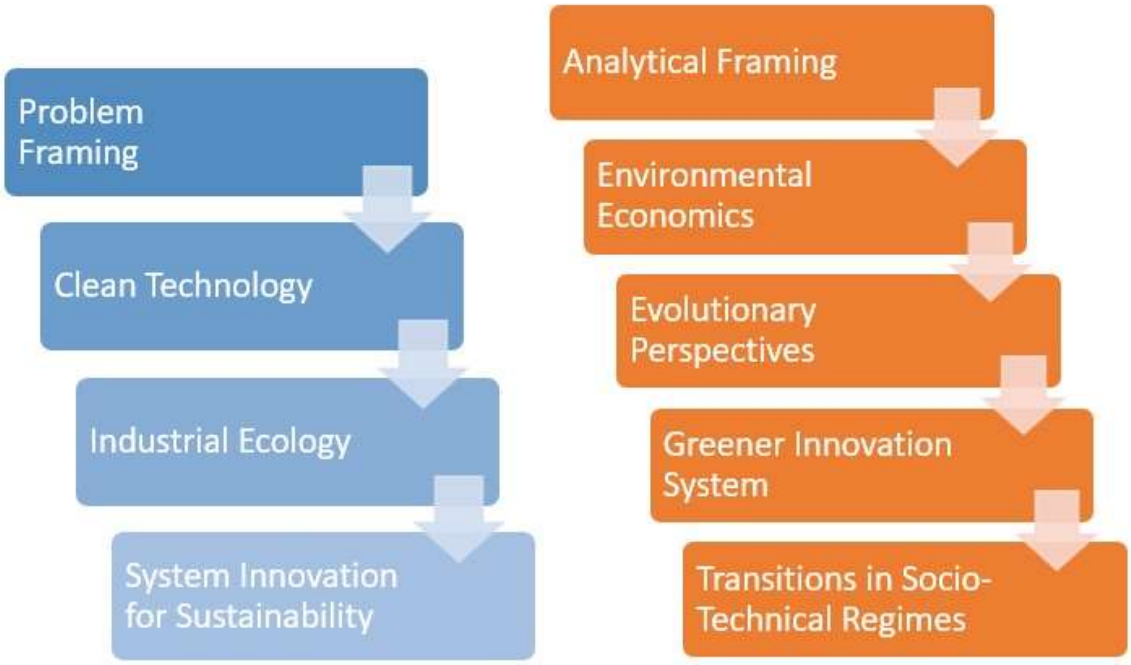


Figure 2 – Evolution of *problem-framing* and *analytical-framing* related to sustainability and innovation studies. Source: adapted from Smith *et al.* (2010)

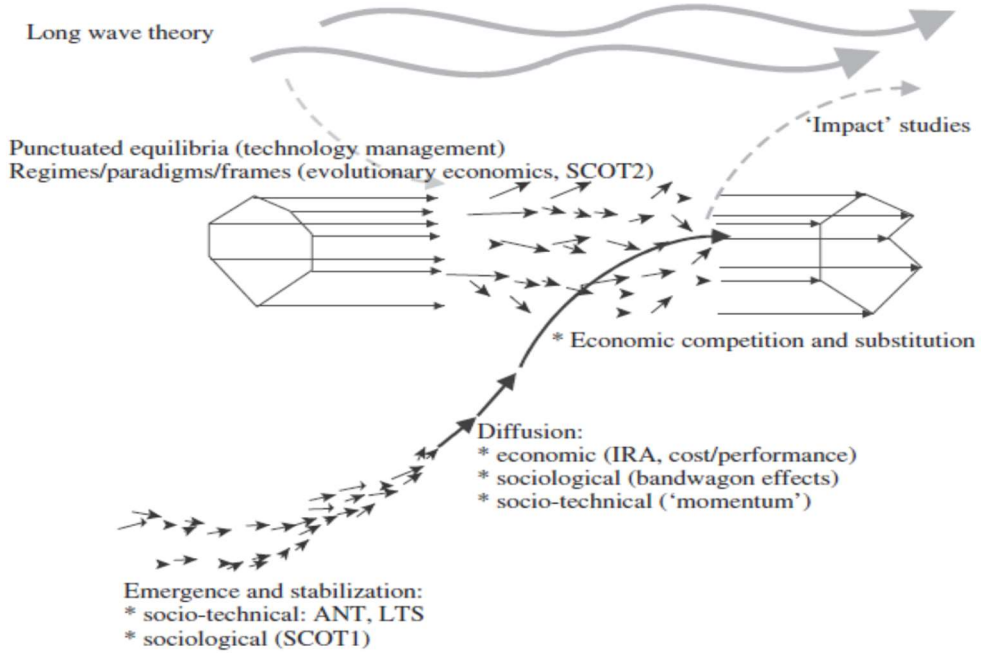
The last and current round of broadening saw the emergence of the multi-level perspective and other conceptual devices to address the issue of "system innovation for sustainability". The MLP aggregates diverse pre-existent theories into a (supposedly) coherent body of relations, as **figure 3**, from Geels (2004, 40) demonstrates.

It is an explicit example of gradual scientific evolution; even Oliveira's observation (1991) (commented in **Box 2**) seems to find evidence here: signs are kept, but functions and meanings are redetermined. In this operation, the long-wave theory, constructed by contributions of Simon Kuznets, J. A. Schumpeter, Carlota Perez and Christopher Freeman is coupled to the *landscape level*, the broadest level in the MLP building. The meso-level is understood in terms of *regimes*, and here not even the word changes, using Nelson and Winter (1982) seminal contribution to evolutionary economics, *i.e.*, the technological regime concept. Finally, the literature dedicated to large technical systems and social studies of science and technology provides the elements to the micro-level, the *niche*, the bearer of change, the level responsible for introducing novelties into the system in a process inspired by the classical diffusion studies. One must understand that the change in terminology is not devoid of meaning: it reflects the changes in the problem and analytical framing of the field.

Of course, its validation by the scientific community might happen or not, and this has more to do with its potential to explain those new problems framed.

While Weber and Rohracher (2012) also abide by the strategy of concept retrofitting, Smith *et al.* (2010) alert to the dangers of an indefinite re-framing of the *problematique* of the area. The larger the scope, the harder to find an adequate, accurate and efficient analytical tool to respond to its challenges. Maybe the problem framing enlargement is part of the process of autonomy construction of the field and we may observe a redefinition and a tighter scope of the problems addressed by sustainability transitions in the future.

Figure 3 – The Old and the New: MLP and a theory patchwork



Source: extracted from Geels (2004)

Still, the days of such close interaction with the previous, consecrated, scientific body, seem to be coming to an end. Loorbach *et al.* (2017) state that new subjects and "intellectual expansions" are drawing the field away from the most popularized socio-technical transition pathway, so akin to innovation studies.[7] A long excerpt from the authors, therefore, is deemed useful here:

> more recent intellectual expansions of the field include [...] socio-ecological system understandings; socio-economic trends and new economy phenomena [...] These so-called intellectual expansions are not just a matter of additional disciplinary perspectives. They represent a shift in the object and dimensions of sustainability transitions: from a focus on socio-technical systems to a recognition of socio-

[7] Actually, Loorbach *et al.* (2017) localize the emergence of ST in two clusters: one is the field of innovation studies (SSST and economics of innovation), and the other one is a generic field of "environmental studies" (environmental assessment, integrated assessment, sustainability governance, environmental policy). One can speculate whether the most popular approach in the field today - MLP - was not elevated to this popular condition precisely because it approached itself to the fields of innovation studies (already consecrated, with prestige and a wide community of practitioners) instead of approximating the myriad of strands generically categorized under the heading of "environmental studies".

ecological, socio-economic, and socio-political systems as equally relevant objects of transition" (LOORBACH *et. al*, 2017:603).

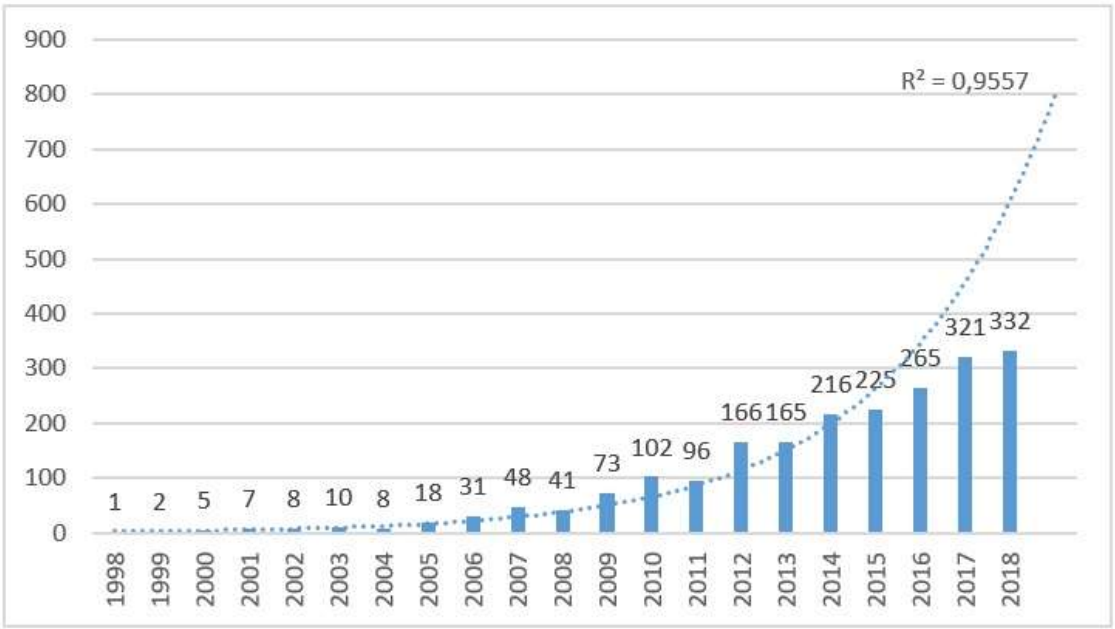
We turn now to the bibliometric evidence with this point in mind: does available data shows this research field in movement? And if so, where to?

Bibliometric Evidence

The results are presented in two parts: the general numbers of the field; then, a comparison between the numbers until 2011, when Markard *et al* (2012) did their assessment and the numbers from 2012 on. This second part intends to show if (and how) the field changed from Markard *et al* (2012) up to now (2018).

A) The General Picture

The field registers an important increase in the number of peer-reviewed articles published since 1998. **Graph 1** shows some important yearly outputs milestones. In 2010, the field registered the first year with 100 publications. It was a substantial growth comparing to the mean between 2005 – 2009. In 2014, four years later, it reached the mark of 216 publications. And three years later, it broke the 300 articles/year mark, in 2017. The pattern of growth shown is literally *exponential*, as the exponential trendline demonstrates (and the high value of R^2). This is a strong evidence that *sustainability transitions* is, indeed, an emerging field of research. There is still no sign of desacceleration and, *ceteris paribus*, the field might register a bigger number of publications in the next years.



Graph 1 – Peer-reviwed articles per year

Tables 1 and 2 account for the most productive authors in the field and for the country of origin of the articles, respectively.

Table 1 – Top 10 Authors by Number of Articles Published in the Field (1998 – 2018)

Nº Articles	Author
22	Smith, A.
21	Brown, R. R.
21	Geels, F. W.
21	Hekkert, M. P.
21	Raven, R.
19	Kern, F.
18	Loorbach, D.
16	Kemp, R.
16	Truffer, B.
14	Foxon, T. J.

Source: author's own.

Table 2 – Articles' countries of origin

Nº Articles	Affiliations
540	United Kingdom
406	Netherlands
257	Germany
250	United States
200	Sweden

Source: author's own.

Source: author's own.

Markard *et al.* (2012) had already pointed to the *European-bias* of the field. The bias remains, as the top authors and counties of affiliation in **table 1** and **table 2** demonstrate. The data shows some signs of deconcentration: China accounts for 51 articles, Japan for 36 and South-Africa registers 32. It is important to remember, though, that the affiliation list is non-excludable, so the same article may be attributed to more than one country of origin.

Tables 3 and **4** take us to the issue of vocabulary, our focus in this study. **Table 3** brings the most used keywords and **table 4** sums up the most recurrent phrases and/or concepts in the titles and abstracts of the article data set.

Table 3 – Recurrent Keywords

Nº Articles	Frequency	Keyword
595	691	Sustainability
481	587	Sustainable development
446	566	Innovation
333	473	Climate change
241	324	Energy policy
232	299	Sustainability transitions
224	282	Transition
187	188	Governance approach
171	174	Renewable resource
164	229	Renewable energy

Source: author's own.

Table 4 – Recurrent Concepts in the Abstracts (NLP Mechanism)

Nº Articles	Frequency	Term
113	190	transition
111	155	development
83	110	process
75	118	innovation
67	94	sustainability
58	72	change
58	74	climate change
53	76	sustained development
52	62	policy
50	65	technology

Source: author's own.

The combined analysis of **tables 3** and **4** allows one to identify a common set of themes (sustainability, sustained/sustainable development, climate change), a concern with specific topics in this field (energy policy, renewable energy, renewable resources), the orientation towards applied knowledge (energy **policy**, governance approach, policy), the dynamic nature of the object (transition, process, change) and its relatedness with another, already established, the field of research, *i.e.*, innovation studies (innovation, technology). The following sub-section will split these numbers into two sub-groups; we expect to capture the evolution of the field before and after 2012.

B) Sub-sets comparison: 1998–2011 versus *2012–2018*

The years of 2011-2012 were chosen as the dividing line of the sub-sets for some reasons: 2011 marks the first publication of *Environmental Innovation and Societal Transitions* (EIST), [8] a dedicated journal to socio-technical transitions; also in 2011, *Sustainability Transition Research Network* (STRN)[9] published its first newsletter; and, in 2012 *Research Policy* published its special issue on sustainability transitions, including Markard *et al.* (2012), which broadly spread the theme and became a landmark.

Breaking down the core-set into two sub-sets has a logic: the earlier publications should reflect the formation of the field and, as it is the hypothesis of this study, display connections to another, already established, research field. We assume that the features of sub-set I (1998-2011) should demonstrate higher relatedness to the innovation studies research area than sub-set II (2012–2018). The higher influence of innovation studies in the earlier, formation phase, of sustainability transition studies, if identified, points to the process of speciation discussed earlier. More specifically, one hopes to find higher importance of terms and concepts that belong to the innovation studies area in sub-set I; the formation and consolidation of a proper lexicon in sub-set II.

[8] "Aims and Scope: The journal offers a platform for reporting studies of innovations and socio-economic transitions to enhance an environmentally sustainable economy and thus solve structural resource scarcity and environmental problems, notably related to fossil energy use and climate change", available in < https://www.journals.elsevier.com/environmental-innovation-and-societal-transitions >, last acess in 25/11/2018.

[9] "STRN is an international network of more than 1'500 scholars interested in sustainability transitions. Sustainability transitions are long-term transformation processes of established industries, socio-technical systems and societies to more sustainable modes of production and consumption", available in < https://transitionsnetwork.org/about-strn/ >, last acess in 25/11/2018.

Table 5 – Top 10 authors comparison

1998-2011		2012-2018	
Articles	**Author**	**Articles**	**Author**
13	Geels, F. W.	18	Brown, R. R.
12	Rotmans, J.	15	Kern, F.
11	Hekkert, M. P.	15	Raven, R.
11	Kemp, R.	13	Frantzeskaki, N.
10	Smith, A.	12	Loorbach, D.
9	Whitmarsh, L.	12	Smith, A.
6	Jacobsson, S.	12	Sovacool, B. K.
6	Loorbach, D.	11	Truffer, B.
6	Negro, S. O.	11	Wells, P.
6	Raven, R.	10	Hekkert, M. P.

Source: author's own.

Table 6 – Top 20 countries (affiliation) comparison

1998-2011			**2012-2018**		
N° Articles	**Frequency**	**Country**	**N° Articles**	**Frequency**	**Country**
131	209	Netherlands	434	689	United Kingdom
106	154	United Kingdom	275	435	Netherlands
50	87	United States	225	344	Germany
44	64	Sweden	200	343	United States
32	47	Germany	156	214	Sweden
28	38	Australia	145	239	Australia
20	28	Canada	89	121	Canada
20	25	Switzerland	76	118	Finland
18	26	Spain	73	132	France
17	32	Finland	66	81	Norway
13	15	France	65	95	Switzerland
12	17	Austria	64	75	Denmark
12	14	Japan	58	66	Austria
8	10	Italy	57	88	Italy
7	7	Belgium	53	84	Belgium
7	7	Denmark	49	78	China
6	6	Norway	43	68	Spain
5	6	Greece	32	43	South Africa
3	5	Thailand	24	42	Japan
2	4	Chile	23	48	New Zealand

Source: author's own.

Table 5 and **6** show that not much has changed from the first to the second set in terms of authors or countries. The object we are looking at remains euro-centric, despite some new entrants. Now, the following **tables** (**7** and 8) bring the more interesting findings.

Table 7 – Keywords comparison

1998-2011		2012-2018	
Articles	**Keywords**	**Articles**	**Keywords**
126	sustainable development	494	sustainability
121	innovation	355	sustainable development
101	sustainability	325	innovation
80	Climate change	253	Climate change
70	energy policy	222	**Sustainability transitions**
50	*Technology change*	178	Transition
46	Transition	171	energy policy
45	*Technology development*	151	governance approach
41	renewable resource	146	Renewable energy
39	*Technology*	140	Energy transition
36	governance approach	130	renewable resource
35	Transition management	118	environmental policy
33	environmental policy	114	alternative energy
27	*Economics*	97	Technology development
26	Public Policy	93	Decision making
25	stakeholder	93	Socio-technical transition
25	strategic approach	83	conceptual framework
24	conceptual framework	82	stakeholder
22	alternative energy	79	Governance
22	*learning*	79	Multi-level perspective

Source: author's own.

Table 7 shows some interesting data. Keywords from the first set seem to be much more related to the field of innovation studies: *technology change*, *technology development*, *technology*, *economics* and *learning* are some of the most iconic themes of innovation studies area. On the other hand, keywords from the second set do not maintain the same pattern: only *technology development* makes the list. In their place, new keywords show up, consolidating a field-specific lexicon. *Multi-level perspective*, *socio-technical transition* and, reverberating the self-entitled name of the newborn research area, *sustainability transitions*. Keywords related to policy and policymaking show up since the first set and remain in the second. This is evidence that the field, in addition to its technical and scientific concerns, has always been connected to an applicability heuristic.

Table 8 - Recurrent concepts in the abstracts (NLP mechanism) comparison

1998-2011			2012-2018		
Articles	**Freq.**	**Abstract NLP**	**Articles**	**Freq.**	**Abstract NLP**
113	190	transition	477	733	transition
111	155	development	365	466	development
83	110	process	311	449	sustainability
75	118	innovation	276	346	research
67	94	sustainability	256	304	analysis
65	76	research	249	308	process
58	72	change	231	362	innovation
58	74	climate change	228	303	change
53	63	concept	228	278	policy
53	76	sustained development	200	277	**sustainability transitions**
52	62	policy	197	265	governing
50	65	*technology*	187	227	climate change
43	56	*system*	184	212	challenge
41	46	potential	174	217	actor
40	58	governing	173	192	case study
40	57	*interaction*	166	214	concept
40	47	*product*	164	188	potential
38	44	case	161	171	case
37	42	society	146	208	transform
36	45	challenge	135	157	social

Source: author's own.

Table 8 depicts fewer changes from the first to the second sub-set than the previous one. From the top 20 terms/concepts in the first sub-set, 16 remain; still, the ones that are left behind are, again, related to innovation studies: *technology*, *system*, *interaction* and *product*. Once again, *sustainability transitions* emerge, confirming the popularity of the name. Sustainable-related terms gain ground, while *innovation* loses *momentum*.

Manuals and Handbooks

The publication of manuals and handbooks is indicative of the formation of some sort of consensus among the research community. It provides some common ground, assumptions that do not sparkle disputes or controversies anymore. That is why Fleck sees the manuals as important in the formation of scientists (Fleck 1979, ix, *apud* Condé 2003, 136). With this intention, I have searched in the STRN newsletters for the publication or indication of manuals and handbooks in the field of sustainability transitions.

The STRN newsletters are a great source of material for this kind of inquiry into the formation of the field. They are quadrimestral and are published since March 2011. For this article, we analyzed from the first to the June 2018 newsletters, totaling 28 documents. They usually cover six topics: (i) words from the chairman, (ii) Environmental Innovation and Societal Transitions (the communities journal, founded in 2011), (iii) Network news, (iv) event announcements, (v) new research projects and (vi) publications. My focus was only on

publications – therefore there is a lot of material that can yet be scrutinized to understand the initial years of this research area.

After reviewing the 28 documents concerning publications in the field, there are zero references to the *manual* and one reference to the *handbook*. The first mention of to handbook is in STRN 12th newsletter:

> There is also a handbook in the making, to be published by Springer, which signals efforts towards **codification**. The Handbook on Sustainability Transition and Sustainable Peace, edited by Hans Günter Brauch, Úrsula Oswald Spring, John Grin, and Jürgen Scheffran, will contain several chapters that aim to take stock of academic developments in the transitions-field in the last 10 years. (STRN 12th newsletter, emphasis added)

Then, the STRN 21st newsletter registers this publication's debut. According to the document, the handbook has been written by "60 authors from many disciplines and 18 countries on five continents" (STRN 21st newsletter). The list of subjects is diverse:

- Moving towards Sustainability Transition;
- Aiming at Sustainable Peace;
- Meeting Challenges of the 21st Century: Demographic Imbalances, Temperature Rise and the Climate–Conflict Nexus;
- Initiating Research on Global Environmental Change, Limits to Growth, Decoupling of Growth and Resource Needs;
- Developing Theoretical Approaches to Sustainability and Transitions;
- Analysing National Debates on Sustainability in North America;
- Preparing Transitions towards a Sustainable Economy and Society, Production and Consumption and Urbanization;
- Examining Sustainability Transitions in the Water, Food and Health Sectors from Latin American and European Perspectives;
- Preparing Sustainability Transitions in the Energy Sector;
- Relying on Transnational, International, Regional and National Governance for Strategies and Policies Towards Sustainability Transition.

Still, the description of the book and its highly heterogeneous formation leaves much more the impression of a compendium than anything else. It is distinct from manuals and handbooks as we can see in other disciplines, *e.g.* economics. Thereby, despite this solitary effort, the field has not yet arrived at a common set of principles, concepts or frameworks at the required level to produce manuals and/or handbooks. This is another evidence of the emergence in process of the area. Summing up results from the three steps:

- The field is still struggling to define itself as an autonomous area – and for this reason, there is still no broad consensus of what are the basic presuppositions or ontological stances that could fit into a manual and/or handbook;
- Bibliometric evidence points to a process of distancing from innovation studies – indicating the consolidation of a common and proper language – more adequate to the problems under concern in the ST area; if the new intellectual avenues mentioned by Loorbach *et al* (2017) in fact gain ground, this process could go further yet and we would see in the near future the diminishing relative importance

of themes, vocabulary and concepts belonging to innovation studies in this new area.

Discussion

Fleck says that it might be impossible to grasp entirely the precise contours of a scientific discipline. Our aim, however, was much more modest. We aimed at the process of emancipation taking place within the sustainability transitions arena. Additionally, I have used this case to reflect upon the epistemological evolutionism potential. Given the evidence here summarized, I come to four conclusions:

1. The sustainability transitions research field is an emergent field;
2. The sustainability transitions research field has an important connection with innovation studies;
3. The aforementioned connection is dynamic: it is a process of inspiration and emancipation, that reflects, through changes in the structure of language and codification, changes in the problem framing and the analytical framing belonging to the field (in a 40-year long process – and still counting);
4. The evidence points to a process of *speciation* in the evolution of this specific field

Concerning the present object, the next steps include collecting the following set of data: authors' network evolution (do they collaborate more with innovation studies authors in the earlier phase of the emerging field than later?); co-occurrence analysis (does the concepts in the articles of the core-set are associated with more innovation studies concepts in the earlier phase of the emerging filed than later? Looking for patterns of redetermination); and citation analysis (does the earlier phase articles cite more innovation studies articles?). Then, this data might be enough to attest that the process of speciation is, indeed, indisputable. Furthermore, understanding the processes of institutional formation, synchronous to the linguistic evolution of the field, could help to understand how co-evolution takes place between the epistemic community and the scientific field itself. Therefore, it would be valuable to observe the formation of this epistemic community, its staff, its formation and legitimation rites, frequency of meetings, shared values and norms.

This article has limitations. First, there is no guaranteed relation between the patterns observed in the emergence of this specific field of research and any other, in any specific area. Even research communities under the same broad category, such as ecology (under the same "environmental studies" umbrella), may present a very different pattern of evolution from the one described here. Second, the description is partial and insufficient: partial because the emergence of this strand of literature is still happening; insufficient, because of the quantity of scientific production related to the sustainability transition which surpasses this author's reading capacity. Finally, there seems to be a grey area of *institutional meddling* that counts a lot to the advancement and establishment of a new research field, *i.e.*, the creation of new journals, universities committees' engagement, associations, scholarships, etc., until that the new area reaches consensus (or, as we shall see, a *Gestalt*) and becomes a candidate to advise public policies (an epistemic community in action). This interesting and compelling element is almost absent from this working paper; eventually, it shall appear in a rather anecdotal fashion. Still, there are strong reasons to defend the accomplishments of this article. First, it sheds light on the emergence of a field that, from its birth, intends to influence public policy on a large scale. Second, it blends a case study (*sustainability transitions*) with a framework discussion on epistemology (*catastrophism* or *evolutionism*).

Thus the article opens space to the debate of different perspectives on the evolution of science.

The epistemological evolutionism, applied to the emergence of a scientific field or scientific discipline seems to deal well with this notion of speciation, *i.e.*, the gradual emancipation of what was once a topic of interest in an established area into an autonomous research area. However, one can think of other types of gradual processes, *e.g.*, fusions, which could be conceptualized as the gradual unification of a diverse array of small strands into a greater area. Actually, if we base ourselves on the double origins of the field, *i.e.*, innovation studies and sustainability studies (LOORBACH *et al*, 2017), both speciation and fusion might have happened in parallel. But that's for another moment.

The linguistic approach applied in this article proved to be a very interesting analytical lens. As we have seen, there is a lot of dispute going on in the field concerning names, terms, concepts and definitions. Language is working, as the mobilized theory suggests, as institutional, grammatical rulemaking, happening through the social praxis of this specific scientific community, or epistemological community. Rossi's view on language is, therefore, vindicated: "if connections, juxtapositions and relations between the terms of language reproduce connections, juxtapositions and relations between things, naming is tantamount to knowing" (Rossi 2001, 231).

A few caveats before the end: this article focuses on processes that occur in the field of social sciences... Even if one would not like to differentiate things *a priori*, we must take this into account. Language-games, to use the expression of Wittgenstein, might have a different dynamic in the natural sciences. Another issue is the existence of a proto-epistemological community, one that exerted the role of midwifery to bring into light this emergent scientific area. The contrast is clear, *e.g.*, there was no epistemic community pushing *ex-ante* for the creation and establishment of economics as a specific discipline (of course, this does not exclude proto ideas and pioneers). I mean: the sustainability area was a political cause[10] and a cultural phenomenon before it started to articulate itself as a scientific area of study. This is a source of idiosyncrasy present in this case.

To conclude, if we follow this lead, that scientific fields of inquiry can form under different contexts, from within other fields, more or less influenced by external events (such as politics), mainly due to social praxis associated with its scientific grammar, does the notion of a well-behaved scientific cycle (normal science – paradigm failure – paradigm contestation – scientific revolution) turns to dust? No, one could answer, because Kuhn's framework seems to be pretty good at explaining intertheory competition (let us leave incommensurability issues apart for now); but, as it turns out, the majority of science is not competing with other strands over the same ideas or objects. It is competing with itself, its self-contained, and struggling to determine its own vocabulary, language and *Gestalt*. For this reason, Goodman's observation seems accurate: "[...] we begin at any time with some old version or old world that we have at hand and to which we are connected until there are determination and conditions to transform it into a new one" (Goodman 1978, 97, *apud* Oliveira 1991, 50).

[10] "Our mission is to **deepen the scientific understanding** of sustainability transitions through a program of networking, research coordination, education and synthesis activities. We also strive to be a **hub for practitioners in policy making**, civil society, and business who are working to advance societies into more sustainable directions" available in < https://transitionsnetwork.org/about-strn/ >, last acess in 16/11/2020. The dual purpose indicated by the group (STRN) demonstrates how it is an area of scientific research with clear purposes of application for public policies and with direct and profound repercussions on the very vision of the world and society.

Conclusion

This article served a dual purpose. It can be read as a historical analysis of the formation of a specific scientific field, the studies of sustainability transitions, and it can be read as a case study of scientific advancement from an evolutionary (linguistic) perspective. Following these purposes, we present elements that demonstrate the autonomy of the studies for sustainability transitions. There is evidence of the formation of a specific language in the field, even though this is a process in the making. There is also evidence that this process was influenced by scientific fields that are already established and with their own traditions and language, strengthening the hypothesis that scientific progress, in this case, appears to be a process of speciation. The article sought to demonstrate with this exercise how the linguistic vision of scientific advancement can provide a robust conception for issues associated with the epistemology and historiography of science.

Acknowledgments

I thank Flávia Consoni, Rosana Corazza and Diego Moraes for their comments in an earlier version of this article. I am especially grateful to Vinicius Muraro for making the Vantage Point software available. I also thank the editors of *Transversal* and two anonymous reviewers. Finally, I would like to thank CAPES for funding the doctoral scholarship in the postgraduate program in Science and Technology Policy at UNICAMP.

Annex 1

Most-cited publications in the field of sustainability transitions (based in Markard *et. al*, 2012 and updated)

No	Title	Author(s), year and journal	Citations (2018)
1	Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study	Geels, F.W., 2002, Research Policy	1664
2	Typology of sociotechnical transition pathways	Geels, F.W., Schot, J., 2007, Research Policy	1296
3	From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory	Geels, F.W., 2004, Research Policy	1062
4	Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management	Kemp, R., Schot, J., Hoogma, R., 1998, Technology Analysis and Strategic Management	1059
5	Understanding carbon lock-in	Unruh, G.C., 2000, Energy Policy	984
6	More evolution than revolution: Transition management in public policy	Rotmans, J., Kemp, R., Van Asselt, M., 2001, Foresight	790
7	The governance of sustainable socio-technical transitions	Smith, A., Stirling, A., Berkhout, F., 2005, Research Policy	785
8	Functions of innovation systems: A new approach for analysing technological change	Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., Smits, R.E.H.M., 2007, Technological Forecasting and Social Change	772
9	On the nature, function and composition of technological systems	Carlsson, B., Stankiewicz, R., 1991, Journal of Evolutionary Economics	739
10	Bricolage versus breakthrough: Distributed and embedded agency in technology entrepreneurship	Garud, R., Karnøe, P., 2003, Research Policy	649

11	Analyzing the functional dynamics of technological innovation systems: A scheme of analysis	Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008, Research Policy	613
12	The multi-level perspective on sustainability transitions: Responses to seven criticisms	Geels, F.W., 2011, Environmental Innovation and Societal Transitions	518
13	Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy	Schot, J., Geels, F.W., 2008, Technology Analysis and Strategic Management	518
14	Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges	Smith, A., Voß, J.-P., Grin, J., 2010, Research Policy	501
15	The politics and policy of energy system transformation - Explaining the German diffusion of renewable energy technology	Jacobsson, S., Lauber, V., 2006, Energy Policy	461
16	The diffusion of renewable energy technology: An analytical framework and key issues for research	Jacobsson, S., Johnson, A., 2000, Energy Policy	452
17	CAUTION! Transitions ahead: Politics, practice, and sustainable transition management	Shove, E., Walker, G., 2007, Environment and Planning A	428
18	Technological innovation systems and the multi-level perspective: Towards an integrated framework	Markard, J., Truffer, B., 2008, Research Policy	422
19	Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective	Geels, F.W., 2010, Research Policy	407
20	The Past and Future of Constructive Technology Assessment	Schot, J., Rip, A., 1997, Technological Forecasting and Social Change	383
21	Transforming the energy sector: The evolution of technological systems in renewable energy technology	Jacobsson, S., Bergek, A., 2004, Industrial and Corporate Change	354
22	Toward a spatial perspective on sustainability transitions	Coenen, L., Benneworth, P., Truffer, B., 2012, Research Policy	314
23	Can cities shape socio-technical transitions and how would we know if they were?	Hodson, M., Marvin, S., 2010, Research Policy	284
24	Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective	Geels, F.W., 2005, Technological Forecasting and Social Change	276
25	The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860-1930)	Geels, F.W., 2005, Technology Analysis and Strategic Management	255
26	Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective	Geels, F.W., 2014, Theory, Culture & Society	251
27	A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies	Geels, F.W., 2012, Journal of Transport Geography	212
28	Strategies for shifting technological systems. The case of the automobile system	Schot, J., Hoogma, R., Elzen, B., 1994, Futures	204
29	Rethinking the multi-level perspective of technological transitions	Genus, A., Coles, A.-M., 2008, Research Policy	184

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