PATHWAYS project

Exploring transition pathways to sustainable, low carbon societies

Grant Agreement number 603942

Deliverable D4.3

Report reviewing the literature on policy and governance of sustainability transitions

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May 28, 2015

Executive summary

This deliverable (D4.3) provides a review of governance and policymaking in the three approaches used to study transitions in PATHWAYS: Quantitative systems modelling, Socio-technical studies, and Initiatives based learning. The aim is to build a synthesis of these governance approaches, to compare and contrast, and to use this analysis as basis for common understanding and integrative thread in PATHWAYS. While this deliverable primarily report on the literature review, Task 4.3 also include developing a joint governance framework that unites the three positions on governance of transitions approaches aiming to ease our integration work, a task that also contributes to the final deliverable D4.4. We have aimed at developing key insights and take the first steps toward this framework, but the core of the report is a review of the literature. The deliverable has been written by WP4 but actual reviewing and assessment of this literature engaged a range of experts form the whole PATHWAYS project in order to make this a collaborative effort and the intended vehicle of integration.

Findings call for more in depth discussions and treatment of governance across the approaches. Our findings show that there is much explicit and implicit agreement of what the challenges for governance of transitions entail. The commonalities with regard to core problem framing and dimensions that need to be considered is stronger than expected. That is surprising given that there is relatively strong variation for how each dimension of governance considered is analysed in practice. There is even (and perhaps a bit more surprising given the relatively small sample of articles reviewed) a lot of variation within approaches. We thus find that there is high potential to draw on the common agreements on the challenges, do develop joint empirical research with more explicit analysis of governance; especially for forward looking analysis. But this demand a truly integrative approach from start in research projects, and probably a narrower focus in domains or problems analyse. Part of the problem is that the role of analysis for transitions governance has a tendency to be either narrow and technical, or broad and ambiguous. It is hard to do both detailed analysis, yet be broadly relevant to the multi-scale problems of sustainability transitions.

The most practical suggestion that we find for future work is to try to develop an approach where a division of labour across the three approaches is organised. Each approach will drawn on for their respective potential, that are limited in itself, but together they provide complementary feasibility checks. The approach being developed in PATHWAYS for contrasting modelling results with case study analysis is a case in point. Our final lesson is that all approaches can benefit from developing case studies that go beyond explanations of current state of the art and that try to better link past assessments with understanding of forward momentum and governance challenges for given solutions.

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1 Introduction

1.1 <u>Purpose and structure</u>

The purpose of this document is to report on activities developed through task 4.3 in Work Package 4 of the PATHWAYS project ('Exploring transition pathways to sustainable, low carbon societies'). The overall aims of WP4 ('Integration and governance') are to develop the means for connecting and linking three perspectives on sustainability transitions; to develop ways of characterising the state of transition pathways; to assess the role of policy and governance in transitions, and to draw scientific conclusions about the nature and dynamics of transitions (and transition types) and their governability. WP4 also provides a structure for iterative collaboration and participation across the entire PATHWAYS project team. WP4 aims to contribute to a conceptual framework that provides a uniform understanding and terminology of policy and governance across the WPs, highlighting the areas for which each of the three research approaches contributes to the analysis of the role of policy and governance in the context of transitions.

Specifically, task 4.3 is concerned with developing an analytical framework for the role of policy and governance in different transition pathways, with the aim to build a synthesis of these governance approaches, and to use this common understanding as an integrative thread in PATHWAYS. Based on a mutual understanding and clarification of the perspectives on and approaches to governance and policy, WP4 will develop a framework on governance and policy that unites the three positions, eases our integration work, and that help advance our understanding of governance needed to realise the transitions studies in PATHWAYS. Our description of work specifically suggests that such a framework should:

(i)   articulate a common set of priorities for society,

(ii)   ensure that priorities and goals are coherent and arrived at through integrated policy-making processes,

(iii)   develop steering capacity towards these goals including design and implementation of policy instruments and other initiatives that change behaviour, and

(iv)   ensure accountability for governing actions, including monitoring efforts and transparent decision-making.

While we will aim for this review to primarily shed light on these four topics, this is a fairly conventional view on governance and policy making. In the last section we elaborate some on what could be added given the results of this review, and draw the contours of a revised framework.

1.2 <u>Goal with this literature review</u>

In this deliverable (D4.3) we contribute to this task by reviewing the literature on policy and governance of sustainability transitions in each of the three approaches. The aim is to put forward a set of recommendations for more integrated transitions analysis in PATHWAYS.

We first provide an overview of important dimensions of governance with regard to our overarching task to develop a governance framework supportive of such integrated analysis. (chapter 2). We then describe our method, showing how we develop an analytical framework to analyse the literature based on these dimensions, and how we selected literature to review (chapter 3). We then present results from our review (chapter 4). The remainder of this document discusses how these findings contribute to a joint understanding of policy making

and governance and how findings thus can ease potential barriers for scientific integration in our project (chapter 5). We draw on the conceptual work on governance challenges developed in PATHWAYS. We conclude with a set of recommendations for transition analysis (chapter 6).

1.3 General objectives and definitions (PATHWAYS approach)

The PATHWAYS concept aims to better understand transition pathways to sustainable, low carbon and resource-efficient societies and the related challenges. The PATHWAYS approach is to link three perspectives often used to study sustainability transitions: Quantitative systems modelling, Socio-technical studies, and Initiative-based learning. Between these approaches there has previously been relatively little interaction, but PATHWAYS aim is to use all three approaches to look at two fundamentally different categories of transitions with the same outcome of achieving sustainability goals: a pathway A that remains close to the existing socio-technical regime and is characterised by limited change to regulative, normative, and cognitive institutional elements, and a second pathway B with deeper change all these dimension.[1] The project does this with a broad analysis across five key domains (the power, buildings, transport, land use, and agro-food sectors) here transitions need to take place in order to reach European targets on sustainable development.

The three approaches considered provide complementary views on transitions and our two selected types of transition pathways. They share problem-driven objectives, but each provides their specific scientific outlook and adopts different conceptualisations of governance:

Quantitative systems modelling combines information on global environmental problems, their main causes and possible response options. The modelling assesses costs and benefits of different options in order to provide a comprehensive quantitative forward-looking macro picture of transition pathways towards sustainability targets. Quantitative systems modelling has typically little to say about the interests or motivations of actors and social groups involved in these transitions (Van Vuuren and Kok 2012, Van Vuuren et al 2011). However, in PATHWAYS we also include examples of agent based models that aim to capture such dynamics and bridge to knowledge form studies of socio-technical systems and transitions of such.

Socio-technical transition studies work at the meso-level, focusing on different social actors (industry, policy-makers, civil society, consumers, etc.) and the degree of alignment or tension in their beliefs, motivations, problem agendas and strategies. The multi-level perspective (MLP) has become a central framework to focus on structural factors, innovation processes, and the role of key actors (Geels and Schot 2007, Foxon et al 2012). While transition studies introduce more complexity in the description of social systems than Quantitative systems modells, it sacrifices the macro-level analysis of needed long-term dynamics in order to full fill a certain sustainability goal.

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[1] See project PATHWAYS deliverable D4.1 for elaboration on the definition of these pathways (including a baseline Pathway 0), and empirical deliverables for early discussion on the operationalisation of these in each approach (D1.1, D2.1, D3.1). These Pathways are an analytical construct of the PATHWAYS project and will be refined over the course of the project.

Initiative-based learning engages with concrete sustainability projects, and research is often conducted with participatory methods. In these projects, actors with different views and motivations need to align technological opportunities, consumer preferences, infrastructure requirements, and policy frameworks into working configurations. Initiative-based analyses reveal the complexity and uncertainty of transitions in the making (Rave et al., 2008). Case study approaches, such as participatory action research, however, often lack a broader understanding of how experiments and niches influence and change regimes or the broader contexts (as provided by other approaches).

Within WP4, we explore and mobilise opportunities for greater integration between these three approaches. We do this by coupling of methods and tools from each approach, in order to create an integrated, multi-scale and transdisciplinary chain of analysis (see task 4.1). This is an iterative process, ongoing throughout the project's lifetime, with regular opportunities for evaluation and improvement. In addition, tasks 4.2 and 4.3 focus on specific cross-cutting aspects ('integrative threads') of relevance to transition pathways: representations and governance, respectively. This deliverable focusses on and reports on the latter task.

1.4   Rationale for a common understanding of policy and governance aspects

Each approach has a different outlook on and proposes different ways to deal with policy and the governance of transition pathways and the purpose of this task is to elaborate on this to move toward a common and integrated understanding.

A key starting point for this analysis is that with respect to informing decision-making, the different approaches to sustainability transitions emphasise specific aspects of transitions but neglect others. *Quantitative systems modelling* efforts have accumulated sophisticated means of exploring future techno-economic options to assist decision-making in relation to long-term policy targets, but with only limited consideration of difficulties related to socio-technical inertia and the practical realisation of deliberate strategic intentions in a real-world context. *Socio-technical transition analyses* have accumulated insights from historical regime transformations that can inform and focus current transition efforts through knowledge of process and trajectory of development, with only limited ability to formulate stylised future projections and to consider the constraints of deliberative governance. *Initiative-based learning* has accumulated considerable insights about local alternatives addressing long-term societal concerns and related sources of failure (e.g., resistance) or success (e.g., legitimation), with only limited attention to interactions with (established or emergent) regime trajectories and limited ability to generate representation of their impact at aggregate levels.

It is hence important to arrive at an understanding of roles and challenges related to governance and policy of transition pathways in different approaches, as well as to develop a common framework that links existing positions.

As an initial step in this direction, this document reports a literature review of governance and policy considerations across the three approaches mobilised in PATHWAYS. We seek to identify governance and policy assumptions inherent to each approach.

1.5   Linkages with overall project structure and related tasks

Task 4.3 is formulated as an 'integrative thread' that runs throughout the project. This means that successive activities and deliverables engage with issues of governance and policy at their own level, enabling and enabled by an ongoing 'meta' reflection on these topics at project level. These processes are both complementary and cumulative.

At WP4 level, a dedicated task force that runs throughout the project lifetime leads the reflection on governance and policy. It is tasked with delivering D4.3 (this literature review), structuring governance and policy workshops, contributing to a PATHWAYS framework for governance and policy, and in this way providing input for the comparative analysis of transition governance in the final deliverable D4.4 of the work package.

2 Governance and policy: general principles

As the purpose of this deliverable is to review how governance is treated and defined in the three approaches, providing a more precise up-front definition risks constraining this analysis. Therefore we will start with only a general framing of governance, before going to the key dimensions for our review and analysis.

Governance in its broadest sense regards coordination of state and society toward collective interest (Pierre and Peters, 2005, p. 6). Achieving sustainability requires fundamental transformations and thus ambitious governance actively steering these processes. It is to be expected that both traditional governmental steering through policies and central decision-making processes, but also novel approaches mobilising governance by non-state actors and new kinds of interventions in social, economic and technological processes is needed. Hence, PATHWAYS is interested in how different analytical perspectives on transitions view policy, steering and governance.

The notion of governance has emerged in past decades as a means to capture changing realities in decision-making and steering contexts, new theoretical thinking, and normative positioning as to the more effective and legitimate forms of intervention (Rosenau and Czempiel 1992; Jordan 2008). For example, governance is general associated with a notion of a changed role of the state, and a need for a broader view of steering (Treib et al, 2007). A number of real-world developments over past decades underpin the shifting focus from government to governance including, i) the gradual de-legitimation of top-down, hierarchical decision-making modes in favour of a greater role for new actors and arrangements (NGOs, industry associations, citizens movements, etc), ii) a diversification of forms and routes to influence public life, including new (policy) instruments, new styles and approaches (e.g., in context of the European union it is often highlighted how bottom up initiatives can influence EU, bypassing the member nation states), iii) the emergence of new societal issues and 'wicked problems' (notably, sustainability). Traditional policy styles, instruments, and agencies still have relevance, but the overall messages is that new fundamental challenges such as sustainability transitions generate substantial governance challenges, which warrant revisiting common assumptions for steering and decision-making and more in depth analysis of the role of political actors and how governance take place.

This chapter now introduces and provides elements to address the key research questions with regard to reviewing governance in our three approaches to transitions:

- What are the analytical dimensions of interest to explore different assumptions and perspectives in relation to the steering of sustainability transitions? (I.e., what are the important elements, processes, mechanisms, etc.)

Following on this, chapter three will outline how we conduct this analysis, that is:

- What is the method for examining the assumptions on governance in the three approaches? (I.e., what is the 'comparative' review strategy)

2.1 <u>Key dimensions</u>

Acknowledging the importance of steering and decision-making for sustainability transitions, we examine the three approaches in search of their underlying assumptions and focus. That is, we want to establish a framework that elaborates each approach's conceptualisation of governance over a set of dimensions that capture the key social mechanisms of relevance. Drawing on Jordan (2008) and Treib et al (2007), we primarily mobilise the following three dimensions: 1) actors and networks, 2) processes, modes and approaches, 3) types of desired

objectives, outcomes. The third dimension, related to objectives, is essentially normative that reflect ideas, belief systems and world views, but this is of relevance to understand and influence transition dynamics towards the desirable directions set out by the EU that motivate the PATHWAYS project. We also expand on this and also include more explicit a reflexive dimension (Loorbach, 2010) capturing adaptive capacity of actors involved in governance of transitions (Sterling et al, 2005).

These considerations and theoretical starting points lead us to formulate the following analytical questions on how governance is conceptualised in each research perspective on transitions:

- Who is (perceived to be) intervening in decision-making for and around sustainability transitions, with whom, with which mandate, etc.? This includes also understanding of what actors across different scales (local, national, EU etc) that are considered involved in governance.

- Which processes and forms of interventions (including policy instruments) are put forward as effective and legitimate?

- What kinds of objectives, outcomes and evaluation criteria are most useful for sustainability transition governance?

Finally, the reflexive dimension aims to provide information on how transitions are evaluated and the learning in real-world decision-making contexts.

- How is transitions governance evaluated? How will we know when we are on target or missing it?

2.2 Actors and networks

This category encompasses the 'whos' of policy and governance, including actors and organisations and the formation of actor constellations in networks of interdependent actors (Treib et al, 2007; Smith et al, 2005). The relationships and the agency they have that contribute to decision-making and influencing societal practices and processes is at focus. The boundaries defining who matters and who is relevant is a matter for observation, interpretation and debate: different actors considered to be intervening in and influencing societal processes will depend on the geographical and/or jurisdictional scale of analysis, but also more fundamental criteria such as inclusiveness, participation and democracy.

The policy analysis literature as well as the econometric and political economy literature has traditionally been interested in decision-making and steering within the boundaries of the state and government. This tradition sees policy-makers as the main agents of steering, their action legitimised by the regular renewal of mandates through the election of individual representatives (politics), and underpinned by the historical extension of state authority over a number of areas of public and private life (policy and administration). The (national) state has progressively evolved to extend the scope of its core activities and responsibilities towards its citizens, from the provision of territorial security, economic security, infrastructure, to welfare in the twentieth century, and more recently environmental protection and preservation (Dryzek, etc.). Within this narrative, 'the state' tends to be seen as a comprehensive apparatus of control over public life and steering for the public good, through the formulation of strategies and their implementation. This state centric view of policy has quite limited examination of alternative forms of governance, besides hierarchical forms of control and power through regulation (Piere and Peters, 2005; Bache and Flinders, 2004). Steering is mainly seen as a top-down activity: policymakers make decisions and impose them on citizens, companies, etc. through the implementation and enforcement of policies.

The public organisation and management literature, starting from a 'government' focus looks inside the formal organisation of governments and public agencies, with an interest at their inner workings and processes. Topics of relevance include organisational structures, the distribution of competences and responsibilities (at different levels), and the operation of decision-making processes. National innovation policies and environmental policies, for instance, may fall under different ministries depending on countries and periods examined, and are increasingly seen as crosscutting issues warranting their own ministerial structure and the ability to strategically mobilise relevant governmental areas (e.g., energy, transport, infrastructure, agriculture, etc.). 'Public' organisations exist and operate at different levels (local, regional, national, and transnational) with varying responsibilities (e.g., European 'subsidiarity' notion), and according to functional divisions often spanning multiple bodies and agencies (e.g., goal-setting, policy formulation and implementation, monitoring and enforcement, evaluation, etc.). Looking into the workings of public organisations allows for fine-grained understanding of the policymakers 'doing the policymaking' within (formal) structures, and across vertical and horizontal boundaries – including an understanding of the failures and successes of policy action. Steering is seen as enabled and constrained by interconnected public organisations and their dynamics.

The *governance* literature within political science, economics, sociology, geography and history has erected itself against state centric (Pierre and Peters, 2006) representations of policymaking as solely enacted by state actors through hierarchical forms of influence:

> "governance is not the same as government: while government centres on the institutions and actions of the state, the term governance allows nonstate actors such as businesses and nongovernmental organisations to be brought into any analysis of societal steering" (Jordan 2008:21)

In terms of the agents of steering, governance perspectives enlarge discussions through the recognition of legitimated authority beyond state actors and includes multiple centres of authority and decision-making (cf. 'multi-actor governance' and constellations, e.g. Newell et al 2012; Hooghe and Marks, 2001; Schout and Jordan, 2005), an emphasis on networks at different levels (inter- or intra-organisational) in structuring relations and interdependences between actors beyond strict hierarchies (e.g. international arenas, sectorial domains, organisational fields, multi-level governance, etc.), and an interest in processes of governing (rather than structures), the agency of actors and the new practices that emerge, their messiness, and the challenges this creates for navigating, steering, or resisting change in contemporary realities (van Kersbergen and van Waarden 2004).

Regarding environmental issues and sustainability transitions, it becomes possible to focus on the role of industry actors, civil society, social movements, municipal and regional networks, consumers, and so on in "the direct governance of global environmental issues" (Bulkeley and Schroeder 2012:745) – whether individually or collectively through networks, partnerships, alliances and other hybrid arrangements. State and nonstate actors alike may resist change and contribute to the inertia and lock-in of existing configurations, while they may also become important actors of change, leading or facilitating transition efforts. Nonstate actors as involved in collective decision-making processes through a variety of roles, as 'stakeholders' in consultation processes, in active partnerships, through knowledge and evidence provision, through lobbying and political bargaining, interest representation, advocacy, whistle-blowing, etc., but also making direct impact on the ground via (sustainability) project, initiatives and experimentation. Initiatives spearheaded by private companies or non-profit associations may generate positive change through example and engagement with alternatives on the ground. The sheer size of customer bases of large companies makes them powerful agents of change, whose decisions have a major downstream impact, for instance. A governance perspective sees the role of actors as context-

dependent and evolving through the process of governing and the coalescence of actors around new issues and problems (Bulkeley and Schroeder 2012).

2.3 Policy processes and governance modes and instruments

This category encompasses the 'hows' of policy and governance, including processes, modes, and 'tools' that contribute to decision-making and influencing societal processes. Ultimately, we seek answers about how transition pathways are (or will be) implemented.

Policy and governance is sometimes treated as a black box according to simplistic models where policymakers (in terms of elected politicians and officials) are seen to come up with regulations and policies in response to (new) problems. Policymaking is mostly treated in such a way because of an interest in *outcomes* and comparatively little attention to *processes* and the difference between the two (Nilsson et al 2012a). For example, a whole set of literatures interested in environmental problems and solutions (e.g., environmental economics, environmental policy, etc.) looks to policymakers in search for practical 'tools': environmental policy instruments. These are inscribed in narratives of negative externalities and economic failures, and implicitly refer to the role of policy as one of generating boundaries to economic activity and correcting undesirable behaviour. The knowledge base on environmental instruments is thus well developed. A common distinction exists between regulatory, market-based and 'soft' or voluntary instruments (Jordan et al, 2005). Rather technical discussions can relate to the choice and design of instrument according to problem type and desired corrective outcome, with instruments commonly evaluated in terms of cost-effectiveness and efficiency (Sterner, 2003). Policy implementation considerations tend to be framed in terms of obstacles and barriers, and policy evaluation is linked to quantifiable performance metrics, for example in the literature on socio technical systems (e.g., Nykvist and Whitmarsh, 2009, and Techology Innovaitons Systems literature literature (e.g., Bergek et al, 2008). This in turn draw on the lessons from institutional theory (Scott, 2001; March and Olsen, 1989, Burns and Flam, 1987) focuses on formal and informal rules as constraining and enabling the agency of actors and so their influence on the social and material world. Rules (regulatory, normative, cultural-cognitive) provide structure and a frame for action. Policy interventions is thus primarily seen as effective and sufficient means of control over social and economic activity, in a rather top-down fashion, and focuses mainly on steering measures and tools ('technologies of government') that impose constraints on the performance of social systems via their outcomes and comparatively little focus on processes.

The governance literature suggests extending the scope of research beyond this focus on barriers and instruments:

> "there is a danger that research on governance and/for sustainable development ends up being a rather dry and technocratic exercise in counting and cataloguing different governing instruments or (in a more normative vein) trying to identify the right governing tool for the job." (Jordan 2008:30)

The governance literature emphasises the messiness of decision-making and steering. Based on a distinction inherited from policy instrument typologies, three main modes of governance are often identified: hierarchies, markets, networks (Treib et al, 2007, Jordan 2008; Nilsson et al, 2012) – drawing on, e.g., earlier work on governance and politics of co-ordination (Peters, 1998; Scharpf, 1993) – that provide frames to explain the influence of non-governmental agencies on socio-political processes. Each mode comes with their implications on the relative powers of actor groups in coordination (Peters, 1998) and the arrangement used has implications on which actors that are legitimized and exercise power. In summary, we draw on these developments and developments in the policy and governance literature, and include

in our review both a) the types of co-ordination and steering, as central or decentralised processes, and, b) the types of instruments separately. Furthermore, we include an explicit dimension tracking how quality of governance is captured.

2.4   Objectives and rationales for sustainability transition governance

This category encompasses the 'whats' and 'whys' of policy and governance, including the objectives and goals of, and the rationales behind steering and intervention strategies Jordan (2008). What is to be steered is the central question and we want to understand how each set of literature defines and discusses what the object of steering is, i.e., we want to understand if steering is viewed as:

- Steering for environmental performance and certain impacts

- Steering for sustainable development more broadly over multiple dimensions, also putting environment it in context of other priorities of actors

- Steering innovation dynamic, e.g., preference to solve sustainability challenges by technology innovation

- Steering as focused on systems change and regimes, and steering of radical transformation

The introduction of new governing objectives and programmes (such as transition governance) has to take existing institutional and political systems in consideration, as well as its prevailing dynamics and inertia. Understanding the dynamics of the change process (e.g., due to institutional inertia) is thus very important. While Jordan (2008) includes evaluation in the objectives dimension, scholars studying the governance of sustainable socio-technical transitions have argued that adaptive capacity calls for particular consideration (Smith et al, 2005). We choose to have a separate dimension for understanding reflexivity and evaluation.

2.5   Reflexivity and evaluation

The fourth analytical dimension deals with real-world interactions between governance as conceptualised in the three approaches and progress achieved towards stated transitions and governance objectives (Smith et al, 2005). The central question in this dimension is 'How are interactions with the real-world taken into account? And how is governance evaluated and adapted?'. The aim is to explore the reflective and adaptive character of governance (Loorbach, 2010), including evaluating of the stated objective with the transition, as well as evaluations in terms of performance on policy instruments and interventions toward the long-terms goals of governance The importance of evaluation is also discussed by transitions scholars Loorbach and Rotmans (2010) reviewing a range of transition case studies. Our review operationalise this with a focus in the review on discussions of evaluation, feedback and iterative learning as these are inherent aspects to more adaptive (Folke et al, 2005) and forward looking forms of governance (Boyd et al, 2015). What specific evaluation criteria are used, if any, e.g., environmental performance according to transition objectives? The reflective part of our review gives room to highlight how the approaches understand governance in relation to real-world changes and the interaction between science and policy.

3   Review methodology

3.1   Review framework

The main core part of the review is conducted by translating the above discussion of key dimensions of governance into an analytical framework that can support a more systematic and comparative analysis of the governance assumptions inherent in each approach. The governance dimensions presented in chapter 2 are thus now used as analytical dimensions in a review framework, operationalized as questions to be assessed in each review. Table 1 presents the framework. Column 1 includes the main analytical dimensions and what is at stake elaborated briefly on in the form of broad questions, and column 3 gives the more specific questions to be assessed. Each paper reviewed was assessed according to the same analytical framework.

Table 1: Analytical grid for the evaluation of governance assumptions

Analytical dimensions	#	Assessment questions
Objectives (of What? and Why?) What are the objectives of steering and intervention strategies? How are problems and transition challenges defined?	O1	Is the **objective of the transition** defined? What is the main phenomenon to be governed? Are there concrete goals or visions?
	O2	At **what scale** is the sustainability problem defined? (e.g., local or global challenge)
	O3	Is the transition a **broader** societal transformation or limited to one dimension (e.g. technology)? (cf. Pathways A and B)
Actors (Who?) Which types of governance actors (e.g., both public, private actors) and networks considered in the approach to transitions?	A1	Who is viewed as **actors governing** the transitions studied?
	A2	At what **scales**? Who are referred to, at local, national and international levels?
	A3	What is the role of **networks** and **alliances**? What brings actors together in processes of change?
Processes (How?) How does the steering of transitions take place? What is desirable? What **instruments and interventions** are used in steering the transition?	P1	**Mode of governance:** a process of central steering from the state, or power and responsibility discussed as shared?
	P2	Is there a definition of **good governance**, i.e., is quality discussed? (e.g., feasibility, effectiveness, transparency, inclusiveness, acceptability, legitimacy, etc.)
	P3	**Types** of instruments/interventions (e.g. regulations, market-based, information-based, etc)
	P4	What is the motivation and theoretical rationale behind the proposed form of instruments/intervention?
Evaluation How is transitions governance evaluated? How will we know when we are on target or missing it?	E1	Are there means / indicators suggested for **evaluating success of instruments/ interventions**? (e.g. feasibility, effectiveness, transparency, inclusiveness, acceptability, legitimacy, etc.)
	E2	Does the understanding of governance enable adjustments to real-world changes (social, political ecological, technological, etc.) over time? (e.g., a process of iteration or feedback)
	E3	Are there stated means of evaluation against long-term objective of the transition?

3.2 Governance challenges explored

The goal of this deliverable is not only to establish a literature review on governance in the three approaches, but also to pave the way to a common governance framework facilitating integration in PATHWAYS. In order to achieve this we included a second part of the review where each reviewer was asked to reflect on respective papers added value to explain five main governance challenges for transitions as outlined by initial work in PATHWAYS (Turnheim et al., unpublished manuscript). These are the challenges of dealing with:

1) multiple scales and temporalities
2) uncertainties associated with radical innovation and limits of prediction
3) the interplay between inertia and emergence of novelty
4) governing innovation in relation to a public good
5) contested perspectives on the governance of complex processes of social economic and technological change.

The five challenges have several themes in common with the review framework, but this section of the review was added in order for each reviewer to not only be limited to the synthesis papers according to the review framework. This gave each review(er) the possibility to reflect on core governance challenges in PATHWAYS, and thereby contributing to the development of our common governance framework.

3.3 Literature selection

In order to cover three rather broad sets of literatures that each host a wide variety of positions and interpretations, the literature selection was guided three main criteria: 1) relevance, 2) novelty, and 3) pragmatism.

We aimed to include contributions that actively mobilise and contribute to the governance of transitions pathways in one form or another. We started from an initial set of articles identified in the development of the PATHWAYS project proposal and concept developed in the inception phase of the project (Deliverable D1.1, D2.1), and then mobilized those contributions that focused on key debates of interest to our on-going integration work (Turnheim et al, Unpublished Manuscript).

This initial selection was extended as the task developed, building on the expert knowledge from the consortium, drawing on a project workshop, consultations with project partners and relevant tasks and deliverables. From this extended set of sources, we identified further literature by 'snowballing' method, picking up relevant sources from each paper.

The result was an extensive set of literature, which we narrowed down to a core set of papers, according to experts from each field involved in the project to keep the task manageable. In order to maximise the richness and diversity in such a small sample, we were guided by the need to minimise duplication and we thus did not include papers of high similarity.

We ended up with a set of 40 papers, spread out over the three main methodological approaches. However, there are a number of overlaps as many contributions discuss and bridge several of the approaches. This shows that the perspective-classification is to some extent arbitrary and this is discussed in section 5. Furthermore – and this perhaps reflects as much our interests (as formulated in the project's objectives) as the state of governance debates within the various fields – we ended up with a larger proportion of papers that fell within the category of socio-technical analysis.

Finally, the review effort was conducted collectively in the project to enrich the integration that the underlying task 4.3 is intended to foster. Each researcher involved in the task was

thus allocated between 2-5 papers and submitted reviews in the same format. Table 2 presents an overview of the selection of paper, according to their positioning with respect to the three perspectives considered.

Table 2: Overview of literature selection

Paper	Main focus	Quantitative systems modelling	Socio-technical analysis	Initiative-based learning	Central integration components
Eom et al (2015)	IAM	x			
Hamilton et al 2015	IAM	x			
Holman et al. (2005)	Scenario with stakeholder input	x			
Moss et al. (2010)	Scenario analysis using IAM	x			
Nilsson et al. (2011)	Senarios, backcasting	x	x		
Staub-Kaminski et al (2014)	IAM, review, methods	x			
Söderholm et al. (2011)	Scenarios, both qualitative and quantitative	x	x		x
van Asselt et al. (1996)	IAM	x			
van Vuuren et al. (2012)	IAM and scenario studies	x			
Foxon et al. (2013)	MLP		x		
Geels (2011)	MLP		x		
Hillman et al. (2011)	MLP and TIS		x		
Hughes et al. (2013)	MLP and scenarios	x	x		x
Jørgensen (2012)	MLP		x		
Lawhon and Murphy (2012)	MLP, geography, political ecology		x	x	x
Loorbach and Rotmans (2010)	Strategic niche management		x	x	
Meadowcroft (2009)	Transition management, MLP		x	x	
Nilsson et al. (2012)	MLP and TIS		x		
Smith (2006)	Strategic niche management		x	x	
Smith and Kern (2009)	Transition management & forward looking storylines		x		
Smith and Raven (2012)	Strategic niche management, TIS, etc		x		
Smith, Voß, Grin (2010)	MLP		x		
Späth and Rohracher (2010)	MLP, Multi-level governance	x	x		
Truffer et al. (2008)	MLP and scenarios		x		
Tukker and Butter (2007)	Transition management		x		
van Bree et al. (2010)	MLP and scenarios		x		x
Betsill and Bulkeley (2006)	Multi-level governance			x	
Cuthill and Fien (2005)	Community empowerment			x	
Fois and Forino (2014)	Community resilience			x	
Fressoli et al. (2015)	Local initiatives and MLP		x	x	
Hodson and Marvin (2010)	MLP at city-scale and local initiatives		x	x	x
Loorbach (2010)	Transition management		x	x	
Ornetzeder and Rohracher (2013)	Grassroots innovation			x	
Seyfang and Smith (2007)	Innovation, community action			x	
Seyfang et al. (2014)	Strategic niche management		x	x	
Shove and Walker (2010)	practice theory			x	
Spaargaren (2011)	practice theory			x	
Smith et al (2005)	Socio-technical transitions, governance, agency, power		x	x	x
Rogge and Reichardt (2015)	Governance and transitions				x

4   Literature review and analysis

In this section, we report the results from the literature review. We first review the different aspects of governance for each analytical approach following the questions in our analytical grid. We then exploring similarities and differences and identify some areas for exploitation of complementarities.

4.1   Quantitative systems modelling

Objectives (of What? and Why?)
Empirical quantitative systems modelling studies apprehend prospective transitions by modelling economic activity, technological developments and land use changes towards specific system performance goals. These goals are often explicit system performance indicators, e.g. specific lower emissions, CO_2 concentrations or intactness or naturalness of various land uses (e.g., Eom et al, 2015) that are mobilised as the endpoint of system changes and as describing specific pathways of change. This is the strength of quantitative modelling, that they can stake clear and quantifiable transitions objectives.

More methodologically focused papers do not necessarily formulate explicit goals (Staub-Kaminsky et al, 2014; van Asselt et al, 1996) but instead prefer to develop general principles for forecasting and back casting techno-economic change. Regardless of their specific inclination, contributions to this tradition make projections of technological and economic change in order to support transition efforts or explore their implications. The relationship to policy objectives can be qualified as one of *translation* from global targets to system constraints.

The sustainability transitions objectives considered tend to be approached from a fairly *macro* scale. For instance, formal modelling tools in Integrated Assessment Modelling (IAMs) take the global scale as their main focus. Global models are, however, often regionalized diving the world in regions based on geographical or ecological boundaries, or implemented with a given horizontal and vertical grid resolution (e.g, in the case of General Circulation Models). Detailed impact assessment modelling spans all scales (e.g., Hamilton et al, 2015) and methodologies such as back-casting are equally often applied on national scales in climate energy modelling to make closer connections to policy systems (see discussion in Nilsson, 2011).

The scope of transitions pathways considered by quantitative systems modelling is clearly limited by its focus on Quantitative systems modelling strategies (Eom et al, 2015). However, broader societal transformations are also typically discussed (Moss et al, 2010; van Asselt et al, 1996), but the details of how the different types of change that underpin such transformations are usually not discussed in detail (Hamilton et al. 2015; van Vuuren, 2015).

So, quantitative systems modelling have a relatively clear formulation of sustainability transitions objectives as the literal *translation* of general sustainability objectives (e.g., CO_2 emission mitigation, biodiversity, food production) into 'hard' constraints for system developments (e.g. emission allowances). In other words, *policy objectives are taken seriously*, and (alternative) transitions pathways are formulated to explore how (or whether) these can be met. Such an approach is crucial to questioning the techno-economic feasibility of policy objectives, and to evaluating progression towards such goals. It should further be mentioned that these type of modelling approaches indeed have been rather successful in interaction with and influencing of policy makers for both ex ante and ex post policy evaluation (REF?).

Actors (Who?)

Quantitative systems modelling studies carry a relatively monolithic consideration of governance, focusing on governments and their policymakers as the central actors setting policy objectives. This simplification is mainly due to methodological imperatives and limitations of model representations with regard to social dimensions of analysis, as typical governance actors might not be mentioned at all (Moss et al, 2010). However, it is also surprisingly often the case that in scenario-storylines actors other than policymakers are discussed or recognised as relevant to transitions processes. Storylines provide a narrative, a logic for the assumptions that need to be made to run the model and define possible developments in areas where formal modelling is not (yet) possible (van Vuuren et al, 2012; van Asselt et al, 1996; Söderholm, 2011; Iris et al, 2014; Holman et al, 2005). Furthermore, there is an increasing tendency for the inclusion of a broad range of actors such as business, consumers, and decision makers in model parameterisations (Holman et al., 2005), albeit superficially and/or implicitly, through alternative scenario-storylines.

Within its predominantly policy-oriented understanding of governance, quantitative systems modelling considers decision-making and goal setting in relation to the scale of relevance to the modelling exercise, itself attuned to the problem at hand. For instance, modelling focused on climate change mitigation tends to adopt a global and/or national scale perspective on policy objectives (Nilsson et al, 2011; van Vuuren 2012), whereas climate change adaptation modelling tends to adopt a more local or sectoral focus (Holman et al, 2005).

Quite unsurprisingly, the relatively broad granularity of modelling strategies with respect to governance actors sets limits on the consideration of actor configurations. Consequently, the dynamics of social networks and political alliances are not usually considered in quantitative systems modelling. Discussions of interactions between different stakeholders can, however, be included (Holman et al., 2005).

Finally, agent based modelling, aimed at more explicit representations of actors interactions take a different approach to systems modelling (e.g., Köhler et al, 2009). However, there are few models that are large scale and thus directly comparable with IAM, and the integration of different types of systems models is yet to be developed. De Vos et al. (2013) have argued, however, that integration of governance in IAMs maybe one bridge to far.

Processes (How?)

Modes of governance are seldom discussed explicitly within quantitative systems modelling, but central steering (Eom et al, 2015; van Vuuren, 2012), first-best economic and market-based (Staub-Kamonski, 2014) views on governance tend to dominate. Staub-Kamonski (2014) provides a useful critique of 'first-best approaches and alternative way for modelling to do better justice to transition-dynamics. Papers aiming at broadening the perspective on governance and the role of institutions in modelling such as also provided by Nilsson et al (2011) remain exceptions.

Modelling papers very seldom discuss normative criteria for 'good governance', which is quite expected from an approach that does not seek to unpack governance more generally. Exceptions can be found in those papers that extend the focus of modelling beyond its traditional boundaries, e.g., exploring governance and institutions in modelling (Nilsson et al, 2011

Types of instruments to use is seldom outlined in detail, but broadly discussed (Staub-Kaminsky, 2014; van Vuuren et al, 2012; Hamilton et al, 2015). Climate modelling focus on market-based solutions such as taxation or cap and trade (e.g., Eom et al, 2015) and the motivation and rationale behind a certain proposed instruments or interventions is often derived from theoretical knowledge of a given instrument (e.g., Eom et al, 2015; Satub-

Kaminsky et al, 2014). Furthermore, a number of efforts bridging between quantitative systems modelling and socio-technical analysis have developed more refined understanding of modes of governance as underpinning specific transitions pathways (Nilsson et al 2011, Foxon, 2013).

Evaluation

Quantitative systems modelling do not specifically formulate success criteria for transitions governance and related interventions. However, some authors discussing the desirability of iterative approaches and interlinkages between stakeholders and modelling (e.g., Hamilton et al, 2015; Holman et al, 2005). Quantitative systems modes are also quite commonly used for ex ante policy evaluation in particular (Nilsson et al, 2008).

4.2   Socio-technical transition analysis

Objectives (of What? and Why?)

Within socio-technical analysis, the objectives of transitions are most often spelled out specifically as urgently needed radical transformations to address societal problems, with a clear focus on the most prominent sustainability challenges of energy, transport, land use and food sectors. This is a quite normative framing, and often motivated by refereeing to policy targets. However, there is also an implicit tendency to focus mainly on the environmental aspects of sustainability. Some papers are more theoretical or more generic on transitions (e.g., Geels, 2002; 2004; Tukker and Butter, 2007; Loorbach and Rotmans, 2010).

Socio-technical analyses of transitions span multiple scales, and in fact, many studies do not actually address scale upfront, viewing the approach as scale-invariant (Smith et al, 2010). The Multi-Level Perspective (MLP) on transitions (Geels, 2002; 2004) has been criticised for this lack of considerations to geography of transitions (Coenen et al, 2012; Coenen, Truffer, 2012). However, its scale-invariant nature – attending instead to different levels of 'structuration' – can also be seen as a strength in that it can be applied at many scales, or across scales (Geels, 2011) to fit the specific analytical purpose. Having said this, empirical transition studies tend to be applied at specific scale. Strategic niche management, for instance, is most often local in character, while MLP studies have a tendency to focus on the national scale through its focus on landscape developments, the dominant regime(s) and niche innovations trying to break through 'from below'. Few empirical studies attend explicitly to the multi-scalarity of transitions, but this is changing with a recent 'geographical turn' in transitions studies (Coenen et al 2012, Markard et al 2012).

In terms of scope, socio-technical analyses have at heart a highly multi-dimensional understanding of transitions, including change on technological, social, cultural, and policy dimensions. Transitions are seen as re-configurations of elements along these different dimensions through processes of alignment. However, in practice, many empirical papers in our selection adopt a more limited focus on technological change (van Bree, 2010; Tukker and Butter, 2007; Truffer et al, 2008; Späth and Rochracher, 2012). It should be noted that MLP theory is clear on including a broad range of dimensions to understand transitions (Geels, 2004; Geels and Schot, 2012).

Actors (Who?)

Socio-technical analysis views transitions as governed by multiple sets of actors, reflecting a refined understanding of the relationship between agency and structure in this literature. This is a key strength of socio-technical analysis, that its focus on actors and actor configurations in the governance of transitions. Transitions are seen as shaped by multiple actors in different

dimensions, including entrepreneurs, businesses and corporations, policymakers, consumers, citizens, normative activists. These actors can be both agents of change and agents of stability, resisting change via different forms of power and influence. When analysing governance aspects more specifically, some authors focus more on policy makers and traditional state centric steering of transitions (Meadowcroft, 2009; Smith and Kern, 2009; van Bree, 2010), while others adopt a broader focus on governance arrangements, etc. (Nilsson et al, 2012, refs.).

When considering specific actors of change in transitions, theoretical contributions to socio-technical analyses range from being scale-invariant, discussing governance generically, to covering multiple scales, reflecting a broad approach or theoretical contributions. Many empirical studies, in practice, focus on the national level (Foxon et al, 2013; Smith 2006; Smith and Kern, 2009) or the local level (van Bree, 2010; Späth and Rochracher, 2012).

The consideration of the role of networks to the governance of transitions is rather ambiguous in this literature. In some papers the negotiation and development of shared understandings in networks is a core aspect of governance processes (Foxon et al, 2013; Jörgensen, 2012; Loorbach and Rotmans, 2010; Smith and Kern, 2012). Another common framing is to view networks as primarily sharing knowledge, contributing to innovation and niche formation (Nilsson et al, 2012; Hillman et al, 2011; Geels, 2011). The latter reflect strands of research that focuses primarily on technological innovation. In summary it is critical for our common governance framework to be developed in PATHWAYS to describe what networked forms of governance are considered to entail.

Processes (How?)
The mode of governance put forward in socio-technical analyses reflects its consideration of multiple actors. Most studies consider forms of governance where steering capacity is spread over multiple actors (e.g., Hillman et al, 2012), and studies attending to the particulars of the politics of transitions tend to adopt an even more pluralistic focus on actors, their participation and representation. A more traditional state-centric focus on national policymakers exists (van Bree, 2010) but is uncommon, and in general the role of the state is seen as that of a facilitator (Meadowcroft, 2009; Nilsson et al 2012b).

Studies applying socio-technical transitions approaches sometimes include explicit discussions on some aspects of good governance (e.g., Späth, Rohracher, 2012; Hillman, 2011). However, lack of discussion is more common, and it is also common that good governance is somewhat conflated with successful transition towards a certain normative goal (e.g., successful energy transition, Loorbach Rotmans, Smit et al, 2010). It should be mentioned that a common framing in the literature is to refrain from explicit normative considerations, but instead unpacking the different normative positions of different actors and in this way treats notions of legitimacy, acceptability, feasibility of change part of the analysis of the dynamics of change in the socio-technical system.

Generally, there is an implicit assumption in socio-technical analysis that traditional policy instruments (e.g. market-based incentives, regulations, voluntary measures) do not attend to the complexity of transitions processes and instead tend to encourage the status quo. With respect to the types of interventions, instruments, and measures recommended for the governance of transitions, socio-technical analysis tends to focus on the governance of specific processes and mechanisms that contribute to shaping transitions. For instance, there is a generic focus on the need to encourage radical innovation and to provide support to emergent configurations in protected spaces (niches) (Smith and Raven, 2012). Fostering niche development (Hillman et al, 2011) is clear in the literature, but not all studies in this strand of research go into detail in discussing what tools and instruments are to be used.

Tools are thus mostly discussed as a need for broad range of measures, acting on all fronts in the system (e.g., Loorbach Rotmans, 2010; Nilsson et al 2012).

It is not possible to distil a clear pattern of the rationale or motivation behind instruments in the socio-technical analysis approach. The breadth of interventions and approaches, and the pluralistic nature of framings in the included literature that covers both transition management, MLP, and critiques of these expanding the scope, makes it difficult to answer this. The reason for this plurality and ambiguity is, however, that the literature generally do not assume that certain instruments will work mechanically. Instead, one should focus on the fostering the conditions that are conducive to change, that enables protective spaces and provides momentum (Geels and Schot, 2007, Smith and Raven, 2012).The emphasis is on long-term developments and attendance to multiple dimensions that foster the conditions for change.

Evaluation

The socio-technical analysis contributions reviewed here do not discuss explicitly how transitions efforts can be evaluated. This may be quite expected, given that this literature tends to refrain from making bold and specific policy advice. It is also telling of a literature that has only recently been taken seriously in high-level decision-making arenas. Developing strong means for evaluation is, however, crucial to greater consistency and robustness of transitions governance. Loorbach and Rotmans (2010) suggest that learning and follow-up on transition measures is crucial to the diffusion and up-scaling of transitions.

Many authors highlight that transitions governance needs to integrate the ability for adjusting to changes over time (Jörgensen, 2012; Truffer et al., 2008; Smith et al 2010; Smith Kern, 2009; Meadowcroft, 2009; Lawhorn and Murphy, 2011; Hillman et al, 2011). It is thus noteworthy that while the means of transitions evaluations are not clearly spelled out, the theoretical need for adaptive governance over time is very clear.

4.3   Initiative-based learning

Objectives (of What? and Why?)

Major governance objectives of initiative-based learning for sustainability transitions are to foster participatory processes, inclusive innovation, and more generally to bring in a more pluralistic perspective on transitions (Fois, Forino, 2014; Cuthil and Fien, 2005). This focus on engagement and participation is seen as more important than stating explicit goals of energy transitions or environmental goals.

Initiative-based learning tends to focus on local implementation in very specific contexts. This local analytical focus, however, is seen as a means to understand the particulars of processes of governance that reach out across multiple scales. In terms of temporality, the analytical focus is set on relatively short-term implementation of initiatives and projects (e.g. 5-10 years or shorter), which is nonetheless contextualized in broader long-term transition processes.

Few studies are delimited to changes in only one dimension and scope is therefore very broad including technological, cultural, and behavioural change (e.g., Shove and Walker, 2010).

Actors (Who?)

Initiative-based learning considers multiple types of actors, ranging from local citizens to industry and policy makers (Spaargaren, 2011; Seyfang et al, 2014). Some empirical studies, however, choose to focus on the most local processes of grassroots innovation (e.g., Cuthil, Fien, 2005). More generally, there is a notable selective emphasis on those actors that are

commonly under-represented, e.g., civil society, social movements and local residents (Seyfang and Smith, 2008, Seyfang et al 2014).

The focus is set on the local context for initiative implementation. The analysis of local processes is, however, most often connected to national or global governance processes, or at least considered in the context of national policy making.

When considering the success of local initiatives and their contribution to broader change dynamics, some initiative-based learning view networks as important for transitions governance. Coordination and learning across local transitions initiatives through intermediary organizations is commonly viewed as conducive to greater momentum of the transition (Hodson and Marvin, 2010; Ornetzeder and Rohracher, 2013; Seyfang, et al, 2014).

Processes (How?)
Unsurprisingly, since initiative-based learning deals with the local level and learning in projects, its representation of governance is of processes distributed over multiple actors. The strength of this approach is the governance process, inclusion of less influent actors and an emphasis of the process of developing shared understandings through social learning. The mode of governance considered is hence always shared, with an attention to the plurality of actors, their perspective, and inclusion in innovative processes.

What constitutes criteria for 'good governance' is not necessarily discussed explicitly, although enhancing the 'legitimacy' of transformative change is a core rationale for such studies. Some studies discuss inclusiveness as a leading to increased legitimacy (Fois Forino, 2014), and the greater effectiveness of local initiatives when coordinated via intermediary organizations coordinating in what can be seen as networked modes of governance (Hodson and Marvin, 2010).

Initiative-based learning, with its natural emphasis on information and learning, highlights the importance of information-based mechanisms and approaches. Learning and collaboration in networks is spread awareness, build momentum, and thereby an active part of transitions governance (e.g., Cuthil and Fien, 2005; Seyfan and Smith, 2008).

The main rationale for governance considerations in initiative-based learning is the need to account of more inclusive forms of steering. With an interest in drawing on local lessons and capacities to shape transitions, a central emphasis is set on the need to ensuring shared visions (e.g., Hodson and Marvin, 2010).

Evaluation
Means for evaluating success and rationales for why it is important to evaluate successful transitions initiatives is present in parts of the literature. While the importance of achieving good governance – such as legitimacy – is clearly one of the foundations for IBL research, there is most often no explicit discussion on the means to evaluate governance. For example, the understanding of governance with regard to enabling adjustments to real-world challenges over time is seldom discussed explicitly. However, learning in local cases over time is put forward. Effort to address local aims and objectives over time, in context, do offer opportunities to adjust (Hodson and Marvin, 2010; Fresoli et al, 2014)

Finally, very few of the papers reviewed give stated means of evaluation against long term objective with the transitions. Among the few exceptions are the examples of cities described by Betsil and Bulkeley (2006) that draw attention to the process of submitting indicators of milestones to achieve to track progress in local efforts.

4.4   Summary of results, similarities, differences

We here present a summary (Table 3) of the results across the three approaches, highlighting the different treatment of governance aspects.

Table 3: Analytical summary of literature overview

	#	Quantitative systems modelling	Socio-technical analysis	Initiative-based learning
Objectives (of What? and Why?)	O1. Objective of the transition	Explicit system performance indicators as targets for projected techno-economic or land use pathways External objectives as 'hard' constraints on future systems	Sustainability transitions framed as urgently needed radical transformations to address societal problems Often sectorial focus (energy, mobility, etc.)	Foster participation in transitions governance
	O2. Scale considered	Macro systems (global, national), with some exceptions	Multiple scales considered Theory is 'scale-invariant' Cases often national	Usually local focus, but linked to wider and longer-term transitions objectives
	O3. Dimensions considered	Mostly techno-economic dimensions are modelled, and sometimes contextualised in wider change	Multi-dimensional understanding of transitions (technological, social, cultural, policy) Processes of alignment and re-configuration	Multi-dimensional focus, often via 'practices' or contextualised projects
Actors (Who?)	A1. Type of actors	Relatively monolithic and implicit understanding of governance, focussed mainly on government and policymakers This framing is being extended at the margin	In theory, multiple actors (entrepreneurs, businesses, policymakers, consumers, citizens, normative activists, etc.) influence change and stability Empirical cases often focussed on policy actors	Multiple types of actors, ranging from local citizens to industry and policy makers Empirical cases often focus on underrepresented actors in grassroots processes (e.g. civil society)
	A2. Scales of actors	Governance level depends on specific problem at hand	In theory, scale-invariant and open to the consideration of multiple scales Empirical cases often focus on the national	Focus on local context for initiative implementation Often considered within the frame of national policymaking
	A3. Networks	Actor dynamics and social networks beyond scope of most models	Ambiguous treatment of networks	Networks are seen as important for coordination and learning across initiatives

Processes (How?)	P1. Mode of governance	Seldom discussed Implicit dominance of central steering, first-best economic approaches and market-based views, despite exceptions	Governance modes where steering capacity is spread over multiple actors Interest in pluralistic focus, where state can be a facilitator Some empirical studies more state-centric	Multiple actors and publics, with different perspectives and differentiated inclusion in innovation processes
	P2. Good governance	Criteria for 'good governance' rarely considered	Good governance is sometimes discussed and considered, but sometimes also conflated with goal normative objective of the transition	Legitimacy through participation and engagement
	P3. Types of instruments	Models sometimes consider the effects of specific instruments, but analysts usually refrain from prescribing	Rejection of 'mechanistic' push-pull instruments Interest in steering transition contexts, e.g. via long-term support and influence over selection mechanisms	Greater emphasis on information-based approaches, and empowerment
	P4. Theoretical rational	Quantifiable objectives and scenarios	Emphasis on uncertainties, long-term commitment and attention to processes across dimensions (socio-political, techno-economic, etc.)	Need for more inclusive forms of steering
Evaluation	Summary of types and means of feedback and evaluations	Modelling results often mobilised as justification and feasibility check over the materialisation of policy objectives	Learning is important in transitions literature Emphasis on adaptive governance (adjusting to change in real-world processes)	Evaluation rarely discussed explicitly Success criteria of initiatives often very local Strong emphasis on learning from local success and replicating across scale

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5 Discussion

In this section we discuss the analysis reported in section 4, extract some research findings that relate to five challenges of transitions governance discussed in the introduction, and we discuss the takeaway messages from this review when developing strategy for governance when integrating the three approaches in PATHWAYS.

5.1 <u>Analysis of results on literature review</u>

The analysis of governance across each approach allows us to highlight a number of points of relevance to integration and consolidation of analytical approaches.

Finding 1: There is strong interest in governance across the three methodological approaches, but there is also large diversity both across and within the approaches
It comes out quite clearly from the contributions reviewed that there is a strong interest in governance, whether it concerns the priorities and objectives of transitions governance in terms of the appropriate interventions, the relevant and legitimate actors taking part in steering, their capacity to act or control transitions dynamics, or their legitimacy. Note, however, that this can perhaps partly be explained by the selection of papers. There is a strong variation of treatment for each of the aspects considered, and perhaps a bit more surprising (given the relatively small sample of articles reviewed), also a lot of variation within approaches. Considering the full set of literature:

- the scale of transitions problems treated range from the global to the very local
- the focus on transitions agents ranges from a traditional focus with government and policymakers, to a much broader consideration of business, consumers, and civil society as the sources of change and stability
- the consideration of relevant dimensions for governance ranges from strictly technological factors (even in socio-technical analysis) to more multi-dimensional accounts based on socio-technical configurations and governance arrangements
- practical considerations of governance processes and types of intervention ranges from a relatively narrow focus on instruments (with 'mechanistic' assumptions of cause-effect) to a broader interest in shaping transitions via contexts and enabling conditions, or a consideration of the voices heard and unheard

The initial lesson to be drawn is that governance is an area of analysis in transitions studies that calls for a multiplicity of perspectives rather than clear-cut and definitive answers. However, what is more noteworthy is that governance is not often treated explicitly and systematically across the approaches, and that there is not one common and consistent model of governance put forward by any approach.

***Lesson 1: Findings call for more in depth discussions and treatment of governance* across the approaches** and confirm the need for more explicit consideration of governance to transitions studies (Nilsson et al, 2012b). From the findings in the review we can start to distil some principles that we need to include in a governance framework developed in PATHWAYS and the approaches share more than they differ on what these principles are.

Finding 2: There is a strong implicit agreement of what transitions governance entails.
There seems to be an agreement in principle about what matters for transitions governance in the real world:

- there is an urgent need for large scale systemic transformations related to environmental objectives
- existing socio-technical trajectories are not on track towards addressing the scope, scale or urgency of transitions challenges.
- Transitions entail multidimensional process of alignment
- The evaluation and governance of transitions pathways needs to bridge between scales and dimensions.
- Transitions governance needs to link global and long-term objectives to more detailed and practical actions that can be implemented here and now
- Governance evaluation is not something that is so much discussed in relations to transitions governance

However, these are not treated equally between approaches, because of trade-offs and the relative strength between the approaches. This risk leading to rather biased insights, should analysis remains superficial. For example, if the focus is unilaterally on one set of instrument or interactions recommended by one approach. Indeed, all three approaches have their limitations, especially in the empirical work across all approaches. The conclusion to be drawn is again that understanding governance in transitions requires to develop a multi-method analysis and triangulation that is often not yet done.

Lesson 2: There is a high potential to draw on the common agreements on the challenges to develop joint empirical research with more explicit analysis of governance; especially for forward-looking analysis. The integration aimed at in PATHWAYS, with a focus on forward-looking work, visualization of scenarios, and deeper understanding of governance is hence very suitably framed. However, the lesson is that a framework for understanding governance need not only cover the relevant dimensions (from theory) and draw on the identified relative strengths of the approaches (as of today). The research conducted in interdisciplinary projects must actively design case studies that combine the approaches. Empirical research in transitions, across the three approaches, has yet to develop more explicit and forward-looking research questions on governance aspects.

Finding 3: The systemic and emergent nature of transitions is difficult to translate into practical and directly actionable knowledge.
There are several inherent trade-offs when addressing governance challenges of sustainability transitions (Turnheim et al (Unpublished manuscript). These include:

- detail vs general messages
- theory and empirical cases. There is a discrepancy between those dimensions that are considered as relevant from a theoretical perspective, and their treatment in practical empirical cases.
- pragmatic approaches and more critical approaches
- broad and long-term goals versus immediately and locally actionable options

That is, if an approach is focusing on higher internal consistence (e.g., methodologically) it tends to analytically bracket certain aspects, which carries the risk of overlooking important processes and leading to biased policy advice. Despite a general agreement that problems should define the scale at which transitions processes (see finding 2) and their governance should be considered, in practice the scale of focus is often determined by methodological imperatives.

Lesson 3: The role of analysis for transitions governance has a tendency to be either narrow and technical or broad and ambiguous. This is an inherent challenge that is probably hard to avoid more refined governance framework for transitions science instead need to accommodate and develop both broad rationales for how to foster change, yet dare dig in to the details of explicit problems in empirical cases. An analogy can be drawn from insights on generic and specific policy instruments for CO2 mitigation. Despite the appeal of cost effective broad instruments such as a carbon tax or cap and trade regulations, the goal of decarbonizing Europe by 2050 cannot be realised by one measure only. This is a multilevel governance challenge that requires both predictable, long term generic polices on CO2 emissions, but also technology specific incentives that encourage innovation, ease cognitive barriers, and build knowledge for all types of actors. In order to foster such innovation, policy making need to overcome the current aversion against technology specific support measures (Azar, C., Sandén, B., 2011). Generic policy measures only will not work for transitions and a mix of policy instruments and interventions will be needed.

Finding 4: Different strengths with relation to overall governance angle and offering
Socio-technical analysis tends to accommodate a relative comprehensive take on transitions governance, with a broad consideration of challenges, related uncertainties, a multiplicity of actors and relevant dimensions, and a deep analysis of transitions processes and underlying mechanisms. While it's descriptive and analytical lens is rich, multi-layered and flexible, socio-technical analysis also takes the risk of offering quite general insight on the relevant conditions and contexts conducing to transitions, with only limited elaboration on the strategies to be implemented in practice to support such dynamics. Hence, while the Socio-technical analysis generally has high resolutions of governance in terms of actors and part of the process dimension, actual forward looking analysis or ex-ante evaluation traditional policy instruments or broader governance arrangements is less common.

Quantitative systems modelling, on the other hand, are comparatively narrower in terms of analysis and systems description, focussing mainly on techno-economic conditions and factors. This narrow focus is reflected also in considerations of governance, which tend to be less rich and focused on traditional policy actors, seen to have greater ability to 'steer' wide- and far-ranging transitions processes. Furthermore, it allows for sharper policy-relevant recommendations on transitions pathways in relation to systems' environmental performance. Quantitative systems modelling have a proven track record in supporting decision-making in terms of future-oriented scenarios to reach specific goals. In this respect, it allows evaluating the feasibility of environmental targets, and offers specific prescriptions about future technological options and the timing of their rollout. There is a strong potential for complementarity with socio-technical analysis here, which could further specify the feasibility of said developmental pathways in light of current trajectories.

Initiative-based learning, while broad and a multi-faceted literature, has a relatively clear governance focus that emphasises the importance of participation from all ranks of society in order to deliver more legitimate and thus more desirable transitions outcomes. In that sense, it is more normatively-driven of the three approaches, as it carries ideals of democratic and inclusive engagement. Initiative based learning provides understanding of the processes that should be followed to increase the feasibility of transitions objectives against local implementation and the expression of a plurality of stakeholder perspectives and expectations, as well as opportunities to learn and amplify movements of change from the ground up.

Lesson 4: Division of labour with regard to integration and governance of transitions– the potential for limited but complementary feasibility checks

All approaches seem to fail in providing straightforward governance prescriptions, but rather focus attention on different determinants of success and sources of uncertainty. Each offer a useful but imperfect and incomplete form of 'feasibility check' of governance for sustainability transitions. The potential is thus strong for further work that combines the approaches when analysing governance challenges. The strengths of the three processes is neatly separated in the three first governance components studied in this review; objectives, actors, and processes. Modelling works well with creating tangible and quantifiable objectives; Socio-technical approaches has a strong focus on the role of actors in the process of change, and the strength of initiative based learning is highlighting the governance processes as it works at the local scale.

Finding 5: Missing governance principles and evaluation

Our review shows that developing means of evaluation and iterative learning is among the least developed aspects in all three approaches. In general, evaluation is very hard, as it is demanding both for the scientific process and methodologies commonly applied that are often short term and case study based for both Socio-technical system studies and Initiative based learning. For Quantitative systems modelling there should be much space for comparison with past modelling result, this still appears quite uncommon. It is at least not a common starting point and rationale for analysis. The lack of reflexivity in how governance is treated across the three approaches means that it is most likely that integrative projects like PATHWAYS will have to look in additional sets of literature. In general, the work to develop a governance framework that is integrative and that help advance our understanding of the steering challenges in transitions studies need to draw on e.g. public policy studies and public administration management (on effectiveness, legitimacy, efficiency), but also engage more with insights on participation and social movements (on inclusion, legitimacy, and engagement) and further bridge to innovation studies (such as TIS, on effectiveness and handling of uncertainties). In particular, longitudinal studies that can provide the abilities to trace dynamics such as hype-declines (e.g., biofuels in 2000s), or the change in political support and appeal of a certain technology (e.g., CCS in the 2010s) as they unfold appear important.

Lesson 5: All approaches can benefit from developing case studies that go beyond explanations of current state of the art and that try to better link past assessments with understanding of forward momentum and governance challenges for given solutions. It is encouraging that the PATHWAYS project already has a clearly expressed goal to develop such thinking in several of the work packages.

5.2   Towards governance framework in PATHWAYS

From the description of work the objectives of the governance framework under development in PATHWAYS is that it should i) articulate a common set of priorities for society, ii) ensure that priorities and goals are coherent and arrived at through integrated policy-making processes, iii) develop steering capacity towards these goals including design and implementation of policy instruments and other initiatives that change behaviour, and iv) ensure accountability for governing actions, including monitoring efforts and transparent decision-making.

With regard to overarching common priorities and challenges, the three approaches appear to share more than they differ. All are cantered on providing understanding of sustainability transitions, relate to problems as crossing scales and dimensions, and have an understanding of the complexities of actually reaching integrated priorities for society. However, turning this awareness and recognition to actual procedures and advice for governance to enable coherent and integrated policy-making processes seem a rather daunting task. The literature review does verify that to further refine and make explicit the approaches developed in PATHWAYS, which combines forward-looking modelling with socio-technical analysis and deeper cases of governance policy challenges, is the right direction. That is, the two latter goals of the governance framework, to develop steering capacity and ensure accountability, are at heart of the ongoing analysis in PATHWAYS. It is the combined analysis of modelling results and in-depth case analysis, where the political feasibility and knowledge of positions and perspectives of broad sets of actors, which can provide better insights on how to steer transitions. What remain most underdeveloped, however, are the processes of reflectivity that put insights from all three approaches and their governance implications to the test.

Without a more explicit focus on governance arrangements and policy instruments, it is difficult to discuss steering capacity, and without more explicit focus on evaluation and the iterative formulation of objectives in light of new knowledge, it is hard to develop coherent goals. The second half of the PATHWAYS project needs to tackle these challenges and strive to pave the way for more tangible new methods of monitoring, projecting and evaluating transitions pathways.

→ Such an approach should extend beyond the 'traditional' aspects of governance that we have mobilised to structure this review (i.e. objectives, actors, processes and evaluation). A comprehensive framework for the governance of sustainability transitions pathways should:

- address usual concerns of policymaking and governance, such as have been spelled out in objectives i) to iv) above;
- explicitly address common 'good governance' criteria including accountability, feasibility, effectiveness, and efficiency, but also accountability, legitimacy, inclusiveness, adaptability and reflexivity;
- mobilise the enhanced evaluative capacity stemming from an integrated analytical approach as set out in the PATHWAYS project (see Turnheim et al, Unpublished manuscript), i.e. a multi-dimensional understanding of sustainability transitions pathways that combines different lenses and styles of explanation;
- build on the review presented in this document, actively mobilising the complementarities, findings and lessons identified for the governance of sustainability transitions pathways; and
- move beyond a view of governance as 'steering' towards a broader agenda that recognises the 'big picture' perspective called for by transitions governance, i.e. moving towards long-term strategies that allow deliberatively *supporting*, *shaping* and *modulating* sustainability transitions pathways.

We have set an ambitious task for ourselves, but we believe that making progress in this direction is paramount to providing actionable knowledge for practitioners involved in policy and real-world decision-making that takes account of the scale, scope and urgency of the challenges ahead for the governance of sustainability transitions pathways.

6 References

Anable, Jillian, Christian Brand, Martino Tran, and Nick Eyre. 2012. "Modelling Transport Energy Demand: A Socio-Technical Approach." *Energy Policy* 41 (February): 125–38. doi:10.1016/j.enpol.2010.08.020.

Andersson, Claes, Anton Törnberg, and Petter Törnberg. 2014. "Societal Systems – Complex or Worse?" *Futures* 63 (November): 145–57. doi:10.1016/j.futures.2014.07.003.

Berkhout, F., J. Hertin, and A. Jordan. 2002. "Socio-Economic Futures in Climate Change Impact Assessment: Using Scenarios as 'Learning Machines.'" *Global Environmental Change-Human and Policy Dimensions* 12 (July): 83–95. ://000178026600002.

Betsill, M. M., and H. Bulkeley. 2006. "Cities and the Multilevel Governance of Global Climate Change." *Global Governance* 12 (April): 141–59. ://000237820500004.

Bree, B. van, G.P.J. Verbong, and G.J. Kramer. 2010. "A Multi-Level Perspective on the Introduction of Hydrogen and Battery-Electric Vehicles." *Technological Forecasting & Social Change* 77: 529–40.

Bulkeley, Harriet, and Heike Schroeder. 2012. "Beyond State/non-State Divides: Global Cities and the Governing of Climate Change." *European Journal of International Relations* 18 (4): 743–66. doi:10.1177/1354066111413308.

Burns, T.R., Flam, H., 1987. The Shaping of Social Organization: Social Rule System Theory with Applications. Sage Publications Ltd., London, England.

van Bree et al. 2010. A multi-level perspective on the introduction of hydrogen and battery-electric vehicles Technological Forecasting & Social Change 77 (2010) 529–540

Coenen, Lars, Paul Benneworth, and Bernhard Truffer. 2012. "Toward a Spatial Perspective on Sustainability Transitions." *Research Policy*, Special Section on Sustainability Transitions, 41 (6): 968–79. doi:10.1016/j.respol.2012.02.014.

Coenen, Lars, and Bernhard Truffer. 2012. "Places and Spaces of Sustainability Transitions: Geographical Contributions to an Emerging Research and Policy Field." *European Planning Studies* 20 (3): 367–74. doi:10.1080/09654313.2012.651802.

Cuthil and Fien (2005)Capacity building: Facilitating citizen participation in local governance. Australian Journal of Public Administration64(4)63-80: December 2005

Duit, Andreas, and Victor Galaz. 2008. "Governance and Complexity - Emerging Issues for Governance Theory." *Governance* 21: 311–35. http://dx.doi.org/10.1111/j.1468-0491.2008.00402.x.

Eom et al. 2015. The impact of near-term climate policy choices on technology and emission transition pathways Technological Forecasting & Social Change, 90:73-88.

Fairbrass, Jenny, and Andrew Jordan. 2004. "Multi-Level Governance and Environmental Policy." In *Muliti-Level Governance*, edited by Ian Bache and Matthew Flinders. Oxford: Oxfors University Press.

Fois, Forino. 2014. The self-built ecovillage in L'Aquila, Italy: community resilience as a grassroots response to environmental shock Disasters, 38(4): 719−739.

Foxon, Timothy J., Peter J.G. Pearson, Stathis Arapostathis, Anna Carlsson-Hyslop, and Judith Thornton. 2013. "Branching Points for Transition Pathways: Assessing Responses of Actors to Challenges on Pathways to a Low Carbon Future." *Energy Policy* 52 (January): 146–58. doi:10.1016/j.enpol.2012.04.030.

Fuerth, Leon S. 2009. "Foresight and Anticipatory Governance." *Foresight* 11 (4): 14–32. doi:10.1108/14636680910982412.

Fresoli et al. (2014) When grassroots innovation movements encounter mainstream institutions: implications for models of inclusive innovation. Innovation and Development

Garud, Raghu, and Joel Gehman. 2012. "Metatheoretical Perspectives on Sustainability Journeys: Evolutionary, Relational and Durational." *Research Policy* 41 (6): 980–95. doi:10.1016/j.respol.2011.07.009.

Geels, F. 2010. "Ontologies, Socio-Technical Transitions (to Sustainability), and the Multi-Level Perspective." *Research Policy* 39 (4): 495–510. doi:10.1016/j.respol.2010.01.022.

Geels, F. 2011. "The Multi-Level Perspective on Sustainability Transitions: Responses to Seven Criticisms." *Environmental Innovation and Societal Transitions* 1 (1): 24–40. doi:10.1016/j.eist.2011.02.002.

Geels, F.W. Schot, J.W., 2007. Typology of sociotechnical transition pathways, *Research Policy*, 36(3): 399-417.

Grin, J., 2010. Understanding transitions from a governance perspective, Part III (pp. 223–314) in: Grin, J., Rotmans, J., Schot, J. 2011??? (in collaboration with D. Loorbach, F. Geels). Transitions to Sustainable Development. New Directions in the Study of Longterm Structural Change. Routledge, New York.

Grin, J. Between governments, kitchens, firms and farms: the governance of transitions between societal practices and supply systems. In: Spaargaren, G., Loeber, A., Oosterveer, P. (Eds.), Food Practices in Transition. Changing Food Consumption, Retail and Production in the Age of Reflexive Modernity. Routledge, New York.

Hajer, Maarten. 2003. "Policy without Polity? Policy Analysis and the Institutional Void." *Policy Sciences* 36 (2): 175–95. http://link.springer.com/article/10.1023/A:1024834510939.

Hamilton, S.H., El Sawah, S., Guillaume, J.H.A., Jakeman, A.J., Pierce, S.A. 2015. Integrated assessment and modelling: Overview and synthesis of salient dimensions Environmental Modelling & Software, 64:215-229.

Hammond, Geoffrey P., and Peter J.G. Pearson. 2013. "Challenges of the Transition to a Low Carbon, More Electric Future: From Here to 2050." *Energy Policy* 52 (January): 1–9. doi:10.1016/j.enpol.2012.10.052.

Hillman, Karl, Måns Nilsson, Annika Rickne, and Thomas Magnusson. 2011. "Fostering Sustainable Technologies: A Framework for Analysing the Governance of Innovation Systems." *Science and Public Policy* 38: 403–15(13).

Hodson, Mike, and Simon Marvin. 2010. "Can Cities Shape Socio-Technical Transitions and How Would We Know If They Were?" *Research Policy* 39 (4): 477–85. doi:10.1016/j.respol.2010.01.020.

Holman, I. P., M. D. A. Rounsevell, S. Shackley, P. A. Harrison, R. J. Nicholls, P. M. Berry, and E. Audsley. 2005. "A Regional, Multi-Sectoral and Integrated Assessment of the Impacts of Climate and Socio-Economic Change in the UK." *Climatic Change* 71 (1-2): 9–41. doi:10.1007/s10584-005-5927-y.

Hooghe, Liesbet, and Gary Marks. 2001. "Types of Multi-Level Governance." *European Integration Online Papers (EIoP)* 5. http://eiop.or.at/eiop/texte/2001-011a.htm.

Hughes, Nick. 2013. "Towards Improving the Relevance of Scenarios for Public Policy Questions: A Proposed Methodological Framework for Policy Relevant Low Carbon Scenarios." *Technological Forecasting and Social Change* 80 (4): 687–98. doi:10.1016/j.techfore.2012.07.009.

Hughes, Nick, Neil Strachan, and Robert Gross. 2013. "The Structure of Uncertainty in Future Low Carbon Pathways." *Energy Policy* 52 (January): 45–54. doi:10.1016/j.enpol.2012.04.028.

Jessop, Bob. 1998. *The Rise of Governance and the Risk of Failure: The Case of Economic Development*. UNESCO.

Jordan, A., 2008. The governance of sustainable development: taking stock and looking forwards, *Environment and Planning C: Government and Policy*, 26: 17-33

Jordan, A., 2009. Revisiting ... The governance of sustainable development: taking stock and looking forwards, *Environment and Planning C: Government and Policy*, 27:762-765.

Jordan, A., Wurzel, R. K. W, Zito, A. 2005. The Rise of 'New' Policy Instruments in Comparative Perspective: Has Governance Eclipsed Government? Political Studies 53 (October): 477–96.

Jørgensen, Ulrik. 2012. "Mapping and Navigating transitions—The Multi-Level Perspective Compared with Arenas of Development." *Research Policy* 41 (6): 996–1010. doi:10.1016/j.respol.2012.03.001.

Kriegler, Elmar, Brian C. O'Neill, Stephane Hallegatte, Tom Kram, Robert J. Lempert, Richard H. Moss, and Thomas Wilbanks. 2012. "The Need for and Use of Socio-Economic Scenarios for Climate Change Analysis: A New Approach Based on Shared Socio-Economic Pathways." *Global Environmental Change* 22 (4): 807–22. doi:10.1016/j.gloenvcha.2012.05.005.

Lawhon, Mary, and James T. Murphy. 2012. "Socio-Technical Regimes and Sustainability Transitions Insights from Political Ecology." *Progress in Human Geography* 36 (3): 354–78. doi:10.1177/0309132511427960.

Loorbach, Derk. 2010. "Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework." *Governance* 23 (1): 161–83. http://onlinelibrary.wiley.com/doi/10.1111/j.1468-0491.2009.01471.x/full.

Loorbach, Derk, and Jan Rotmans. 2010. "The Practice of Transition Management: Examples and Lessons from Four Distinct Cases." *Futures* 42 (3): 237–46. doi:10.1016/j.futures.2009.11.009.

Magnusson, T, and A Rickne. 2012. "Multilevel Governance and Innovation System Functionality: Hybrid-Electric Vehicle Technology in Sweden 1990-2009." In *Paving the Road for Sustainable Transportation: Governance and Innovation in Low-Carbon Vehicles*, by M Nilsson, A Rickne, K Hillman, and T Magnusson, 189–99. London, UK: Routledge.

March, J.G., Olsen, J.P., 1989. Rediscovering institutions. Free Press, New York.
Scott, R.W., 2001. Institutions and organisations, 2nd ed. Sage, London.

Markard, Jochen, Rob Raven, and Bernhard Truffer. 2012. "Sustainability Transitions: An Emerging Field of Research and Its Prospects." *Research Policy* 41 (6): 955–67. doi:10.1016/j.respol.2012.02.013.

Meadowcroft (2009) What about the politics? Sustainable development, transition management, and long term energy transitions Policy Sciences, 42, 323-340

McDowall, Will. 2014. "Exploring Possible Transition Pathways for Hydrogen Energy: A Hybrid Approach Using Socio-Technical Scenarios and Energy System Modelling." *Futures* 63 (November): 1–14. doi:10.1016/j.futures.2014.07.004.

Moss, Richard H., Jae A. Edmonds, Kathy A. Hibbard, Martin R. Manning, Steven K. Rose, Detlef P. van Vuuren, Timothy R. Carter, et al. 2010. "The next Generation of Scenarios for Climate Change Research and Assessment." *Nature* 463 (7282): 747–56. doi:10.1038/nature08823.

Newell, Peter. 2008. "The Political Economy of Global Environmental Governance." *Review of International Studies* 34 (03). doi:10.1017/S0260210508008140.

Nilsson, M, Jordan, A., Turnpenny, J., Hertin, J., Nykvist, B., Russel, D. 2008. The Use and Non Use of Policy Appraisal Tools in Policy Making: Empirical Patterns across Three European Countries and the European Commission. Policy Sciences 4 (4): 335–55.

Nilsson, Måns, Karl Hillman, and Thomas Magnusson. 2012. "How Do We Govern Sustainable Innovations? Mapping Patterns of Governance for Biofuels and Hybrid-Electric Vehicle Technologies." *Environmental Innovation and Societal Transitions* 3: 50–66.

Nilsson, M., Zamparutti, T., Petersen, J., Nykvist, B., Rudberg, P., and McGuinn, J. 2012a. Understanding Policy Coherence: Analytical Framework and Examples of Sector–Environment Policy Interactions in the EU. Environmental Policy and Governance Published online in Wiley Online Library DOI: 10.1002/eet.1589.

Nilsson, Måns, Lars J. Nilsson, Roger Hildingsson, Johannes Stripple, and Per Ove Eikeland. 2011. "The Missing Link: Bringing Institutions and Politics into Energy Future Studies." *Futures* 43 (10): 1117–28. doi:10.1016/j.futures.2011.07.010.

Ornetzeder, M., Rohracher, H. 2013. Of solar collectors, wind power, and car sharing: Comparing and understanding successful cases of grassroots innovations. Global Environmental Changes, 23, 856-867

Ozanne, Julie L., and Bige Saatcioglu. 2008. "Participatory Action Research." *Journal of Consumer Research* 35 (3): 423–39. doi:10.1086/586911.

Peters, B. Guy, and Jon Pierre. 2004. "Multi-Level Governance and Democracy: A Faustian Bargin." In *Muliti-Level Governance*, edited by Ian Bache and Matthew Flinders. Oxford: Oxfors University Press.

Pierre, Jon, and B. Guy Peters. 2005. *Governing Complex Societies*. New York: Palgrave Macmillan.

Rosenau, J., Czempiel, E.O., (eds) 1992. *Governance without Government*. Cambridge: CUP.

Seyfang, G., Smith, A., 2007. Grassroots innovations for sustainable development: Towards a new research and policy agenda, *Environmental Politics*, 16(4): 584-603, DOI: 10.1080/09644010701419121

Seyfang et al. 2014. A grassroots sustainable energy niche? Reflections on community energy in the UKEnvironmental Innovation and Societal Transitions,13: 21-44

Schout, J., Jordan, A. 2005. Coordinated European governance: Sel-organized or centrally steered? Public Administration Vol. 83 No. 1:201–220.

Shove, Elizabeth, and Gordon Walker. 2010. "Governing Transitions in the Sustainability of Everyday Life." *Research Policy* 39 (4): 471–76. doi:10.1016/j.respol.2010.01.019.

Smith, A. 2006. Green niches in sustainable development: the case of organic food in the United Kingdom Environment and Planning C: Government and Policy, vol 24, 439-458

Smith, A., Kern, F., 2009. The transitions storyline in Dutch environmental policy. *Environmental Politics*, 18 (1), 78–98.

Smith, A., Stirling, A., Berkhout, F. 2005. The governance of sustainable socio-technical transitions. Research Policy 34:1491-1510

Smith, A., Raven, R., 2012. What is protective space? Reconsidering niches in transitions to sustainability, *Research Policy*, 41: 1025–1036.

Smith, A., and A. Stirling. 2010. The politics of social-ecological resilience and sustainable socio-technical transitions. *Ecology and Society* **15**(1): 11.

Smith, A., Stirling, A., 2007. Moving Outside or Inside? Objectification and Reflexivity in the Governance of Socio-Technical Systems, Journal of Environmental Policy & Planning, 9(3-4): 351–373.

Smith, A., A. Stirling, and F. Berkhout. 2005. "The Governance of Sustainable Sociotechnical Transitions." *Research Policy* 34: 1491–1510.

Smith, Adrian, Jan-Peter Voß, and John Grin. 2010. "Innovation Studies and Sustainability Transitions: The Allure of the Multi-Level Perspective and Its Challenges." *Research Policy* 39 (4): 435–48. doi:10.1016/j.respol.2010.01.023.

Späth and Rohracher. 2012. Local Demonstrations for Global Transitions—Dynamics across Governance Levels Fostering Socio-Technical Regime Change Towards Sustainability European Planning Studies Vol. 20, No. 3, 461-479

Staub-kaminski, Zimmer, Jakob and Marschinski (2014) Climate policy in practice: a typology of obstacles and implications for integrated assessment modelling. Climate Change Economics, Vol. 5, No. 1 (2014) 1440004

Sterner, T. 2003. Policy Instruments for Environmental and Natural Resource Management. RFF Press, Washington DC.

Söderholm, Patrik, Roger Hildingsson, Bengt Johansson, Jamil Khan, and Fredrik Wilhelmsson. 2011. "Governing the Transition to Low-Carbon Futures: A Critical Survey of Energy Scenarios for 2050." *Futures* 43 (10): 1105–16. doi:10.1016/j.futures.2011.07.009.

Spaargaren, Gert. 2011. "Theories of Practices: Agency, Technology, and Culture." *Global Environmental Change* 21 (3): 813–22. doi:10.1016/j.gloenvcha.2011.03.010.

Späth, Philipp, and Harald Rohracher. 2010. "'Energy Regions': The Transformative Power of Regional Discourses on Socio-Technical Futures." *Research Policy* 39 (4): 449–58. doi:10.1016/j.respol.2010.01.017.

Treib, Oliver, Holger Bähr, and Gerda Falkner. 2007. "Modes of Governance: Towards a Conceptual Clarification." *Journal of European Public Policy* 14: 1–20.

Truffer, B., J.-P. Voß, and K. Konrad. 2008. "Mapping Expectations for System Transformations." *Technological Forecasting and Social Change* 75 (9): 1360–72. doi:10.1016/j.techfore.2008.04.001.

Tukker, A., Butter, M., 2007. Governance of sustainable transitions: about the 4(0) ways to change the world, *Journal of Cleaner Production*, 15: 94-103.

Turnheim, B., Berkhout, F., Geels, F., Hof, A., McMeekin, A., Nykvist, B., van Vuuren, D. Unpublished manuscript. Evaluating sustainability transitions pathways: bridging analytical approaches to address governance challenges. Submitted to Global Environmental Change.

Van Asselt, Marjolein BA, Arthur HW Beusen, and Henk BM Hilderink. 1996. "Uncertainty in Integrated Assessment: A Social Scientific Perspective." *Environmental Modeling & Assessment* 1 (1-2): 71–90. http://link.springer.com/article/10.1007/BF01874848.

Van de Kerkhof, Marleen, and Anna Wieczorek. 2005. "Learning and Stakeholder Participation in Transition Processes towards Sustainability: Methodological Considerations." *Technological Forecasting and Social Change* 72 (6): 733–47. doi:10.1016/j.techfore.2004.10.002.

van Kersbergen, K., van Waarden, F., 2004. `Governance' as a bridge between disciplines, *European Journal of Political Research*, 43, 143-171.

Van Vuuren, Detlef P., Marcel T.J. Kok, Bastien Girod, Paul L. Lucas, and Bert de Vries. 2012. "Scenarios in Global Environmental Assessments: Key Characteristics and Lessons for Future Use." *Global Environmental Change* 22 (4): 884–95. doi:10.1016/j.gloenvcha.2012.06.001.

van Vuuren, D.P., Kok, M., 2012 (Eds.). *Roads from Rio+20 Pathways to achieve global sustainability goals by 2050,* PBL Netherlands Environmental Assessment Agency: Bilthoven. The Netherlands.

van Vuuren, D.P., et al., 2011. The representative concentration pathways: An overview, *Climatic Change*, 109(1), 5-31.

Vogler, John. 2003. "Taking Institutions Seriously: How Regime Analysis Can Be Relevant to Multilevel Environmental Governance." *Global Environmental Politics* 3: 25–39.