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# Studying transitions: Past, present, and future

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ABSTRACT

The domain of transition studies has been drawing more and more scholarly attention and, as a result, its body of knowledge is rapidly growing. This raises new challenges as well as opportunities, not the least regarding the methodological and philosophical underpinnings of research in this domain. In this respect, transition research, as a relatively young field of inquiry, has been little concerned with methodological investigation and reflection. We propose a framework that enables this reflection: the so-called 'transition research onion'. Subsequently, we utilize this framework to systematically assess 217 peer-reviewed papers in the field of transition studies, to distill key methodological patterns and trends of the field. The findings suggest that the methodology of transition studies, in terms of depth and diversity, is underdeveloped. These insights serve to guide future research on transition processes.

## 1. Introduction

Systemic innovations directed toward more sustainable socio-technical systems are increasingly understood in terms of 'transitions' (Smith et al., 2010). A transition involves far-reaching structural changes in socio-technical systems that enable particular desirable societal functions (e.g., mobility, energy, healthcare). In this respect, transitions are multi-dimensional processes that often include technological, material, organizational, institutional, political, economic, and socio-cultural changes. As such, transitions typically involve a broad range of actors (e.g., individuals, firms and organizations, and collective actors), institutions (e.g., societal and technical norms, regulations, standards of good practice), and technological elements (e.g., material artifacts and knowledge).

The domain of transition studies has experienced a rapid growth over recent years. Much work in this area has focused on studying the characteristics of historical transitions and applying the obtained insights to the development of governance frameworks to guide ongoing (e.g., energy, food and health) transition processes. Only recently has the field started to broaden, as new scholars from different disciplinary backgrounds became (more) engaged. Examples of disciplines engaging with transition studies are sociology (Geels, 2005; van Lente and Rip, 1998), psychology (Axsen and Kurani, 2014; Sorrell, 2015), economics (Rogge and Hoffmann, 2010; Trutnevyte et al., 2015), political science (Kern, 2012; Meadowcroft, 2011; Scrase and Smith, 2009), management (Walrave and Raven, 2016; Walrave et al., 2018), engineering (Davis et al., 2013), geography (Coenen et al., 2012) and philosophy (Paredis, 2011). This broadening of the field also implies the introduction of diverging methodological and philosophical underpinnings.[1]

As an increasing number of researchers with different backgrounds have become interested in transition challenges, we believe the time is right to reflect on *how to study transition problems*. Indeed, "reflections on methodologies for transitions research" is one of the key themes for future research identified in a recent, collaboratively developed research agenda for the field (Köhler et al., 2019: 4). Despite a few pioneering exceptions (e.g., Garud and Gehman, 2012; Geels, 2009, 2010; Genus and Coles, 2008; Loorbach et al., 2011; Pel, 2014; Turnheim et al., 2015), transition scholars have been little concerned with methodological reflection (Markard et al., 2012)—while being influenced by many different research traditions. In this study, we take stock of the kinds of research methods that have been used so far, in order to provide directions on how to move forward.

Such an effort requires an evidence-based approach, in order to map and understand the various methodological designs already used in transition research (cf. Tranfield et al., 2003). Here, we draw on the so-called 'transition research onion' to review 217 transition studies. The results shed light on various aspects of transition problems and the

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[1] For instance, formal modelling approaches to transitions are being explored (Holtz et al., 2015; Walrave and Raven, 2016).

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corresponding research designs that have been used so far—but also signal that the methodology of transition studies is underdeveloped. Subsequently, these insights allow us to identify various research opportunities for transition studies.

The next section contains a brief overview of the prevailing methodological debates in transition research. Section 3 explains our research approach, involving a systematic literature review informed by the transition research onion. Subsequently, section 4 presents the results of the review. Section 5 provides a discussion of these results, including opportunities for future work on transitions.

## 2. Transition research and methodological challenges

Transition research is an interdisciplinary field, firmly rooted in the tradition of system thinking (Grin et al., 2010; Rodrigo et al., 2015). There is no agreed list of fields that constitute transition studies, similar to what Fagerberg et al. (2012) observed for the field of innovation studies. At the heart of transition studies is the socio-technical system[2] as the unit of analysis, and the features of fundamental structural change as the main object of research.[3] But, transition researchers have been drawing on insights from many different areas[4] : Complex adaptive systems theory (e.g., Holland, 1995; Kauffman, 1995; Prigogine and Stengers, 1984), post-normal science (e.g., Ravetz, 1999), governance (e.g., Sabatier and Jenkins-Smith, 1999), evolutionary economics (e.g., Dosi, 1982; Nelson and Winter, 1982), innovation studies (e.g., Smits and Kuhlmann, 2004), science and technology studies (e.g., Bijker and Law, 1992), history (e.g., Hughes, 1983), and institutional theory (e.g., Scott, 1995).

As a result, transition researchers have contributed to theoretical progress at the cross-roads of many different fields, in particular with regard to questions related to sustainable development (e.g., Markard et al., 2012; Martens and Rotmans, 2005; Smith et al., 2005). However, there has been little reflection on the methodological challenges that arise when one builds upon different fields and perspectives with distinct methodological traditions. The study by Genus and Coles (2008) is one of few notable exceptions, as it reviews the challenges of the multi-level perspective (MLP) in understanding transition processes. Genus and Coles (2008) call for research that includes the role of agency and political dimensions, moving beyond the MLP as a high-level heuristic tool. Furthermore, they are also concerned about the quality of data and data analysis in transition studies (e.g., the observer-expectancy bias and boundaries of analysis). Similar criticisms and suggestions have been voiced by others (e.g., Hurlbert, 2011; Markard and Truffer, 2008; Smith et al., 2010; Vasileiadou and Safarzyńska, 2010).

In response to such criticisms, Geels (2011) reviews specific challenges arising from the MLP and provides important epistemological and methodological arguments about transition studies. In this respect, regarding the heuristic nature of the MLP framework, he argues that the MLP framework serves as a middle range theory, rather than a 'truth machine' in which researchers insert data to get an automatic answer to a question. Geels also argues that research on complex phenomena, such as transitions, cannot be reduced to models with detailed methodological procedures, such as the statistically verifiable models commonly used in management and marketing studies. He also claims that research on the MLP will always (need to) involve the creative interpretation of researchers (cf. observer-expectancy bias), and therefore largely draw on qualitative research methods (Geels, 2011).

In addition, MLP's hierarchical levels often give rise to ambiguity in definitions, boundaries and (conceptions of) relationships among niche, regime and landscape. In this respect, Shove and Walker (2010) recommend that social practice theory is used to conceptualize transition problems. In this view, the unit of analysis changes to practices, rather than societal functions delivered through socio-technical systems[5] . Accordingly, stability and change are conceptualized in terms of how actors actively combine the elements of practice within and between 'regimes'. The main questions of transition research thus become reformulated as "how variously sustainable practices come into existence, how they disappear and how interventions of various forms [of practice] may be implicated in these dynamics" (Shove and Walker, 2010: 471). In contrast to the hierarchical perspective assumed by MLP, which requires some sort of definition of the boundaries and mechanisms of level relationships, a practice-based view implies a horizontal view of transitions.

In this vein, Jørgensen (2012) tried to moderate the limitations of MLP by addressing the role of agency. Inspired by actor-network and sense-making theories, Jørgensen (2012) introduced a flat and process oriented approach, called arenas of developments (AoD), to explore situated actors' possibilities of engaging in transitional processes. An AoD consists of actor constellations and the actors' collective sense-making activities in interpreting context and performing interventions. Accordingly, change dynamics arise from tensions between actor-worlds resulting in changing alignments and boundaries, rather than MLP's focus on discrepancies between regimes, niches, and landscapes.

Furthermore, some scholars are seeking new ways to study socio-technical change and explore deeper methodological issues in transition studies. In this respect, Geels (2010) discusses seven social science ontologies, their assumptions regarding agency and causal mechanisms, and their views on socio-technical transitions and environmental sustainability. This serves to identify an ontological foundation for MLP (Geels, 2010). Similarly, Loorbach et al. (2011) provide general reflections and guidelines on the methodological requirements of the transition field. They demonstrate that research designs in this field should have an integrative nature, be normative in their ambitions, have a desire to contribute to societal change, and be planned through the active involvement of scientists, policy makers, and various stakeholders—both in the development of new knowledge and in its application.

Wittmayer and Schäpke (2014) focus on action research and process-oriented approaches, and more specifically transition management, to study sustainability transition problems. In this respect, they identified ideal-type roles and activities that help researchers create and maintain space for societal learning. These roles are as follows: change agent, knowledge broker, reflective scientist, self-reflexive scientist and process facilitator. Finally, they acknowledged the importance of different research designs and related competences and skills of transition researcher to carry out each role.

In another effort to extend the methodological choices for transition researchers, Holtz et al. (2015) provide an overview of specific opportunities, benefits and challenges of various modeling approaches. Specifically, they call for more precise versions of the various transition frameworks to be conducive to modeling exercises (see also de Haan and Rotmans, 2011; Haxeltine et al., 2008; Walrave and Raven, 2016). McDowall and Geels (2017) also assess the challenges of modeling, and proposed pluralist 'bridging strategies' and a dialogue between analytic approaches to exploit the full analytic and practical potential of

[2] Loorbach et al. (2017) distinguished three different perspectives on transition research: the socio-technical, socio-institutional, and socio-ecological perspective. In this paper, we focus on the socio-technical approach that constitutes the roots of transition studies.

[3] These are co-evolutionary, multi-dimensionality, multi-actor, multi-level, path-dependency, long term thinking and non-linearity (Geels, 2002; Holtz, 2011).

[4] Also see: van der Brugge and van Raak (2007); Geels et al. (2008), and Frieler et al. (2015).

[5] Shove et al. (2012: 14) define the elements of practice as: "(1) materials – including things, technologies, tangible physical entities, and the stuff of which objects are made; (2) competences – which encompasses skill, know-how and technique; and (3) meanings – in which we include symbolic meanings, ideas and aspirations'.

modeling. They demonstrate that mutual learning and cooperation of both modelers and non-modelers within the transition field can facilitate such synergy. In a similar vein, recent studies integrated the different approaches of transition studies (e.g., Geels et al., 2016; Pel, 2014; Trutnevyte et al., 2014; Turnheim et al., 2015) to reveal the underlying assumptions, strengths and weaknesses of existing analytical tools, which in turn could help to develop crossovers and bridges between the different approaches and thereby generate a deeper understanding of transition processes and outcomes.

Despite these initial efforts, the methodological debate has remained rather ad-hoc, unstructured, and largely conceptual and abstract in nature. Therefore, there is a need for a structured procedure that *systematically* assesses the state of the field. In the remainder of this paper, we conduct a systematic review of transition research methods to shed light on the past, present and future of research methodology in this field.

## 3. Method: systematic review

To systematically appraise the contribution of a given body of literature, an analytical approach is needed (Ginsberg and Venkatraman, 1985). To this end, we adopt a systematic review approach to identify, analyze and consolidate relevant sources of data regarding the methodological choices in transition studies. A systematic review involves a comprehensive, explicit, replicable and synthesized review of all relevant literature regarding a particular question of interest (Tranfield et al., 2003). Generally, systematic reviews involve three main stages: (1) the planning stage that often starts with a research question, which in turn informs the searching and screening steps in the selection of articles; (2) the conducting stage, typically involving data extraction and coding that are usually accompanied by data synthesis, analysis and interpretation; and (3) the stage of reporting what was (not) found with respect to the research question (Tranfield et al., 2003; Briner and Denyer, 2012).

In the *planning* stage, the goal of our review was to answer: 'What are the methodological practices (dimensions) that are explicitly mentioned in transition studies?' Building on the work by Markard et al. (2012), who also conducted a systematic literature review in this field of studies, we applied the same search string[6] in Scopus, to gather relevant literature. In addition, we also identified all papers, published before 2016, that refer to one or more of the 20 core papers (in field of sustainability transitions) listed by Markard et al. (2012). Notably, in order to extract only the most relevant articles and keep the size of the review workable, we focused on the five most influential journals in the field—based on relative number of publications and citations on transitions studies. These journals are Energy Policy, Research Policy, Technological Forecasting and Social Change (TFSC), Technology Analysis and Strategic Management (TASM) and Environmental Innovation and Societal Transitions (EIST). Markard et al. (2012) demonstrated that the first four journals are the main transitions-focused journals. We added EIST because this journal has been established specifically for the sustainability transitions research community.

By applying this search strategy, we distilled 350 potentially relevant papers. Since our goal is to review methodological practices in transition studies, we only included papers that address one (or more) empirical transition problem(s). As such, we excluded 133 conceptual papers (e.g., opinion-driven or purely theoretical papers[7]). Table 1 lists the final number of reviewed papers for each journal. The final database of papers, subject to further analysis, included 217 papers.

To review how transition problems are investigated, we need to systematically examine the methods applied. In this regard, we also need to determine the various issues that influence method selection in the field, such as paradigms, theoretical frameworks, and so forth. In management research, the 'research onion' framework has been successfully used to depict the different methodological dimensions, in terms of the choice of data collection and data analysis techniques (Saunders et al., 2015). Accordingly, we adapt and customize this framework to explain and evaluate the methodologies employed in transition studies. The framework outlined in Fig. 1 involves different layers (with sub-layers or options). From the core to the outer layer, these are: (1) research question, (2) paradigms, (3) theoretical frameworks, (4) research methods, (5) data collection methods and data sources, and (6) time horizons. In the following paragraphs, each layer is further detailed. Whenever necessary, operational definitions are provided to assure the consistency and replicability of the review (Babbie, 2010).

**(1) Research question.** A research question typically guides a study (Bryman, 1992; Patton, 1990). Methodological fit is often assessed in terms of the research question, which in turn is likely to be influenced by the goal of the research, the background, skills and expertise of the researcher, interests of the stakeholders, and available time, data and other resources (Brannen, 2005; Flood, 1995; Marsland et al., 2000). To transform various research questions to a standardized form, for the purpose of this review, a qualitative coding procedure is used, following Saldaña (2015). Here, the first author of this study read each paper to identify and extract information about the research question(s) mentioned. In line with the inductive nature of the review approach, we avoided the use of any predetermined categories (Saldaña, 2015) to code the research questions. The categories were thus allowed to emerge, through comparing and finding common features among research questions. This coding process was iterative in nature, to assure reasonable relations between categories and data to emerge. For example, when a new potential category was identified, the researcher would return to the papers already read to explore if there was any related evidence. This coding process of category determination through continual and iterative comparison proceeded until no new categories emerged and, as such, saturation in coding was achieved.

**(2) Paradigm.** A paradigm refers to the set of key beliefs and assumptions that affect (or guide) method selection. Within transition studies, four paradigms are identified, which serve as 'options': the positivist, critical realist, interpretivist, and pragmatist paradigm. The main components of each paradigm are the researchers' assumptions about the nature and relation of the relevant realities on transitions (i.e., ontological assumptions), the nature and limitations of knowledge about transitions (i.e., epistemological assumptions), and the role of values and ethics within the transition research processes (i.e., axiological assumptions) (Burrell and Morgan, 1979; Crotty, 1998; Geels, 2010; Lincoln and Guba, 1985; Tashakkori and Teddlie, 2010). Notably, each paradigm implies distinctive assumptions for studying transition problems that may, in turn, require different methods. The four paradigms are generally acknowledged 'ideal types' in the social sciences (Weber, 1978). In coding the paradigm(s) used in each paper, we placed it in one or more paradigms, thus also allowing for positioning it between paradigms.

Empirical researchers often do not explicitly define and discuss their paradigmatic orientations (Alise and Teddlie, 2010). In case of such a paper, the paradigmatic designation resulted from our interpretation of the ontology, epistemology, and axiology actually used in the study, as well as information provided on the theoretical frameworks and research methods used.

**(3) Theoretical framework.** Theoretical frameworks shed new light on specific transition problems, and thus act as a lens that can make researchers consider only specific concepts and/or theories (Sovacool and Hess, 2017). However, there is no agreement on the definition of 'theory' and the boundaries between theory and non-theory (e.g., Mintzberg, 2005). Following Sovacool and Hess (2017), we

[6] To find the relevant papers for the systematic review we used the following search string: (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)))

[7] For example, we excluded the conceptual papers by Azar and Sandén (2011); Halbe et al. (2015) and Meadowcroft (2011) from the review.

**Table 1**
Number of articles included in the systematic review (per journal).

| Publication | Number of papers after applying the primary inclusion criteria | Subset of papers that address at least one empirical transition problem |
|---|---|---|
| Energy Policy | 118 | 82 |
| Technological Forecasting and Social Change | 81 | 50 |
| Environmental Innovation and Societal Transition | 72 | 40 |
| Technology Analysis and Strategic Management | 40 | 28 |
| Research Policy | 39 | 17 |
| | **350** | **217** |

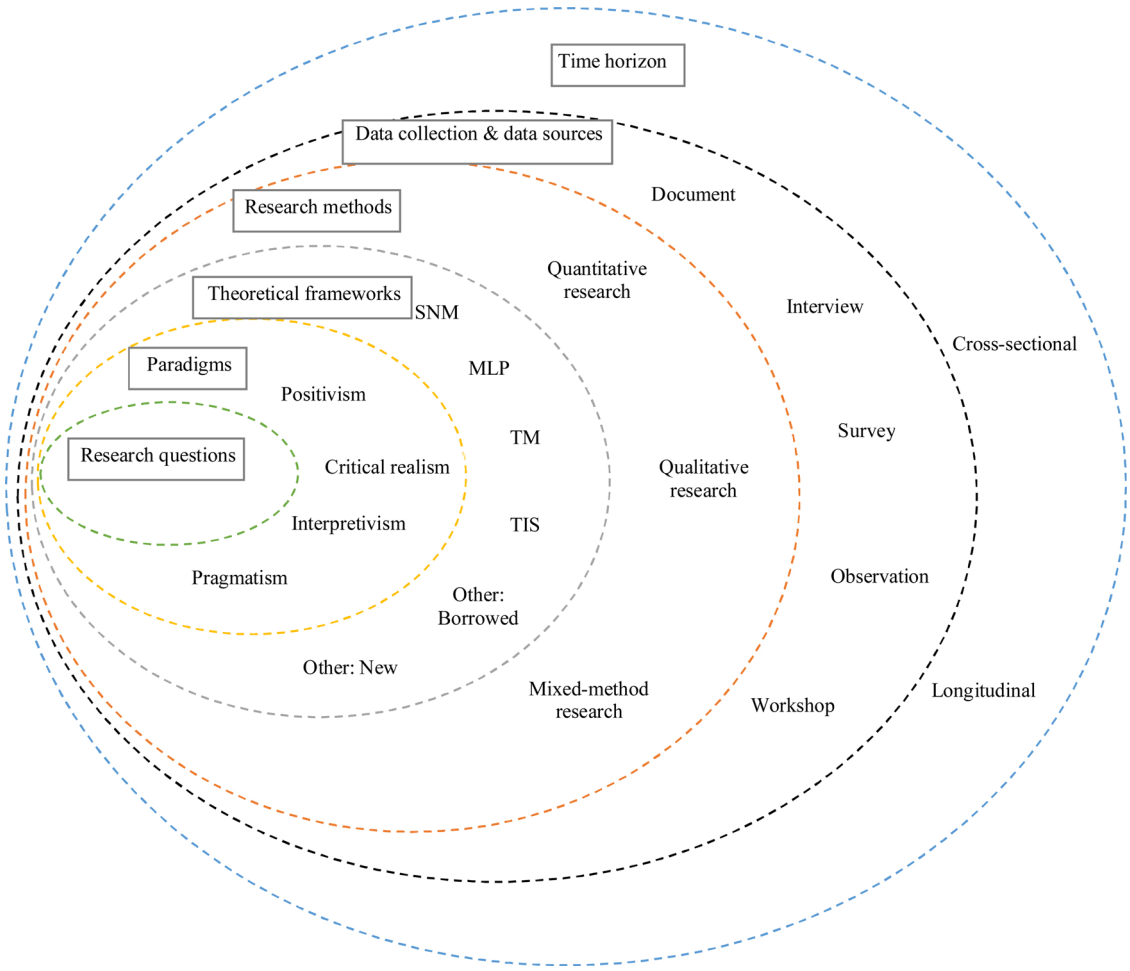


**Fig. 1.** Transition research onion.
Note: the options identified for each layer were first pre-specified based on some initial literature, and then complemented and extended by additional literature (reported in this section). This approach helped to ensure that each option is accurately labeled and unambiguous in its meaning.

consider theoretical frameworks to be any theoretical construct, conceptual framework, analytical tool, heuristic device, analytical framework, concept, or model that guides transition research. Accordingly, theoretical frameworks in transition studies are grounded in the theories and concepts of the relevant disciplinary contexts and areas[8] . For

[8] Most recently, Sovacool and Hess (2017) presented the results of 35 semi-structured interviews with experts to identify theories and conceptual frameworks of socio-technical change. The authors identified 96 conceptual frameworks, spanning 22 identified disciplines, which can be used for transition studies. Here, we only mention some of the theories that have been used more substantially in the transitions literature: *Evolutionary economics* (Nelson and Winter, 1982; van den Bergh and Gowdy, 2000) (self-organization and complexity theory [e.g., Rotmans and Loorbach, 2009], path dependence and lock-in [Arthur et al., 1987; Cowan, 1990; David, 1985], and longwave theories

(*footnote continued*)
[Freeman and Louçã, 2001; Perez, 2002]); *industrial economics* (industry life cycle approach (McGahan et al., 2004), the innovation systems tradition, disruptive innovations (Christensen, 1997) and technological discontinuities (Anderson and Tushman, 1990)); *economic geography* (regional innovation systems (Asheim and Isaksen, 2002; Cooke, 2002; Cooke et al., 2004)); *management* (resource-based view of the firm (Barney, 1991; Wernerfelt, 1984) and corporate political action (Sarasini, 2013)); *science and technology studies* (actor–network theory (Callon, 1984; Law and Hassard, 1999), social construction of technology (Bijker et al., 1987), large technical systems theory (Coutard, 1999; Hughes, 1983, 1987; La Porte, 1991; Mayntz and Hughes, 1988; Summerton, 1994)); *political science* (the advocacy coalition framework (Sabatier and Jenkins-Smith, 1999)); *institutional theory* (institutional work (Lawrence and Suddaby, 2006; Voronov and Vince, 2012)); and *sociology* (practice theory (Reckwitz, 2002; Schatzki, 1996; Shove, 2003; Shove et al., 2012)).

this layer, we provide statistics on four theoretical frameworks identified in the set of papers reviewed: the multi-level perspective (MLP)[9], strategic niche management (SNM)[10], transition management (TM)[11], and technological innovation systems (TIS).[12] Furthermore, in our review we also identified two additional sets of theoretical frameworks: (1) 'borrowed frameworks' that were originally developed in other disciplines and then used to study transition problems and (2) 'new frameworks' that are designed by the authors by combining concepts and theories from disciplinary perspectives such as sociology, (industrial and evolutionary) economics, political science, and cultural studies.

**(4) Research method**. Research methods are organized and systematic ways of inquiry to address specific research questions. When conducting empirical research, transition researchers have three general options regarding the research method (Guba and Lincoln, 1989; Niglas, 2010; Tashakkori and Teddlie, 1998; Teddlie and Tashakkori, 2009; van de Ven, 2007). First, they can draw on qualitative research methods that involve narrative data sources and data analysis techniques such as ethnography, action research, grounded theory development, and narrative inquiry. These methods typically adopt idealist (relativist), subjectivist, deductive, value-bound inquiry and provide an ideographic understandings of the concerned problems. Second, one can use quantitative research methods that involve numeric data sources and analytical approaches such as mathematical and statistical methods. These methods derive realist, objectivist, inductive, value-free and nomothetic approaches to study the phenomena of interest. Third, transition researchers can draw on mixed research methods in which different research strategies and methodological aspects are combined (e.g., using both qualitative and quantitative viewpoints and/or inference techniques) for the purpose of breadth and depth of understanding and corroboration (Johnson et al., 2007). We labeled a research method as mixed if both qualitative and quantitative methods were used for data analysis.[13]

**(5) Data collection method and source.** Any data collection method involves the act of gathering data from a particular source. Our review implies that transition researchers collect data from the following sources (see Fig. 1): document, interview, survey, observation, and workshop. In codifying the data sources and collection methods in the papers reviewed, we coded very specific sources and methods in one of the aforementioned categories. For example, we considered a 'narrative walk' and 'informal discussion' to be a kind of interview.

**(6) Time horizon.** It is critical to understand how time and timing affects transition processes (e.g., Ancona et al., 2001; George and Jones, 2000; Poole et al., 2000). As such, a time horizon is a key attribute of research that significantly limits the choices made at other levels of the research onion. Generally, there are two fundamental types of research, which consider the role of time in an opposing manner (van de Ven, 2007): (1) cross-sectional studies that are designed to look at a variable at a particular point in time and (2) longitudinal studies that are directed to study a particular phenomenon (or phenomena) over an (extended) period of time.

In the second phase of the review process, one of the authors of this study conducted the work on inclusion/exclusion and the data extraction from the papers reviewed, to ensure coding consistency (based on the options and their definitions depicted previously), while another author double coded 10% of all papers reviewed (22 articles). This subset of papers included those papers which were found problematic by the first coder. The inter-rater reliability was 96%, indicating a high level of reliability. In those cases where there was disagreement between the coders (5 out of 132 cases), the article was reassessed until consensus was reached. All information was collected in a tabular format (in Microsoft Excel).

Whilst this paper provides some interesting lessons, there are a number of limitations arising from such research setup. While comprehensive in nature, our review is still bounded by inclusion/exclusion criteria, which may indeed have affected the results of our study.[14] The main limitation is, however, linked to the limited number of articles we reviewed; the reviewed evidence thus excludes articles published in other journals as well as monographs and edited books. Nevertheless, the selected papers appear to sufficiently represent the current body of knowledge on transition studies. Because we achieved the saturation point in coding all papers, the inclusion of more studies in the review is not likely to significantly change our main findings. Nonetheless, the layers and the options of the onion are open to change, as scholars and practitioners are continually exploring new directions and perspectives to study transition problems.

## 4. Main findings

### 4.1. Research questions

Transition problems can be categorized in terms of societal functions (e.g., energy, transportation and food) or with regards to various themes in the transition process (e.g., governance, power and politics, civil society, culture and social movements).[15] However, for the purpose of our review, a classification of research questions based on their methodological requirements is more relevant. Accordingly, four main categories of transition research questions were identified:

*Questions that relate to explaining a whole, or part of, a transition.* Examples are questions about how transitions come about, the emergence and progress of an innovation in a market, and factors that stimulate or hinder the development and diffusion of a particular technology. For instance, "how do the various subsystems of regional innovation systems [science, politics, public administration, industry, finance, intermediaries and civil society] trigger, push or hinder regional change, and how do these subsystems interact with each other in local energy transition processes?" (Mattes et al., 2015: 256), how the slow diffusion of biomass digestion technology in the Netherlands can be explained (Negro et al., 2007), and "exploring the historical evolution of the electricity regime in the province of Ontario from 1885 to 2013" (Rosenbloom and Meadowcroft, 2014: 670).

*Questions about particular transition policies and transition pathways,* including exploring future transition trajectories (as well as transition patterns and mechanisms), scenario development and assessment of historical policies or analysis of future policy options. Examples are studies assessing the cost effectiveness of potential future pathways and

[9] The multi-level perspective has been developed specifically for analysing transition problems and builds particularly on evolutionary economics, science and technology studies, and institutional theory (with many extensions made after its original inception in the 1990s) (e.g., Geels, 2002; Rip and Kemp, 1998; Schot, 1998).

[10] See, e.g., Kemp et al., 1998; Schot et al., 1994.

[11] See, e.g., Rotmans et al., 2001.

[12] See, e.g., Bergek et al., 2008; Carlsson and Stankiewicz, 1991; Carlsson et al., 2002; Hekkert et al., 2007; Jacobsson and Bergek, 2006.

[13] This is a more specific definition than the broader definitions of 'mixed methods' proposed by others (e.g., Creswell and Plano Clark, 2007; Denzin and Lincoln, 2011).

[14] For instance, we identified relatively few studies that took a transdisciplinary approach, which has been adopted by some transition scholars to complement their fundamental/theoretical work with societal knowledge and expertise (Grin et al., 2010; Scholz, 2017), but may have been published in different journals than the five core to our analysis. In addition, we discovered limited action research and knowledge co-production studies. These approaches may not only benefit policy officers and planners with new knowledge, but can also serve scientists to discover overlooked aspects of transitions (Audet and Guyonnaud, 2013; Frantzeskaki and Kabisch, 2016; Wittmayer and Schäpke, 2014; Wittmayer et al., 2014).

[15] These dimensions, among others, have been identified in the 2017 STRN research agenda (Köhler et al., 2017).

the influence of government policy on growth and diffusion of sustainability-oriented innovations. Some of the research questions in the reviewed articles are: appraising the investment and total system costs of the UK transition to a low-carbon electricity system under different governance pathways from 2010 to 2050 (Trutnevyte et al., 2015), or exploring how "the nature and scope of transition pathways vary with differing economic development realities and priorities" in Brazil, Malawi and Sweden (Johnson and Silveira, 2014: 2), and "how do different lock-in mechanisms of socio-technical regimes influence new transition pathways" (Klitkou et al., 2015: 23).

*Questions that address the influence of specific variables or factors underlying transition processes.* Examples of questions in this category are "how political conditions and industrial events influenced the rise and fall of offshore wind on the political agenda in Norway between 2005 and (Normann, 2015: 180), "how does an exogenous shock [i.e., the Fukushima nuclear accident] affects the onset, magnitude, and permanence of changes in key energy-related metrics, such as electricity consumption" in Japan (Wakiyama et al., 2014: 655), and how important non-economic factors are influencing technological change across technology and country contexts (Hultman et al., 2012).

Questions that involve the role and influence of (networks of) actors (e.g., users, customers, citizens, firms, and collective actors) on transition processes. These research questions thus address the role of beliefs, expectations, cognitions, and characteristics of heterogeneous agents in transition process. Accordingly, issues that emerge from network communication through discourses, narratives, power relations and usages of language and meaning are placed in this category. Examples include the analysis of "how and the extent to which an individual academic, Professor Hofbauer, has influenced the formation of a TIS centered on gasified biomass in Austria" (Hellsmark and Jacobsson, 2009: 5597), "what are the rationales of actors to support a socio-technical transition and to take part in niche-activities" (Bakker, 2014: 61), "what is the dominant discourse amongst incumbents in the Dutch energy regime regarding the future of the energy system and which developments put pressure on their discourse" (Bosman et al., 2014: 47), and "what is the relation between changing actor expectations and changing actor strategies" (Budde et al., 2012: 1037).

Table 2 shows how the papers reviewed are distributed across the categories. Note that some papers formulate more than one research question. In these cases, each question was separately coded. In other words, any given paper may include one or more question types (see Table 3). The results indicate that the first question type, which relates to general questions about a (part of a) transition currently prevails in transition studies. Table 2 also provides examples of the methods used for each kind of research question. Deductively, the four question types can be linked to holistic analysis, pathway analysis, actor analysis and variance-oriented analysis, respectively. However, our review suggests that such a clear relationship does not exist. That is, methods with the same functions have been applied to address different types of questions.

### 4.2. Paradigms

All paradigms previously identified are found in the papers reviewed. Table 4 provides illustrations. Only a few papers, however, make their paradigmatic stance explicit and, as such, we do not report numbers in Table 4. Table 4 describes the philosophical assumptions underlying the main paradigms in transition research and provides examples of papers drawing on each philosophy. While many authors do not explicitly define their paradigmatic stance, traces of this stance (e.g., in theoretical frameworks and research methods used) allowed us to effectively distill the paradigms used in most articles. For instance, the study by Choi and Anadón (2014: 80) "provides a quantitative analysis of the interactions between different types of solar photovoltaic (PV) networks at the niche level, the complementary semiconductor sector at the complementary regime level, and the solar PV policies". Although these authors do not explicitly mention their paradigmatic stance, they assessed the relationship (by means of three equations) between different independent variables on a dependent variable (i.e., technology diffusion, production, and knowledge generation in the solar PV sector). As such, we categorized this paper as an example of positivist transition research (see Table 4, Positivist transition research).

Another example is Bosman et al. (2014), who used argumentative discourse analysis to scrutinize discursive regime dynamics in the Dutch energy transition. Accordingly, they hypothesized about "the discursive changes and how this affects positioning, coalitions and regime structures through time" (Bosman et al., 2014: 56). They also accepted a certain degree of subjectivity in the results, because of the qualitative and explorative nature of their research. We designated this study as a critical realist transition research, as it aims to shed light on the underlying dynamics, within a particular regime, that might be a precondition for a transition to occur (see Table 4, Critical realist transition research).

Bakker (2014) used interpretative analysis to explore the interests and expectations of the niche actors (involved in electric vehicle recharging) for explaining their rationales in supporting the e-mobility transition. Here, the author explicitly mentions he is conducting interpretative research (compared to, for example, a more structured approach such as codifying the interview data). Therefore, we considered this paper as an interpretivist transition research paper (See Table 4, Interpretivist transition research).

Finally, Martin and Rice (2015) analyze the velocity of Australia's renewable energy project approvals through shifts in policy. They explicitly use a pragmatic approach, following Sperling et al. (2010) who "commend the merits of using combinative governance, planning and community engagement as the cornerstone of renewable energy projects approval" (Martin and Rice, 2015: 130). This pragmatism is also

**Table 3**
Number of studies that address one or more research question types.

| Question types | Whole | | Pathway | | Actor | | Variable | |
|---|---|---|---|---|---|---|---|---|
| Whole | 83 | (38%) | | | | | | |
| Pathway | 11 | (5%) | 44 | (20%) | | | | |
| Actor | 10 | (5%) | 8 | (4%) | 20 | (9%) | | |
| Variable | 7 | (3%) | 4 | (2%) | 6 | (3%) | 24 | (11%) |

**Table 2**
Total number of distilled generic research questions and their typical research methods observed in the sample.

| Research question or transition problem | Number | Percentage | Examples of methods used |
|---|---|---|---|
| Questions that relate to explaining a whole, or part of, a transition. ('Whole' questions.) | 111 | 51% | Case study, multi-facet analysis, PEST analysis, historical event analysis, qualitative analysis, thematic analysis, grounded theory |
| Questions about particular transition policies and transition pathways. ('Pathway' questions.) | 67 | 31% | Sustainability foresight method, Quantitative modeling and assessment, and dynamic decision trees |
| Questions that involve the role and influence of (networks of) actors. ('Actor' questions.) | 44 | 20% | Survey based studies, Q methodology, meta inquiry and discourse analysis. |
| Questions that address the influence of specific variables or factors underlying transition processes ('Variable' questions.) | 41 | 19% | Econometric models, multivariate analysis, autoregressive moving average model, qualitative comparative analysis and process tracing (coding). |

**Table 4**
Philosophies underlying the main paradigms in transition research (adapted from Saunders et al., 2015).

| | Ontology | Epistemology | Axiology | Typical methods | Examples |
|---|---|---|---|---|---|
| **Positivist transition research** | There is a real and external transition process independent of the researcher. Also, only one true transition reality exists (universalism). Transitions are made up of solid, granular 'things' in an ordered form. | The scientific method can provide the knowledge about transition. Transitions are composed of observable and measurable facts, and law-like generalizations on transition can thus be discovered. As such, numbers play a pivotal role in developing knowledge. Causal explanation is critical to making predictions. | Transition studies are value-free. The researcher is detached, neutral and independent of what is being researched, and thus maintains an objective stance. | Typically, deductive, highly structured, large samples, measurement, typically quantitative methods of analysis, but a range of data can be analyzed. | Schmidt et al., 2012; Boon and Dieperink, 2014; Choi and Anadón, 2014 |
| **Critical realist transition research** | A transition is stratified and composed of three layers: the empirical layer (i.e. events that are actually observed or experienced), the actual layer (i.e. events and non-events generated by the real layer; which can or cannot be observed) and the real layer (i.e. causal structures and mechanisms with enduring properties). Also, the reality of transition is external and independent of the researcher. There are objective and intransient (relatively unchanging) structures and causal mechanisms in any transition process. | Concentration on in-depth historical analysis of structures to provide a bigger picture of which we see only a small part of transition. As such the critical realist adopts an epistemological relativism (Reed, 2005), a (mildly) subjectivist approach to knowledge. Causality in transition cannot be reduced to statistical correlations and quantitative methods, and a range of methods is acceptable (Reed, 2005). Historical causal explanation is the main contribution of transition research. | Transition studies is value-laden research. Transition researcher acknowledges bias by worldviews, cultural experience and upbringing. Transition researcher tries to minimize these biases and errors. Transition researcher is as objective as possible | Retroductive (Sayer, 1992), that is, in-depth historically situated analysis of pre-existing structures and emerging agency. Range of methods and data types to fit subject matter. | Bosman et al., 2014; Jhagroe and Loorbach, 2015; Fuenfschilling and Truffer, 2014 |
| **Inter-pretivist transition research** | The nature of transition is complex and rich. However, transition is socially constructed through culture and language. With its focus on complexity, richness, multiple interpretations and meaning-making, interpretivist transition research is explicitly subjectivist. Transition involves a flux of processes, experiences and practices. | Theories and concepts of transition are too simplistic to capture the full richness of the world. Transition knowledge can be obtained by focusing on narratives, stories, perceptions and interpretations of actors involved. New understandings and worldviews are the contribution of transition research. | Transition research is value-bound. Researchers are part of what is researched and subjective interpretations of transition researcher is key to contribution of the research. Transition researcher is reflexive about own thinking and writing. | Typically inductive. Small samples, in-depth investigations, qualitative methods of analysis, but a range of data can be interpreted. | Bakker, 2014; Diaz et al., 2013; Sarasini, 2013; Domènech et al., 2015 |
| **Pragmatist transition research** | The nature of transition research is complex, rich and external to transition researcher. A transition is the practical consequence of ideas, and knowledge is valued for enabling actions to be carried out successfully. Transition involves a flux of processes, experiences and practices. | Practical meaning of knowledge in specific contexts is emphasized. 'True' transition theories and knowledge are those that enable successful action. Focus on problems, practices and relevance of transition. The contribution of transition research is problem solving and informed future practice. | Transition research is value-driven, and is initiated and sustained by the researcher's doubts and beliefs. Researcher is reflexive about own thinking and writing. | Following research problem and research question. Range of methods: mixed, multiple, qualitative, quantitative, action research. Emphasis on practical solutions and outcomes | Martin and Rice, 2015; Bos and Brown, 2014; Kiss and Neij, 2011; Yuan et al., 2012 |

**Table 5**
Total number of theoretical frameworks observed in the sample.

| Theoretical frameworks | New framework | Borrowed framework | MLP | SNM | TIS | TM | Not defined |
|---|---|---|---|---|---|---|---|
| TFSC | 22 | 10 | 5 | 1 | 8 | 1 | 4 |
| EIST | 13 | 11 | 10 | 1 | 1 | 3 | 1 |
| TASM | 11 | 7 | 4 | 3 | 2 | 2 | 1 |
| Research Policy | 12 | 3 | 1 | 1 | 0 | 0 | 0 |
| Energy Policy | 22 | 24 | 12 | 2 | 5 | 2 | 17 |
| | 80 (37%) | 55 (25%) | 32 (15%) | 8 (4%) | 16 (7%) | 8 (4%) | 23 (11%) |

reflected in the research design of the paper, involving business process analysis coupled with qualitative analysis (see Table 4, Pragmatist transition research).

### 4.3. Theoretical frameworks

Our review demonstrates that most researchers in transition studies (around 90 percent of the papers reviewed) use a theoretical framework. Table 5 provides an overview. This also implies that 21 papers in our sample do not report any particular framework for data collection/analysis. As can be seen in Table 5, around 29 percent of the reviewed papers adopted one specific transition framework (i.e., MLP, SNM, TIS, or TM) individually or in combination with other theories and concepts.[16] Among the specific transition frameworks, MLP has been adopted most frequently.

Table 5 also shows that 62 percent of the papers in our sample use a framework other than those designed specifically for transition studies (i.e., MLP, TIS, SNM and TM). Notably 55 papers (25%) use a 'borrowed framework' while 80 papers (37%) designed a completely new framework. With respect to the latter, Wesseling et al. (2015), for instance, designed a conceptual framework that combines corporate innovation and political influence strategies. Also, Elzen et al. (2011) drew on innovation studies and the multi-level perspective with insights from social movement theory and political science. Furthermore, Naus et al. (2014) developed a framework derived from 'practice theory' in sociology, and 'informational governance' in particular, for analyzing the role of information flows in smart grids. Examples of the former include the societal needs framework in social psychology used by de Haan et al. (2014), the application of the political sociology of science and technology based on Moore et al. (2011) by Hess and Mai (2014) and the use of actor network theory and the notions of 'framing and overflowing' developed by the French sociologist Callon (1998) in Jolivet and Heiskanen (2010). Table 5 illustrates that researchers resort to new and borrowed frameworks rather often—independent of the journal that published their work; and Fig. 2 shows they increasingly do so. Furthermore, Fig. 2 illustrates that in recent years studies started to appear that do not define their theoretical framework (i.e., from 2012 onward).

### 4.4. Research methods

We also assessed all 217 papers in terms of the research method layer in the onion framework. For most papers, this was a straightforward exercise but 21 papers did not explicitly describe the method(s) adopted. These studies were initially labelled as 'no method mentioned'. Subsequently, 10 out of these 21 papers were coded by screening the entire text for words such as review, analysis, description, discussion and explanation; the paragraphs in which these words were used then often served as good indications of the methods adopted. The remaining 11 papers appeared to apply or test an existing theoretical framework in an exemplary transition problem and, as such, no method was explicitly mentioned. Based on what the authors in each of these studies actually did, it was possible to classify them under one of the three main research methods. As a result, 20 papers in this set were categorized as using a qualitative research method and one paper as using a mixed research.

Table 6 shows the results for the entire set of papers. As such, qualitative methods are used most frequently in transition research (82%). Fig. 3 denotes that this has always been the case. That is, we see a relative decrease in the number of quantitative and mixed method studies. As such, while the relative amount of such types of studies has always been rather low, they are becoming even more exceptional. Only 19 papers (9%) adopts a quantitative research method such as econometric methods and statistical analysis. We also identified 19 papers that adopted a mixed method approach (9%).[17] According to Table 6, all three types of research methods can be found in a substantial amount of work published by TFSC and Energy Policy. With a few exceptions, Research Policy, EIST and TASM primarily published qualitative papers.

Our review also demonstrates that transition researchers most frequently adopt a case study method (in 116 articles, 53% of the papers reviewed). This includes single cases as well as multiple and comparative case studies, and theory-guided as well as explorative case studies. Moreover, various quantitative and qualitative techniques have been adopted by transition scholars drawing on case studies: for example, (double) coding, content analysis, discourse analysis, thematic analysis, ethnography and patent analysis.

### 4.5. Data collection and data sources

Table 7 demonstrates that published and unpublished documents are used in 82% of the papers reviewed. The primary and secondary data sources of these documents include, among others, legal documents, annual reports, press releases (e.g., in newspapers and magazines), position papers, policy documents, parliamentary hearings, research reports, minutes and slides from meetings, informative internet websites, blogs, company websites, governmental websites; and academic sources such as books, journals and conference proceedings. More than half of all the studies used interviews as a data collection method. Different interview techniques are utilized, such as formal and informal interviews, and structured and semi-structured interview protocols. Surveys, observations and workshops are utilized in less than 15% of the papers reviewed. Furthermore, 121 studies (about 56%) used more than one data source and data collection method.

### 4.6. Time horizon

Table 8 demonstrates the distribution of research designs in terms of the time horizon. This table shows that 88% of the papers reviewed has a longitudinal research design, while only 12% of the papers use a cross-sectional research design with a relatively short time horizon. Fig. 4 suggests that transition scholars have long been preferring

[16] For example, while Raven (2007) follows the MLP framework, Diaz et al. (2013) used MLP in combination with actor network theory.

[17] Note that a combination of two qualitative methods, or two quantitative methods, is not considered a mixed method.

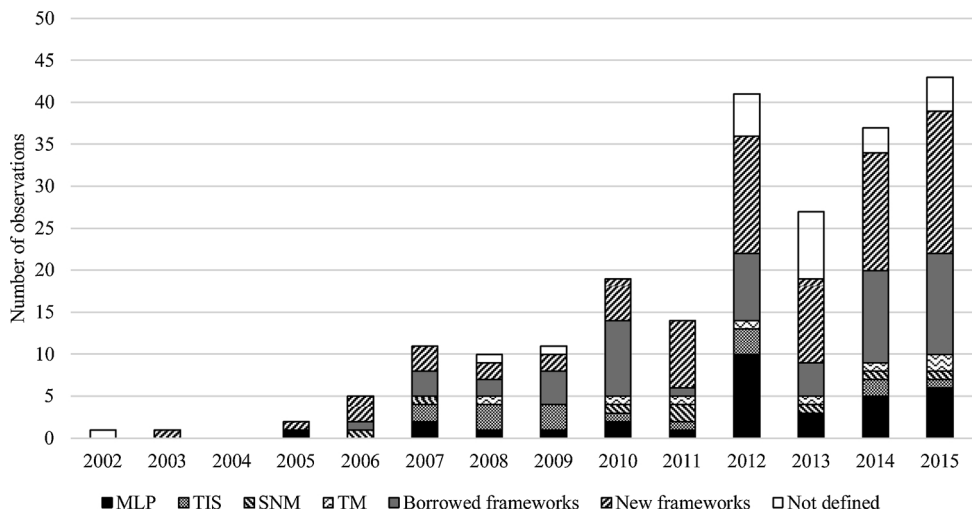


**Fig. 2.** Number of theoretical frameworks observed in the sample, per year.

**Table 6**
Distribution of research methods observed in the sample.

| | Qualitative methods | Quantitative methods | Mixed methods (Quan-Qual) |
|---|---|---|---|
| TFSC | 39 | 4 | 7 |
| EIST | 39 | 1 | 0 |
| TASM | 27 | 1 | 0 |
| Research Policy | 15 | 1 | 1 |
| Energy Policy | 59 | 12 | 11 |
| | 179 (82%) | 19 (9%) | 19 (9%) |

longitudinal research designs. That is, longitudinal studies, relatively, are becoming increasingly dominant over time. Notably, 18 papers (8%) did not explicitly mention their time horizon. The time horizon of these papers was coded based on indirect evidence, such as the time dimension (implicit in) the research question. Also, around 80% of the papers included data for a period beyond ten years in the past or the future, naturally aligning with the long-term nature of transition processes. While only 28 articles (13%) considered a period less than 10 years, 88 articles (41%) specified a time horizon between 10–30 years, and 83 studies (38%) focus on a period of more than 30 years to answer their research question.

**Table 7**
Distribution of data collection methods and sources observed in the sample.

| Data collection/sources | Number of studies | Percentage |
|---|---|---|
| Documents (published and unpublished) | 177 | 82% |
| Interviews | 125 | 58% |
| Surveys | 28 | 13% |
| Observations | 23 | 11% |
| Workshops | 12 | 6% |
| Several data collection methods used | 121 | 56% |

**Table 8**
Time horizon: Longitudinal vs. cross-sectional observed in the sample.

| | Numbers in the papers reviewed | Percentages in the papers reviewed |
|---|---|---|
| Cross sectional | 27 | 12% |
| Longitudinal | 190 | 88% |

## 5. Discussion

Many research domains have become methodologically more diverse, and as a result, scholars in these domains have engaged in methodological reflection to progress these domains (e.g., Hanson and

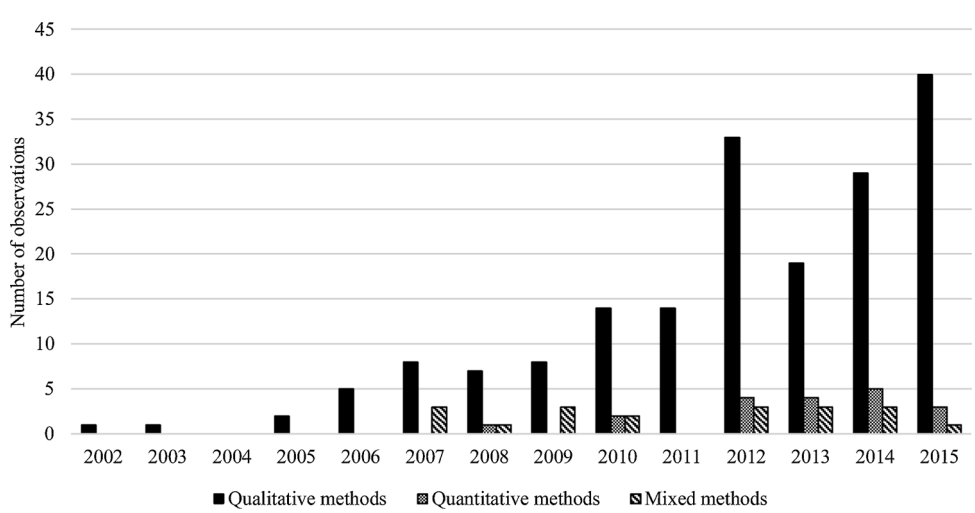


**Fig. 3.** Number of used research methods observed in the sample, per year.

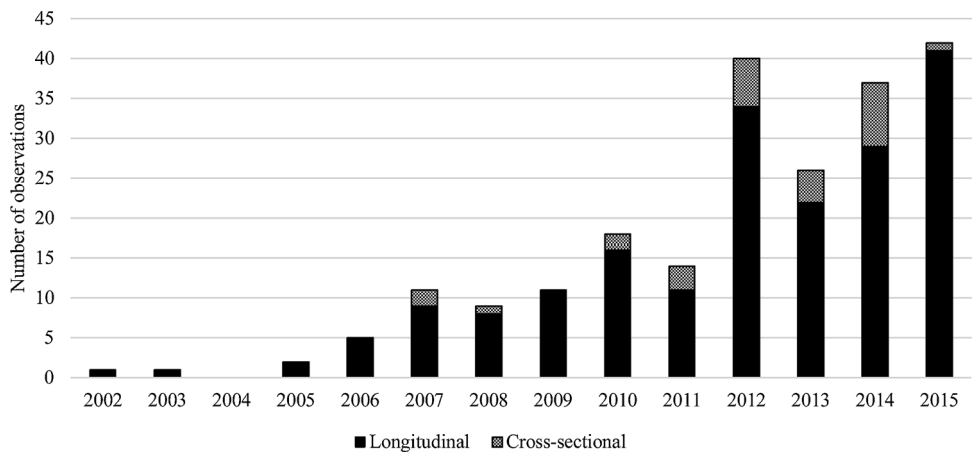


**Fig. 4.** Time horizons observed in the sample over time.

Grimmer, 2007; Hurmerinta-Peltomäki and Nummela, 2006; Hutchinson and Lovell, 2004; Molina-Azorín, 2009; Scandura and Williams, 2000; Wells et al., 2015). The field of transition research has also been experiencing a substantial growth in methodological diversity. This is a positive trend, as researchers from different fields bring along different methodological traditions, but it also reinforces the need for reflection on method selection. The onion framework proposed in this paper serves to integrate the contributions that can be achieved by means of different methods (e.g., what types of studies can solve what types of transition-related research questions), and may also create higher levels of synergy between different types of studies in the transition field.

Although this framework does not provide any detailed guidelines, it can be used as a heuristic to assess and advance the methodological depth and diversity of the field. Methodological *depth* here involves the coherence between the different elements of the transition research onion, that is, research questions, philosophical assumptions, theoretical frameworks, etcetera. In this respect, transition researchers can also turn to Table 4—and in particular the 'Typical methods' column—for guidance on achieving coherence in their research design. Specifically, this table offers information on the relationship between paradigmatic stance and method used. The notion of methodological *diversity* reflects the variety within each level of the research onion, as an important source of creativity and future growth of the field. As such, the focus here is on the question of how transition problems should be studied. This implies that we seek to contribute to transition research by (a) observing and discussing the limitations of the methodological boundaries currently prevailing in transitions research; and (b) developing a research agenda that spurs knowledge development in this field. In the remainder of this section, we explore these two contributions.

### 5.1. Transition research: limitations, reflections, and challenges

First, questions (should) drive research and, as such, greatly determine all other layers of the research onion. We found that 51% of the transition problems observed include a 'whole question', and as such adopt a bird's-eye view on matters (see Tables 2 and 3). This is in line with the STRN research agenda: "Some scholars are 'zooming-out' to develop an even more encompassing understanding of transitions. This includes interactions between multiple systems such as electricity-transport, agriculture-transport, and heat-electricity" (Köhler et al., 2017: 12). On the other hand, scholars are also zooming-in to study and understand the roles of particular actors (e.g. users, firms, civil society actors) and dimensions in transitions and the MLP (Köhler et al., 2017). Although important, it is important to position this type of work in a larger context, in order to include aspects like co-evolution and multi-actor dynamics (Köhler et al., 2017).

Second, most theoretical frameworks in the papers reviewed fit the category of 'new and borrowed' frameworks (62%) rather than specific transition frameworks (i.e. MLP, TIS, TM and SNM) (30%). This is a notable advancement of the field, given Shove and Walker's (2007: 768) plea for "loosening the intellectual grip of innovation studies, for backing off from the nested, hierarchical multilevel model as the only model in town, and for exploring other social scientific, but also systemic theories of change" (see also Köhler et al., 2017). Our analysis also appears to signal a recent broadening of the field in terms of new dimensions (e.g., geography, politics, strategic and organizational issues) that are increasingly acknowledged as critical, previously overlooked, dimensions shaping transition processes. However, we note that while new and/or borrowed frameworks are increasingly used to study transitions (see Fig. 2), such studies often build upon frameworks and traditions from related disciplines, which may trigger further methodological complexity, and implies a need for continued methodological advancement and reflection.

Third, we observed no clear relationships between the types of questions being addressed and the methods applied. As mentioned earlier, a significant number of the papers reviewed does not explicitly describe the method used. Moreover, many of the other papers we reviewed did not fully articulate their methods and theoretical/analytical frameworks, justify their research design, or mention any limitations of their research. Some studies even fail to explicitly elaborate on the applied method—in relation to other options identified in the research onion—regardless of whether the chosen approach was (not) valid for the research question under investigation. This is highly remarkable because of the close relationship between the type of method and the knowledge that can be obtained by it, and therefore missing methodological information severely constrains the legitimacy of the knowledge claims made in these studies.

Fourth, methodological investigation gives a sense of the kind of knowledge that is warranted or closed off in a particular field, by studying the relative usages or lack of certain methodological options (Bryman, 2011). For one, our analysis demonstrates that more than 80% of the studies draw on qualitative approaches, and more than 50% of all articles are based on case studies. In 38% of all articles reviewed, various types of methods were identified (see section 4.4). Furthermore, as illustrated in section 4.5, around 56% of the papers used more than one data source and data collection method, while surveys (13%), observations (11%) and workshops (6%) are less frequently utilized than interviews and documents. Although these statistics indicate a substantial level of diversity, they do point at a potential asymmetry in theoretical insights arising from several data sources possibly being underused. In other words, it might be the case that most knowledge is developed by drawing on subjective data (following from interviews

etc.), at the cost of knowledge building by means of collecting and analyzing large scale data and/or observations techniques. Future research needs to assess whether this asymmetry actually occurs and what its implications are.

Fifth, the ratio between quantitative and qualitative studies (see section 4.4) suggests that few studies draw on realist, objectivist, inductive, value-free and nomothetic approaches, and idealist (relativist), subjectivist, deductive, value-bound inquiry and ideographic understandings prevail in transition studies (section 4.2; see also Niglas, 2010; Tashakkori and Teddlie, 1998; Teddlie and Tashakkori, 2009; Guba and Lincoln, 1989). Some have argued that the latter understandings are more compatible with the nature of transitions, because of epistemological and ontological reasons (McDowall and Geels, 2017). Qualitative research and especially narrative theories have been advocated as being more suited to handle the heterogeneous, contingent and multi-level nature of socio-technical transitions (see, e.g., McDowall and Geels, 2017; Andersson et al., 2014). In this respect, within the various research paradigms there are particular preferences for research methods. We argue that, while quantitative approaches may not be compatible with *all* transition-related research questions, they might be rather valuable for *particular* transition-related research questions. For example, specific variables or conditions of decision making processes that determine the purchase of sustainable goods and services may be derived more effectively from controlled experiments than from any other research method; another example involves the long-term consequences of a range of policy interventions—which can be derived from simulation modeling in addition to field work.

More importantly, the dominance of particular methodologies and paradigms over others may limit the societal impact of transition research. Public policy makers and company executives also exhibit particular preferences for paradigms and research designs. In fact, their decision-making processes may more often than not align better with research results expressed in quantitative ways (e.g., in tables and statistical correlations) than with contextualized knowledge requiring substantial interpretation, such as insights and narratives developed in qualitative case studies. The challenge here is to find the right balance between doing justice to the real-world complexities of transitions (that some have argued are best addressed by narrative approaches) versus the ability to communicate and align with the realities of decision-making in policy and business (in which results expressed in straightforward quantitative ways are often perceived as more legitimate). By reflecting more explicitly on who the primary client/audience of a particular transition research project is, and adapting the methodology accordingly, this balance is more likely to be found and sustained.

Sixth, given the relative usage of longitudinal versus cross-sectional studies (section 4.6), process research appears to be far more prevalent in transition studies compared to variance research.[18] This may be due to the temporal nature of transition processes—which resonates better with longitudinal than cross-sectional data. While this might be true for complete transition processes, transition scholars also need to study sub-elements/systems of these processes by means of variance studies, in order to better understand the complex matter associated with a transition. In other words, detailed studies of the relationships between specific variables might serve to build a better understanding of the overall transition process. As such, in addition to analyzing the systemic nature of transition processes, one needs to study the interactions and associations of sub-systems and social groups which shape overall emergent patterns and behaviors at the systems level. Van de Ven (2007) argues there is a strong complementary relationship between process and variance approaches, that is, any answer to variance questions requires answers to the corresponding process questions, and vice versa.

While the number of cross-sectional studies has recently been growing (see Fig. 4), transition scholars traditionally prefer longitudinal research designs. We believe that this potentially undermines knowledge development on more specific sub-elements and/or systems driving transitions. In this respect, our findings resonate with the recently updated STRN research agenda that also emphasizes the need for more studies combining qualitative and quantitative approaches (Köhler et al., 2017): accordingly, transitions research would need to develop (1) approaches "for 'structured navigation' between broad transition frameworks, including the multiplicity of transitions and more precise theories and concepts for studying more confined phenomena" (Köhler et al., 2017: 43); and (2) methodologies "for combining quantitative and qualitative methods in the context of sustainability transitions research" (Köhler et al., 2017: 47).

### 5.2. Methods in transitions research: a research agenda

Based on the analysis earlier in this paper, we believe the following avenues are important for enhancing the methodological rigour and richness of transition studies.

First, while current transition research is relatively strong in explaining past transitions and case studies, it seems less strong in designing (practical) interventions. Indeed, the focus has primarily been on process questions of "how things develop and change over time" at the expense of studies focusing on variance or causal questions of "what causes what" (van de Ven, 2007: 146). Extending the methodological toolbox beyond primarily qualitative process theories might lead to a better understanding on possible intervention strategies—and as such, greater policy impact. In this respect, transition studies might be best positioned at the interface of the social sciences and the design (intervention-oriented) research, or what Simon (1969) called a design science. One can thus consider the transition field to be part of a broader set of design science disciplines including architecture, medicine, information systems, and similar fields (Boehnert et al., 2018; Irwin et al., 2015). Subsequently, we can learn from how some of these other interdisciplinary disciplines have built—and continue to build—a collective body of knowledge that is adaptive to particular local conditions, cultural constraints, social values, and so forth. One key insight is that different methods, with distinctive underlying assumptions and epistemologies, result in different *types* of insights that can be synthesized in a body of knowledge about the contextual conditions, generative mechanisms, intervention strategies and outcomes of societal transitions (e.g., March and Smith, 1995; van Aken and Romme, 2012; van Burg and Romme, 2014).

Second, in order to achieve such an ambitious goal, transition scholars need to make and communicate methodological and epistemological choices in an informed and transparent manner. Practically, this implies that transition scholars should consider designing their studies based on the options available in each layer of the research onion, developed in this paper. The key purpose of selecting options from each layer in the onion is to achieve coherence in research design, with a sufficient level of methodological depth and diversity. As such, researchers need to explicitly report all important choices, with respect to the options chosen *as well as* the coherence between these choices across layers of the onion. This will also allow for a more structured methodological dialogue across different approaches in transition studies, by enabling a better articulation of underlying methodological assumptions and choices across different studies. As detailed, our in-depth review illustrates that this articulation often does not take place, which impedes such a dialogue. Of course, any attempt to explicitly design a transition study involving all layers and options may be a mission impossible and result in overly complicated research designs. As such, the research onion's main function is to make transition scholars aware of and reflect on the methodological dimensions of their research efforts.

[18] In general terms, variance theory aims to explain relationships in terms of correlations among a set of variables, while process theory aims to explain change as result of a particular sequence of events unfolding over time (van de Ven, 2007).

Third, our analysis suggests that the four transition question types we identified (section 4.1) can be deductively linked to holistic analysis, pathway analysis, actor analysis and variance-oriented analysis. Powerful tools and techniques are available for each of these types of analysis, but some of them are rarely used in the papers we reviewed. These tools and techniques can be related to all the identified paradigms and their ontological and epistemological requirements. Therefore, this suggestion cannot be considered in support for, or against, a specific paradigm. For instance, various types of systems modeling are drawing their pre-assumptions from positivism, interpretivist, pragmatism and critical realism (see, e.g., Jackson, 2003; Mingers, 2006). Likewise actor-oriented approaches can adopt different paradigmatic assumptions (e.g., Pruyt, 2010). For instance, (systems) modeling and simulation methods[19] can support a pathway and/or actor analysis, because they especially serve to handle and dissect key features of transition problems involving non-linear, complex, multi-dimensional, multi-level and multi-actor processes (e.g., Squazzoni, 2008; Holtz, 2011; Holtz et al., 2015; Halbe et al., 2015; McDowall and Geels, 2017; Köhler et al., 2018; Walrave and Raven, 2016).

Likewise, policy analysis and scenario planning tools[20] could be utilized more for pathway analysis. As an applied discipline, policy analysis draws on multiple methods of inquiry and arguments to produce client-oriented knowledge and advice towards resolving transition policy problems (e.g., Dunn, 1981; Weimer and Vining, 2017). Also, a scenario approach serves to develop future situations and describe the (transition) paths from any given present to these future situations (Pillkahn, 2008; Raven and Walrave, 2018). As such, scenarios can be instrumental in recognizing, considering and reflecting on the uncertainties inherent in possible future system discontinuities, to identify the nature and timings of transition processes, to project the consequences of any particular choice or policy decision, and to highlight the interactions among several trends and events in transition processes (e.g., Strauss and Radnor, 2004).

Moreover, methods and frameworks for actor analysis[21] serve to address questions that involve the role and influence of (networks of) actors (e.g., users, customers, citizens, firms, and collective actors) on transition processes. Methods for actor analysis focus on identifying key characteristics of the various actors involved. These methods can be classified, theoretically, in terms of perceptions, values, resources and networks (Hermans and Thissen, 2009). Accordingly, such methods help transition scholars to capture important (effects arising from) features of the various actors in a specific transition process.

Finally, we reflect on the potential contribution of mixed methods. The prevalence rate[22] of mixed research in the social and behavioral sciences has been estimated to be 15 percent (Alise and Teddlie, 2010).[23] However, our review implies that only 9% of papers in transition studies apply a mixed research strategy (section 4.4). Although a mixed strategy is not necessarily always the best choice, given the preliminary research question, the application of mixed methods in transition research may offer several benefits (see, e.g., Andersson et al., 2014; Geels et al., 2016; Markard et al., 2012; Tashakkori and Teddlie, 2010; Turnheim et al., 2015). These benefits include the ability to address problems more comprehensively as well as enhanced opportunities to generate more valid inferences by triangulating different sources of data and methods (Howick and Ackermann, 2011; Ivankova and Kawamura, 2010).

Notably, mixed research can be also conducted at the level of paradigms and theories. In this respect, future work can and should engage much more in permutations and cross-overs between existing paradigms and related theoretical frameworks (Geels, 2010). The 'new' and 'borrowed' frameworks identified in Table 5 do not necessarily constitute examples of mixed theorizing, as many of these studies build on a single theory. Because mixed research is not a novel idea,[24] transition scholars can draw on the experiences of other fields (e.g., behavioral sciences and operations research). Accordingly, customizing and adopting frameworks from other disciplines can be a highly interesting and promising route for future research (e.g., Creswell and Plano Clark, 2007; Jackson and Keys, 1984; Jackson, 1997a, 1997b; Midgley, 2000; Mingers and White, 2010; Pollack, 2009; Tashakkori and Teddlie, 2010; Zolfagharian et al., 2018).

Overall, the field of transition studies would greatly benefit from developing clear protocols for reporting and explaining the methods used, to increase the quality of transition research efforts and outcomes, but also to facilitate the replication of findings obtained in empirical papers. In this respect, the transition research onion provides a platform for exploring many available methodological options—also to the benefit of journal reviewers and editors.

## 6. Concluding remarks

In this paper, we reviewed the methodological foundations of transition research. Drawing on the so-called transition research onion, we identified and explained various methodological challenges. The research onion framework can guide researchers to achieve more coherence throughout their research as well as to inform and guide fundamental shifts in socio-technical systems. Our review suggests there are major opportunities to grow the methodological transparency and diversity of the field of transition studies. Notably, we observed that many studies fail to articulate the methods used, and also pointed at an imbalance between qualitative versus quantitative research. It is clear that the path-dependent nature of any academic field does, over time, increasingly facilitate the usage of specific methodological options and demotivate the use of others. This also implies a stabilized preference for particular types of knowledge, once the field becomes more established. Arguably, an unbalanced usage of methodological options can also signal that particular kinds of scholarly expertise and skills are lacking. In any case, the plurality of the field of transition studies implies any effort—in terms of data and/or method—to build a broader and more pluralistic body of knowledge is a worthwhile one.

## Conflicts of interests

There are no conflicts of interests.

[19] For example, see Pidd (2004) for an overview of systems modeling in theory and practice, and Holtz et al. (2015) for an appraisal of experiences and suggestions for modeling transitions.

[20] See Amer et al. (2013) and Varum and Melo (2010) for literature reviews of scenario planning.

[21] For example, see Hermans and Thissen (2009) for an overview of methods and frameworks in this area.

[22] Prevalence rate here refers to the proportion of articles using a particular methodological approach (Alise and Teddlie, 2010).

[23] Various numbers (5% to 29%) are reported for the prevalence rates of mixed method research in the literature. The rates differ based on several factors including topical content of the journals selected, the operational definition of 'mixed methods,' and the time period examined (Alise and Teddlie, 2010).

[24] Creswell and Plano Clark (2007) specified four, often overlapping, time periods in the emergence and evolution of mixed methods: the formative period (1950s - 1980s) characterized by the initial interests to use more than one method in a single study; the paradigm debate period (1970s - late 1990s) that was dedicated to discussions on the role of paradigms in mixed research; the procedural development period (late 1980s – 2000) involving a shift towards the methods or procedures of designing a mixed methods study; and finally the advocacy of mixed research as a separate design (2000 to date) alongside quantitative and qualitative approaches. Nowadays, there is an established community of mixed method researchers with several handbooks, journals and conferences in different fields including the social, behavioural, educational, and health sciences.

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## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.respol.2019.04.012.

## References

Alise, M.A., Teddlie, C., 2010. A continuation of the paradigm wars? Prevalence rates of methodological approaches across the social/behavioral sciences. J. Mix. Methods Res. 4 (2), 103–126.
Amer, M., Daim, T.U., Jetter, A., 2013. A review of scenario planning. Futures 46, 23–40.
Ancona, D.G., Goodman, P.S., Lawrence, B.S., Tushman, M.L., 2001. Time: a new research lens. Acad. Manage. Rev. 26 (4), 645–663.
Anderson, P., Tushman, M.L., 1990. Technological discontinuities and dominant designs: a cyclical model of technological change. Adm. Sci. Q. 35 (4), 604–633.
Andersson, C., Törnberg, A., Törnberg, P., 2014. Societal systems – complex or worse? Futures 63, 145–157.
Arthur, W.B., Ermoliev, Y.M., Kaniovski, Y.M., 1987. Path-dependent processes and the emergence of macro-structure. Eur. J. Oper. Res. 30 (3), 294–303.
Asheim, B.T., Isaksen, A., 2002. Regional innovation systems: the integration of local' sticky' and global' ubiquitous' knowledge. J. Technol. Transf. 27 (1), 77–86.
Audet, R., Guyonnaud, M.F., 2013. Transition in practice and action in research. A French case study in piloting eco-innovations. Innov.: Eur. J. Social Sci. Res. 26 (4), 398–415.
Axsen, J., Kurani, K.S., 2014. Social influence and proenvironmental behavior: the reflexive layers of influence framework. Environ. Plann. B. Plann. Des. 41 (5), 847–862.
Azar, C., Sandén, B.A., 2011. The elusive quest for technology-neutral policies. Environ. Innov. Soc. Transit. 1 (1), 135–139.
Babbie, E.R., 2010. The Practice of Social Research, 13th ed. Wadsworth, Belmont Calif.
Bakker, S., 2014. Actor rationales in sustainability transitions – interests and expectations regarding electric vehicle recharging. Environ. Innov. Soc. Transit. 13, 60–74.
Barney, J., 1991. Firm resources and sustained competitive advantage. J. Manage. 17 (1), 99–120.
Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. Research Policy 37 (3), 407–429.
Bijker, W.E., Law, J., 1992. Shaping Technology: Studies in Sociotechnical Change. MIT Press, Cambridge, Massachusetts.
Bijker, W.E., Hughes, T.P., Pinch, T. (Eds.), 1987. The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology. MIT Press, Cambridge, Massachusetts.
Boehnert, J., Lockton, D., Mulder, I., 2018. Editorial: designing for transitions. Storni, C., Leahy, K., McMahon, M., Lloyd, P., Bohemia, E. (Eds.), Proceedings of the Design Research Society 2018 (DRS2018) Volume 3 (Section 9), 892–895.
Boon, F.P., Dieperink, C., 2014. Local civil society based renewable energy organisations in the Netherlands: exploring the factors that stimulate their emergence and development. Energy Policy 69, 297–307.
Bos, J.J., Brown, R.R., 2014. Assessing organisational capacity for transition policy programs. Technol. Forecast. Social Change 86, 188–206.
Bosman, R., Loorbach, D., Frantzeskaki, N., Pistorius, T., 2014. Discursive regime dynamics in the Dutch energy transition. Environ. Innov. Soc. Transit. 13, 45–59.
Brannen, J., 2005. Mixed Methods Research: A Discussion Paper. downloaded on 15 May 2018 from. NCRM Methods Review Papers. ESRC National Centre for Research Methods. http://eprints.ncrm.ac.uk/89/1/MethodsReviewPaperNCRM-005.pdf).
Briner, R.B., Denyer, D., 2012. Systematic review and evidence synthesis as a practice and scholarship tool. In: Rousseau, D.M. (Ed.), The Oxford Handbook of Evidence-Based Management. Oxford University Press, New York, pp. 112–129.
Bryman, A., 1992. Quantitative and qualitative research: further reflections on their integration. In: Brannen, J. (Ed.), Mixing Methods. Qualitative and Quantitative Research, Avebury, Aldershot, pp. 57–58.
Bryman, A., 2011. Mission accomplished? Research methods in the first five years of leadership. Leadership 7 (1), 73–83.
Budde, B., Alkemade, F., Weber, K.M., 2012. Expectations as a key to understanding actor strategies in the field of fuel cell and hydrogen vehicles. Technol. Forecast. Social Change 79 (6), 1072–1083.
Burrell, G., Morgan, G., 1979. Sociological Paradigms and Organisational Analysis: Elements of the Sociology of Corporate Life. Heinemann Educational, London.
Callon, M., 1984. Some elements of a sociology of translation: domestication of the scallops and the fishermen of St brieuc Bay. Sociol. Rev. 32 (1_suppl), 196–233.
Callon, M., 1998. An essay on framing and overflowing: economic externalities revisited by sociology. Sociol. Rev. 46 (1_suppl), 244–269.
Carlsson, B., Stankiewicz, R., 1991. On the nature, function and composition of technological systems. J. Evol. Econ. 1 (2), 93–118.
Carlsson, B., Jacobsson, S., Holmén, M., Rickne, A., 2002. Innovation systems: analytical and methodological issues. Res. Policy 31 (2), 233–245.
Choi, H., Anadón, L., 2014. the role of the complementary sector and its relationship with network formation and government policies in emerging sectors: the case of solar photovoltaics between 2001 and 2009. Technol. Forecast. Social Change 82, 80–94.
Christensen, C.M., 1997. The Innovator'S Dilemma: When New Technologies Cause Great Firms to Fail. Harvard Business School Press, Boston, Massachusetts.
Coenen, L., Benneworth, P., Truffer, B., 2012. Toward a spatial perspective on sustainability transitions. Res. Policy 41 (6), 968–979.
Cooke, P., 2002. Knowledge Economies: Clusters, Learning and Co-Operative Advantage. Routledge, London.
Cooke, P., Heidenreich, M., Braczyk, H.-J. (Eds.), 2004. Regional Innovation Systems: The Role of Governances in a Globalized World, 2nd ed. Routledge, London.
Coutard, O., 1999. The Governance of Large Technical Systems. Routledge, London.
Cowan, R., 1990. Nuclear power reactors: a study in technological lock-in. J. Econ. Hist. 50 (3), 541–567.
Creswell, J.W., Plano Clark, V.L., 2007. Designing and Conducting Mixed Methods Research. SAGE, Thousand Oaks, Calif.
Crotty, M., 1998. The Foundations of Social Research: Meaning and Perspective in the Research Process. SAGE Publications, Thousand Oaks, Calif.
David, P.A., 1985. Clio and the economics of QWERTY. Am. Econ. Rev. 75 (2), 332–337.
Davis, K., Mazzuchi, T., Sarkani, S., 2013. Architecting technology transitions: a sustainability-oriented sociotechnical approach. Sys. Eng. 16 (2), 193–212.
de Haan, F.J., Rotmans, J., 2011. Patterns in transitions: understanding complex chains of change. Technol. Forecast. Social Change 78 (1), 90–102.
de Haan, F.J., Ferguson, B.C., Adamowicz, R.C., Johnstone, P., Brown, R.R., Wong, T.H.F., 2014. The needs of society: a new understanding of transitions, sustainability and liveability. Technol. Forecast. Social Change 85, 121–132.
Denzin, N.K., Lincoln, Y.S. (Eds.), 2011. The Sage Handbook of Qualitative Research, 4th ed. SAGE Publications, Thousand Oaks, Calif.
Diaz, M., Darnhofer, I., Darrot, C., Beuret, J.-E., 2013. Green tides in brittany: what can we learn about niche-regime interactions? Environ. Innov. Soc. Transit. 8, 62–75.
Domènech, L., March, H., Vallès, M., Saurí, D., 2015. Learning processes during regime shifts: empirical evidence from the diffusion of greywater recycling in Spain. Environ. Innov. Soc. Transit. 15, 26–41.
Dosi, G., 1982. Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change. Res. Policy 11 (3), 147–162.
Dunn, W.M., 1981. An Introduction to Public Policy Analysis. Prentice Hall, Upper Saddle River, NJ.
Elzen, B., Geels, F.W., Leeuwis, C., van Mierlo, B., 2011. Normative contestation in transitions 'in the making': animal welfare concerns and system innovation in pig husbandry. Res. Policy 40 (2), 263–275.
Fagerberg, J., Fosaas, M., Sapprasert, K., 2012. Innovation: exploring the knowledge base. Res. Policy 41 (7), 1132–1153.
Flood, R.L., 1995. Total systems intervention (TSI): a reconstitution. J. Oper. Res. Soc. 46 (2), 174–191.
Frantzeskaki, N., Kabisch, N., 2016. Designing a knowledge co-production operating space for urban environmental governance—Lessons from Rotterdam, Netherlands and Berlin, Germany. Environ. Sci. Policy 62, 90–98.
Freeman, C., Louçã, F., 2001. As Time Goes by: From the Industrial Revolutions to the Information Revolution. Oxford University Press, Oxford.
Frieler, K., Levermann, A., Elliott, J., Heinke, J., Arneth, A., Bierkens, M.F.P., Ciais, P., Clark, D.B., Deryng, D., Döll, P., Falloon, P., Fekete, B., Folberth, C., Friend, A.D., Gellhorn, C., Gosling, S.N., Haddeland, I., Khabarov, N., Lomas, M., Masaki, Y., Nishina, K., Neumann, K., Oki, T., Pavlick, R., Ruane, A.C., Schmid, E., Schmitz, C., Stacke, T., Stehfest, E., Tang, Q., Wisser, D., Huber, V., Piontek, F., Warszawski, L., Schewe, J., Lotze-Campen, H., Schellnhuber, H.J., 2015. A framework for the cross-sectoral integration of multi-model impact projections: Land use decisions under climate impacts uncertainties. Earth Syst. Dyn. 6 (2), 447–460.
Fuenfschilling, L., Truffer, B., 2014. The structuration of socio-technical regimes—Conceptual foundations from institutional theory. Res. Policy 43 (4), 772–791.
Garud, R., Gehman, J., 2012. Metatheoretical perspectives on sustainability journeys: evolutionary, relational and durational. Res. Policy 41 (6), 980–995.
Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Res. Policy 31 (8-9), 1257–1274.
Geels, F.W., 2005. Co-evolution of technology and society: the transition in water supply and personal hygiene in the Netherlands (1850–1930)—A case study in multi-level perspective. Technol. Soc. 27 (3), 363–397.
Geels, F.W., 2009. Foundational ontologies and multi-paradigm analysis, applied to the socio-technical transition from mixed farming to intensive pig husbandry (1930-1980). Technol. Anal. Strateg. Manage. 21 (7), 805–832.
Geels, F.W., 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. Res. Policy 39 (4), 495–510.
Geels, F.W., 2011. The multi-level perspective on sustainability transitions: responses to seven criticisms. Environ. Innov. Soc. Transit. 1 (1), 24–40.
Geels, F.W., Hekkert, M.P., Jacobsson, S., 2008. The dynamics of sustainable innovation journeys. Technol. Anal. Strateg. Manage. 20 (5), 521–536.
Geels, F.W., Berkhout, F., van Vuuren, D.P., 2016. Bridging analytical approaches for low-carbon transitions. Nat. Clim. Change 6 (6), 576–583.
Genus, A., Coles, A.-M., 2008. Rethinking the multi-level perspective of technological transitions. Res. Policy 37 (9), 1436–1445.

George, J., Jones, G.R., 2000. The role of time in theory and theory building. J. Manage. 26 (4), 657–684.
Ginsberg, A., Venkatraman, N., 1985. Contingency perspectives of organizational strategy: a critical review of the empirical research. Acad. Manage. Rev. 10 (3), 421–434.
Grin, J., Rotmans, J., Schot, J.W. (Eds.), 2010. Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change. Routledge, London.
Guba, E.G., Lincoln, Y.S., 1989. Fourth Generation Evaluation. SAGE Publications, Newbury Park, Calif.
Halbe, J., Reusser, D.E., Holtz, G., Haasnoot, M., Stosius, A., Avenhaus, W., Kwakkel, J.H., 2015. Lessons for model use in transition research: a survey and comparison with other research areas. Environ. Innov. Soc. Transit. 15, 194–210.
Hanson, D., Grimmer, M., 2007. The mix of qualitative and quantitative research in major marketing journals, 1993-2002. Eur. J. Mark. 41 (1/2), 58–70.
Haxeltine, A., Whitmarsh, L., Bergman, N., Rotmans, J., Schilperoord, M., Köhler, J., 2008. A conceptual framework for transition modelling. Int. J. Innov. Sustainable Dev. 3 (1/2), 93–114.
Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., Smits, R.E.H.M., 2007. Functions of innovation systems: a new approach for analysing technological change. Technol. Forecast. Soc. Change 74 (4), 413–432.
Hellsmark, H., Jacobsson, S., 2009. Opportunities for and limits to academics as system builders—The case of realizing the potential of gasified biomass in Austria. Energy Policy 37 (12), 5597–5611.
Hermans, L.M., Thissen, W.A.H., 2009. Actor analysis methods and their use for public policy analysts. Eur. J. Oper. Res. 196 (2), 808–818.
Hess, D.J., Mai, Q.D., 2014. Renewable electricity policy in Asia: a qualitative comparative analysis of factors affecting sustainability transitions. Environ. Innov. Soc. Transit. 12, 31–46.
Holland, J.H., 1995. Hidden Order: How Adaptation Builds Complexity. Addison-Wesley, Reading, Mass.
Holtz, G., 2011. Modelling transitions: an appraisal of experiences and suggestions for research. Environ. Innov. Soc. Transit. 1 (2), 167–186.
Holtz, G., Alkemade, F., Haan, F.Jd., Köhler, J., Trutnevyte, E., Luthe, T., Halbe, J., Papachristos, G., Chappin, E., Kwakkel, J., Ruutu, S., 2015. Prospects of modelling societal transitions: position paper of an emerging community. Environ. Innov. Soc. Transit. 17, 41–58.
Howick, S., Ackermann, F., 2011. Mixing OR methods in practice: past, present and future directions. Eur. J. Oper. Res. 215 (3), 503–511.
Hughes, T.P., 1983. Networks of Power: Electrification in Western Society, 1880-1930. John Hopkins University Press, Baltimore.
Hughes, T.P., 1987. The evolution of large technological systems. In: Bijker, W.E., Hughes, T.P., Pinch, T. (Eds.), The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology. MIT Press, Cambridge, Massachusetts, pp. 51–82.
Hultman, N.E., Malone, E.L., Runci, P., Carlock, G., Anderson, K.L., 2012. Factors in low-carbon energy transformations: comparing nuclear and bioenergy in Brazil, Sweden, and the United States. Energy Policy 40, 131–146.
Hurlbert, M.A., 2011. Evaluating climate justice – attitudes and opinions of individual stakeholders in the United Nations framework climate change convention Conference of the parties. J. Integr. Environ. Sci. 8 (4), 267–286.
Hurmerinta-Peltomäki, L., Nummela, N., 2006. Mixed methods in international business research: a value-added perspective. Manage. Int. Rev. 46 (4), 439–459.
Hutchinson, S.R., Lovell, C.D., 2004. A review of methodological characteristics of research published in key journals in higher education: implications for graduate research training. Res. Higher Edu. 45 (4), 383–403.
Irwin, T., Kossoff, G., Tonkinwise, C., Scupelli, P., 2015. Transition Design: A New Area of Design Research, Practice and Study That Proposes Design-Led Societal Transition Toward More Sustainable Futures. Carnegie Mellon School of Design, Pittsburgh, PA.
Ivankova, N., Kawamura, Y., 2010. Emerging trends in the utilization of integrated designs in the social, behavioral, and health sciences. In: Tashakkori, A., Teddlie, C. (Eds.), SAGE Handbook of Mixed Methods in Social & Behavioral Research, 2nd ed. SAGE Publications, Thousand Oaks, CA, pp. 581–612.
Jackson, M.C., 1997a. Critical systems thinking and information systems research. In: Mingers, J., Stowell, F.A. (Eds.), Information Systems. An Emerging Discipline? McGraw-Hill, London, pp. 201–230.
Jackson, M.C., 1997b. Pluralism in systems thinking and practice. In: Mingers, J., Gill, A. (Eds.), Multimethodology. The Theory and Practice of Integrating Management Science Methodologies. John Wiley & Sons, Chichester, pp. 345–378.
Jackson, M.C., 2003. Systems Thinking: Creative Holism for Managers. Wiley, Chichester.
Jackson, M.C., Keys, P., 1984. Towards a system of systems methodologies. J. Oper. Res. Soc. 35 (6), 473–486.
Jacobsson, S., Bergek, A., 2006. A framework for guiding policy-makers intervening in emerging innovation systems in 'catching-up' countries. Eur. J. Dev. Res. 18 (4), 687–707.
Jhagroe, S., Loorbach, D., 2015. See no evil, hear no evil: the democratic potential of transition management. Environ. Innov. Soc. Transit. 15, 65–83.
Jørgensen, U., 2012. Mapping and navigating transitions—The multi-level perspective compared with arenas of development. Res. Policy 41 (6), 996–1010.
Johnson, F.X., Silveira, S., 2014. Pioneer countries in the transition to alternative transport fuels: comparison of ethanol programmes and policies in Brazil, Malawi and Sweden. Environ. Innov. Soc. Transit. 11, 1–24.
Johnson, R.B., Onwuegbuzie, A.J., Turner, L.A., 2007. Toward a definition of mixed methods research. J. Mix. Methods Res. 1 (2), 112–133.
Jolivet, E., Heiskanen, E., 2010. Blowing against the wind—An exploratory application of actor network theory to the analysis of local controversies and participation processes in wind energy. Energy Policy 38 (11), 6746–6754.
Kauffman, S., 1995. At Home in the Universe: The Search for the Laws of Self-Organization and Complexity. Oxford University Press, New York.
Kemp, R., Schot, J.W., Hoogma, R., 1998. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. Technol. Analy. Strateg. Manage. 10 (2), 175–198.
Kern, F., 2012. the discursive politics of governing transitions towards sustainability: the UK carbon trust. Int. J. Sustainable Dev. 15 (1/2), 90–106.
Kiss, B., Neij, L., 2011. The importance of learning when supporting emergent technologies for energy efficiency—A case study on policy intervention for learning for the development of energy efficient windows in Sweden. Energy Policy 39 (10), 6514–6524.
Klitkou, A., Bolwig, S., Hansen, T., Wessberg, N., 2015. the role of lock-in mechanisms in transition processes: the case of energy for road transport. Environ. Innov. Soc. Transit. 16, 22–37.
Köhler, J., Haan, F.Jd., Holtz, G., Kubeczko, K., Moallemi, E., Papachristos, G., Chappin, E., 2018. Modelling sustainability transitions: an assessment of approaches and challenges. J. Artif. Societies Soc. Simulation 21 (1).
Köhler, J., Geels, F.W., Kern, F., Onsongo, E., Wieczorek, A., 2017. A Research Agenda for the Sustainability Transitions Research Network (downloaded on 24 January 2018 from. https://transitionsnetwork.org/wp-content/uploads/2018/01/STRN_Research_Agenda_2017.pdf).
Köhler, J., Geels, F.W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M.S., Nykvist Bjorn, Pel Bonno, Raven, R., Rohracher, H., Sandén, B., Schot, J., Sovacool, B., Turnheim Bruno, Welch Dan, Wells, P., 2019. An agenda for sustainability transitions research. State of the art and future directions. Environ. Innov. Soc. Transit. 1–32 (Accepted/In press).
La Porte, T.R., 1991. Social Responses to Large Technical Systems: Control or Anticipation. Springer Sciences + Business Media, B.V, Dordrecht.
Law, J., Hassard, J., 1999. Actor Network Theory and After. Blackwell, Oxford.
Lawrence, T.B., Suddaby, R., 2006. Institutions and institutional work. In: Clegg, S.R., Hardy, C., Lawrence, B.S., Nord, W.R. (Eds.), The Sage Handbook of Organization Studies, 2nd ed. SAGE Publications, Thousand Oaks, CA, pp. 215–254.
Lincoln, Y.S., Guba, E.G., 1985. Naturalistic Inquiry. SAGE Publications, Beverly Hills, Calif.
Loorbach, D., Frantzeskaki, N., Thissen, W.H., 2011. A transition research perspective on governance for sustainability. In: In: Jaeger, C.C., Tàbara, J.D., Jaeger, J. (Eds.), European Research on Sustainable Development Volume 1. Transformative science approaches for sustainability. Springer, pp. 73–90.
Loorbach, D., Frantzeskaki, N., Avelino, F., 2017. Sustainability transitions research: transforming science and practice for societal change. Annu. Rev. Environ. Resour. 42 (1), 599–626.
March, S.T., Smith, G.F., 1995. Design and natural science research on information technology. Decis. Support Syst. 15, 251–266.
Markard, J., Truffer, B., 2008. Technological innovation systems and the multi-level perspective: towards an integrated framework. Res. Policy 37 (4), 596–615.
Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: an emerging field of research and its prospects. Res. Policy 41 (6), 955–967.
Marsland, N., Wilson, I., Abeyasekera, S., Kleih, U., 2000. A methodological framework for combining quantitative and qualitative survey methods. An Output from the DFID-Funded Natural Resources Systems Programme (Socio-Economic Methodologies Component) Project R7033 Titled Methodological Framework Integrating Qualitative and Quantitative Approaches for Socio-Economic Survey Work. Statistical Services Centre, University of Reading.
Martens, P., Rotmans, J., 2005. Transitions in a globalising world. Futures 37 (10), 1133–1144.
Martin, N., Rice, J., 2015. Improving Australia's renewable energy project policy and planning: a multiple stakeholder analysis. Energy Policy 84, 128–141.
Mattes, J., Huber, A., Koehrsen, J., 2015. Energy transitions in small-scale regions – what we can learn from a regional innovation systems perspective. Energy Policy 78, 255–264.
Mayntz, R., Hughes, T.P. (Eds.), 1988. The Development of Large Technical Systems. Westview Press, Boulder, Colorado.
McDowall, W., Geels, F.W., 2017. Ten challenges for computer models in transitions research: commentary on holtz et al. Environ. Innov. Soc. Transit. 22, 41–49.
McGahan, A.M., Argyres, N., Baum, J.A.C., 2004. Context, technology and strategy: forging new perspectives on the industry life cycle. In: Baum, J.A.C., McGahan, A.M. (Eds.), Business Strategy Over the Industry Lifecycle. Emerald Group Publishing Limited, pp. 1–21.
Meadowcroft, J., 2011. Engaging with the politics of sustainability transitions. Environ. Innov. Soc. Transit. 1 (1), 70–75.
Midgley, G., 2000. Systemic Intervention: Philosophy, Methodology, and Practice. Springer, Boston, MA.
Mingers, J., 2006. Realising Systems Thinking: Knowledge and Action in Management Science. Springer Science & Business Media, New York.
Mingers, J., White, L., 2010. A review of the recent contribution of systems thinking to operational research and management science. Eur. J. Oper. Res. 207 (3), 1147–1161.
Mintzberg, H., 2005. Developing theory about the development of theory. In: Smith, K.G., Hitt, M.A. (Eds.), Great Minds in Management. The Process of Theory Development.

Oxford University Press, Oxford, pp. 355–372.
Molina-Azorín, J.F., 2009. Understanding how mixed methods research is undertaken within a specific research community: the case of business studies. Int. J. Mult. Res. Approaches 3 (1), 47–57.
Moore, K., Kleinman, D.L., Hess, D.J., Frickel, S., 2011. Science and neoliberal globalization: a political sociological approach. Theory Soc. 40 (5), 505–532.
Naus, J., Spaargaren, G., van Vliet, B.J.M., van der Horst, H.M., 2014. Smart grids, information flows and emerging domestic energy practices. Energy Policy 68, 436–446.
Negro, S.O., Hekkert, M.P., Smits, R.E., 2007. Explaining the failure of the Dutch innovation system for biomass digestion—A functional analysis. Energy Policy 35 (2), 925–938.
Nelson, R.R., Winter, S.G., 1982. An Evolutionary Theory of Economic Change. Belknap Press of Havard University Press, Cambridge, Massachusetts.
Niglas, K., 2010. The multidimensional model of research methodology: an integrated set of continua. In: Tashakkori, A., Teddlie, C. (Eds.), SAGE Handbook of Mixed Methods in Social & Behavioral Research, 2nd ed. SAGE Publications, Thousand Oaks, CA, pp. 215–236.
Normann, H.E., 2015. the role of politics in sustainable transitions: the rise and decline of offshore wind in Norway. Environ. Innov. Soc. Transit. 15, 180–193.
Paredis, E., 2011. Sustainability transitions and the nature of technology. Foundations Sci. 16 (2-3), 195–225.
Patton, M.Q., 1990. Qualitative Research & Evaluation Methods: Integrating Theory and Practice, 2nd ed. SAGE Publications, Thousand Oaks, California.
Pel, B., 2014. Intersections in system innovation: a nested-case methodology to study co-evolving innovation journeys. Technol. Anal. Strateg. Manage. 26 (3), 307–320.
Perez, C., 2002. Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages. Edward Elgar Pub, Cheltenham.
Pidd, M., 2004. Systems Modelling: Theory and Practice. Wiley, Chichester.
Pillkahn, U., 2008. Using Trends and Scenarios as Tools for Strategy Development. Publicis Corporate Publishing, Erlangen, Germany.
Pollack, J., 2009. Multimethodology in series and parallel: strategic planning using hard and soft OR. J. Oper. Res. Soc. 60 (2), 156–167.
Poole, M.S., van de Ven, A.H., Dooley, K., Holmes, M.E., 2000. Organizational Change and Innovation Processes: Theory and Methods for Research. Oxford University Press, Oxford.
Prigogine, I., Stengers, I., 1984. Order Out of Chaos: Man'S New Dialogue Nature. BANTAM Books, New York.
Pruyt, E., 2010. Multi-actor systems and ethics. Int. Trans. Oper. Res. 17 (4), 507–520.
Raven, R., 2007. Co-evolution of waste and electricity regimes: multi-regime dynamics in the Netherlands (1969-2003). Energy Policy 35 (4), 2197–2208.
Raven, R., Walrave, B., 2018. Overcoming transformational failures in the dynamics of technological innovation systems. Technol. Forecast. Social Change (Accepted/In press). https://www.sciencedirect.com/science/article/pii/S0040162516308460.
Ravetz, J.R., 1999. What is post-normal science? Futures 31 (7), 647–653.
Reckwitz, A., 2002. Toward a theory of social practices. Eur. J. Social Theory 5 (2), 243–263.
Reed, M., 2005. Reflections on the 'realist turn' in organization and management studies. J. Manage. Stud. 42 (8), 1621–1644.
Rip, A., Kemp, R., 1998. Technological change. In: In: Rayner, S., Malone, E.L. (Eds.), Human Choice and Climate Change Volume 2. Battelle Press, Columbus, Ohio, pp. 327–339.
Rodrigo, P., Muñoz, P., Wright, A., 2015. Transitions dynamics in context: key factors and alternative paths in the sustainable development of nations. J. Cleaner Prod. 94, 221–234.
Rogge, K.S., Hoffmann, V.H., 2010. The impact of the EU ETS on the sectoral innovation system for power generation technologies – findings for Germany. Energy Policy 38 (12), 7639–7652.
Rosenbloom, D., Meadowcroft, J., 2014. The journey towards decarbonization: exploring socio-technical transitions in the electricity sector in the province of Ontario (1885-2013) and potential low-carbon pathways. Energy Policy 65, 670–679.
Rotmans, J., Loorbach, D., 2009. Complexity and transition management. J. Ind. Ecol. 13 (2), 184–196.
Rotmans, J., Kemp, R., van Asselt, M., 2001. More evolution than revolution: transition management in public policy. Foresight 3 (1), 15–31.
Sabatier, P.A., Jenkins-Smith, H., 1999. The advocacy coalition framework: an assessment. In: Sabatier, P.A., Weible, C.M. (Eds.), Theories of the Policy Process, 3rd ed. Westview Press, Boulder, Colorado, pp. 117–166.
Saldaña, J., 2015. The Coding Manual for Qualitative Researchers, 3rd ed. SAGE, Los Angeles.
Sarasini, S., 2013. Institutional work and climate change: corporate political action in the Swedish electricity industry. Energy Policy 56, 480–489.
Saunders, M., Lewis, P., Thornhill, A., 2015. Research Methods for Business Students, 6th ed. Pearson, London.
Sayer, A., 1992. Method in Social Science: A Realist Approach, 2nd ed. Routledge, London.
Scandura, T.A., Williams, E.A., 2000. Research methodology in management: current practices, trends, and implications for future research. Acad. Manage. J. 43 (6), 1248–1264.
Schatzki, T.R., 1996. Social Practices: A Wittgensteinian Approach to Human Activity and the Social. Cambridge University Press, Cambridge.
Schmidt, T.S., Schneider, M., Hoffmann, V.H., 2012. Decarbonising the power sector via technological change – differing contributions from heterogeneous firms. Energy Policy 43, 466–479.
Scholz, R.W., 2017. The normative dimension in transdisciplinarity, transition management, and transformation sciences. New Roles Sci. Universities Sustainable Transitioning Sustainability 9 (6).
Schot, J.W., 1998. The usefulness of evolutionary models for explaining innovation. The case of the Netherlands in the nineteenth century. Hist. Technol. 14 (3), 173–200.
Schot, J.W., Hoogma, R., Elzen, B., 1994. Strategies for shifting technological systems. Futures 26 (10), 1060–1076.
Scott, R.W., 1995. Institutions and Organizations. Ideas, Interests and Identities. SAGE Publications, Thousand Oaks, CA.
Scrase, I., Smith, A., 2009. The (non-)politics of managing low carbon socio-technical transitions. Environ. Polit. 18 (5), 707–726.
Shove, E., 2003. Comfort, Cleanliness and Convenience: The Social Organization of Normality. Berg, Oxford.
Shove, E., Walker, G., 2007. Caution! Transitions ahead: politics, practice, and sustainable transition management. Environ. Plann. A: Economy Space 39 (4), 763–770.
Shove, E., Walker, G., 2010. Governing transitions in the sustainability of everyday life. Res. Policy 39 (4), 471–476.
Shove, E., Pantzar, M., Watson, M., 2012. The Dynamics of Social Practice: Everyday Life and How It Changes. SAGE Publications Ltd.
Simon, H.A., 1969. The Sciences of the Artificial. MIT Press, Cambridge, Massachusetts.
Smith, A., Stirling, A., Berkhout, F., 2005. The governance of sustainable socio-technical transitions. Res. Policy 34 (10), 1491–1510.
Smith, A., Voß, J.-P., Grin, J., 2010. Innovation studies and sustainability transitions: the allure of the multi-level perspective and its challenges. Res. Policy 39 (4), 435–448.
Smits, R.E., Kuhlmann, S., 2004. The rise of systemic instruments in innovation policy. Int. J. Foresight Innov. Policy 1 (1/2), 4–32.
Sorrell, S., 2015. Reducing energy demand: a review of issues, challenges and approaches. Renewable Sustainable Energy Rev. 47, 74–82.
Sovacool, B.K., Hess, D.J., 2017. Ordering theories: typologies and conceptual frameworks for sociotechnical change. Soc. Stud. Sci. 47 (5), 703–750.
Sperling, K., Hvelplund, F., Mathiesen, B.V., 2010. Evaluation of wind power planning in Denmark – towards an integrated perspective. Energy 35 (12), 5443–5454.
Squazzoni, F., 2008. A (computational) social science perspective on societal transitions. Comput. Math. Organ. Theory 14 (4), 266–282.
Strauss, J.D., Radnor, M., 2004. Roadmapping for dynamic and uncertain environments. Res. Technol. Manage. 47 (2), 51–57.
Summerton, J. (Ed.), 1994. Changing Large Technical Systems. Westview Press, Boulder/San Francisco, Oxford.
Tashakkori, A., Teddlie, C., 1998. Mixed Methodology: Combining Qualitative and Quantitative Approaches. SAGE, Thousand Oaks, CA.
Tashakkori, A., Teddlie, C. (Eds.), 2010. SAGE Handbook of Mixed Methods in Social & Behavioral Research, 2nd ed. SAGE Publications, Thousand Oaks, CA.
Teddlie, C., Tashakkori, A., 2009. Foundations of Mixed Methods Research: Integrating Quantitative and Qualitative Approaches in the Social and Behavioral Sciences. SAGE Publications, Thousand Oaks, CA.
Tranfield, D., Denyer, D., Smart, P., 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British J. Manage. 14 (3), 207–222.
Trutnevyte, E., Barton, J., O'Grady, Á., Ogunkunle, D., Pudjianto, D., Robertson, E., 2014. Linking a storyline with multiple models: a cross-scale study of the UK power system transition. Technol. Forecast. Soc. Change 89, 26–42.
Trutnevyte, E., Strachan, N., Dodds, P.E., Pudjianto, D., Strbac, G., 2015. Synergies and trade-offs between governance and costs in electricity system transition. Energy Policy 85, 170–181.
Turnheim, B., Berkhout, F., Geels, F.W., Hof, A., McMeekin, A., Nykvist, B., van Vuuren, D.P., 2015. Evaluating sustainability transitions pathways: bridging analytical approaches to address governance challenges. Global Environ. Change 35, 239–253.
van Aken, J.E., Romme, A.G.L., 2012. A design science approach to evidence-based management. In: Rousseau, D.M. (Ed.), The Oxford Handbook of Evidence-Based Management. Oxford University Press, New York, pp. 43–57.
van Burg, E., Romme, A.G.L., 2014. Creating the future together: toward a framework for research synthesis in entrepreneurship. Entrep. Theory Pract. 38, 369–397.
van de Ven, A.H., 2007. Engaged Scholarship: A Guide for Organizational and Social Research. Oxford University Press, Oxford.
van den Bergh, J.C.J.M., Gowdy, J.M., 2000. Evolutionary theories in environmental and resource economics: approaches and applications. Environ. Resour. Econ. 17 (1), 37–57.
van der Brugge, R., van Raak, R., 2007. Facing the adaptive management challenge: insights from transition management. Ecol. Soc. 12 (2).
van Lente, H., Rip, A., 1998. The rise of membrane technology: from rhetorics to social reality. Soc. Stud. Sci. 28 (2), 221–254.
Varum, C.A., Melo, C., 2010. Directions in scenario planning literature – a review of the past decades. Futures 42 (4), 355–369.
Vasileiadou, E., Safarzyńska, K., 2010. Transitions: taking complexity seriously. Futures 42 (10), 1176–1186.
Voronov, M., Vince, R., 2012. Integrating emotions into the analysis of institutional work. Acad. Manage. Rev. 37 (1), 58–81.
Wakiyama, T., Zusman, E., Monogan, J.E., 2014. Can a low-carbon-energy transition be sustained in post-Fukushima Japan? Assessing the varying impacts of exogenous shocks. Energy Policy 73, 654–666.
Walrave, B., Raven, R., 2016. Modelling the dynamics of technological innovation systems. Res. Policy 45 (9), 1833–1844.
Walrave, B., Talmar, M., Podoynitsyna, K.S., Romme, A.G.L., Verbong, G.P.J., 2018. A multi-level perspective on innovation ecosystems for path-breaking innovation. Technol. Forecast. Soc. Change (Accepted/In press).

Weber, M., 1978. Economy and Society: An Outline of Interpretive Sociology. University of California Press, Berkeley.
Weimer, D.L., Vining, A.R., 2017. Policy Analysis: Concepts and Practice. Routledge, New York.
Wells, R.S., Kolek, E.A., Williams, E.A., Saunders, D.B., 2015. "How we know what we know": a systematic comparison of research methods employed in higher education journals, 1996-2000 v. 2006-2010. J. Higher Educ. 86 (2), 171–198.
Wernerfelt, B., 1984. A resource-based view of the firm. Strateg. Manage. J. 5 (2), 171–180.
Wesseling, J.H., Farla, J., Hekkert, M.P., 2015. Exploring car manufacturers' responses to technology-forcing regulation: the case of California's ZEV mandate. Environ. Innov. Soc. Transit. 16, 87–105.
Wittmayer, J.M., Schäpke, N., 2014. Action, research and participation: roles of researchers in sustainability transitions. Sustainability Sci. 9 (4), 483–496.
Wittmayer, J.M., Schäpke, N., van Steenbergen, F., Omann, I., 2014. Making sense of sustainability transitions locally. How action research contributes to addressing societal challenges. Crit. Policy Stud. 8 (4), 465–485.
Yuan, J., Xu, Y., Hu, Z., 2012. Delivering power system transition in China. Energy Policy 50, 751–772.
Zolfagharian, M., Romme, A.G.L., Walrave, B., 2018. Why, when, and how to combine system dynamics with other methods: towards an evidence-based framework. J. Simulation 12 (2), 1–17.