sustainability

MDPI

Review

Cities and Systemic Change for Sustainability: Prevailing Epistemologies and an Emerging Research Agenda

Marc Wolfram [1,*] and Niki Frantzeskaki [2]

[1] Department of Urban Planning and Engineering, Yonsei University, Seodaemun-gu, Sincheon-dong, 50 Yonsei-ro, Seoul 03722, Korea
[2] Dutch Research Institute for Transitions, Erasmus University Rotterdam, Postbus 1738, Rotterdam 3000 DR, The Netherlands; n.frantzeskaki@drift.eur.nl
* Correspondence: m.wolfram@yonsei.ac.kr; Tel.: +82-2-2123-5895; Fax: +82-2-393-6298

Academic Editors: Thorsten Schuetze, Hendrik Tieben, Lorenzo Chelleri and York Ostermeyer
Received: 30 November 2015; Accepted: 22 January 2016; Published: date

Abstract: Cities are key for sustainability and the radical systemic changes required to enable equitable human development within planetary boundaries. Their particular role in this regard has become the subject of an emerging and highly interdisciplinary scientific debate. Drawing on a qualitative literature review, this paper identifies and scrutinizes the principal fields involved, asking for their respective normative orientation, interdisciplinary constitution, theories and methods used, and empirical basis to provide orientations for future research. It recognizes four salient research epistemologies, each focusing on a distinct combination of drivers of change: (A) transforming urban metabolisms and political ecologies; (B) configuring urban innovation systems for green economies; (C) building adaptive urban communities and ecosystems; and (D) empowering urban grassroots niches and social innovation. The findings suggest that future research directed at cities and systemic change towards sustainability should (1) explore *interrelations* between the above epistemologies, using relational geography and governance theory as boundary areas; (2) conceive of cities as places shaped by and shaping interactions between *multiple* socio-technical *and* social-ecological systems; (3) focus on *agency* across systems and drivers of change, and develop corresponding approaches for intervention and experimentation; and (4) rebalance the empirical basis and methods employed, strengthening transdisciplinarity in particular.

Keywords: cities; sustainability; socio-technical systems (STS); social-ecological systems (SES); system transformation; system transition; resilience; interdisciplinarity; transdisciplinarity; epistemology

1. Introduction

From the origins of the concept of "sustainable development" until today, there is a well substantiated concern about the role and contribution of cities. It can be traced from the Brundtland report and its analysis of the "urban challenge" to the more recent identification of an "urban opportunity" [1], or the formulation of a dedicated "urban" sustainable development goal [2]. This concern refers not only to the quantitative weight of cities in terms of urban population, metabolism and form in a quickly urbanizing world. Most importantly, it recognizes their qualitative momentum as networked places that concentrate the conditions, resources and opportunities for change—as well as for inertia and stagnation.

In a context of dramatically changing global ecosystems and imminent resource limits, the particular role of cities as barriers and drivers for achieving sustainability has therefore been underlined repeatedly [3–5]. Developing *urban* responses that can invert the trends and accelerate

change towards both local and global sustainability has thus become an imperative for research and policy alike. However, this has increasingly been related to the necessity of understanding and influencing the complex systemic interactions between social, ecological and economic processes across spatial and temporal scales that are shaping and shaped by cities *cf.* [6–8].

Over the past two decades, a highly interdisciplinary scientific field has thus emerged, focusing on cities and systemic change for sustainability. This involves a particular spectrum of research areas dealing with urban development, systemic configurations and system innovation dynamics. These areas draw on complementary theories and concepts, but also display constitutive features and overlaps that have benefitted their gradual interconnection, and the articulation of a certain range of research perspectives.

Against this backdrop, this paper explores this emerging interdisciplinary field of study by scrutinizing the characteristics of the various research strands involved, asking for commonalities and differences, as well as areas of convergence and resulting gaps. Section 2 describes the methodology employed for conducting the qualitative literature review that informs our discussion. The results are then synthesized by first outlining the main interdisciplinary trajectories identified in terms of their subject and theories used, acknowledging for boundary areas and shared orientations, as well as methodological and empirical features (3). Based on that, attention is drawn to four currently prevailing research epistemologies and the transformation dynamics they put forward, differentiated by their respective emphasis on particular combinations of basic drivers of change (4). Finally, suggestions are made for a future research agenda for cities and systemic change for sustainability that addresses critical blind spots and potential synergies of the epistemologies discussed (5).

2. Review Methodology

In order to identify pertinent contributions and map out their scientific characteristics, a qualitative literature review has been carried out *cf.* [9,10]. To define the corpus for the review, a keyword search has been realized in three scientific literature databases (Scopus, Web of Science, Google Scholar). Boolean search terms were formed to capture an explicit concern for both cities *and* systemic change, expressed through the adoption of particular terminology ("system transition"; "system transformation"; "sustainability transition"; "sustainability transformation" AND urban; city; cities). This narrow filter has been necessary to effectively distinguish the field of interest here from the abundant literature on cities and sustainability or on systemic change in general. Therefore, it may also have excluded individual contributions that do share similar research interests, but predominantly use other terminology, *i.e.*, especially not adopting the above four expressions for systemic change (towards sustainability).

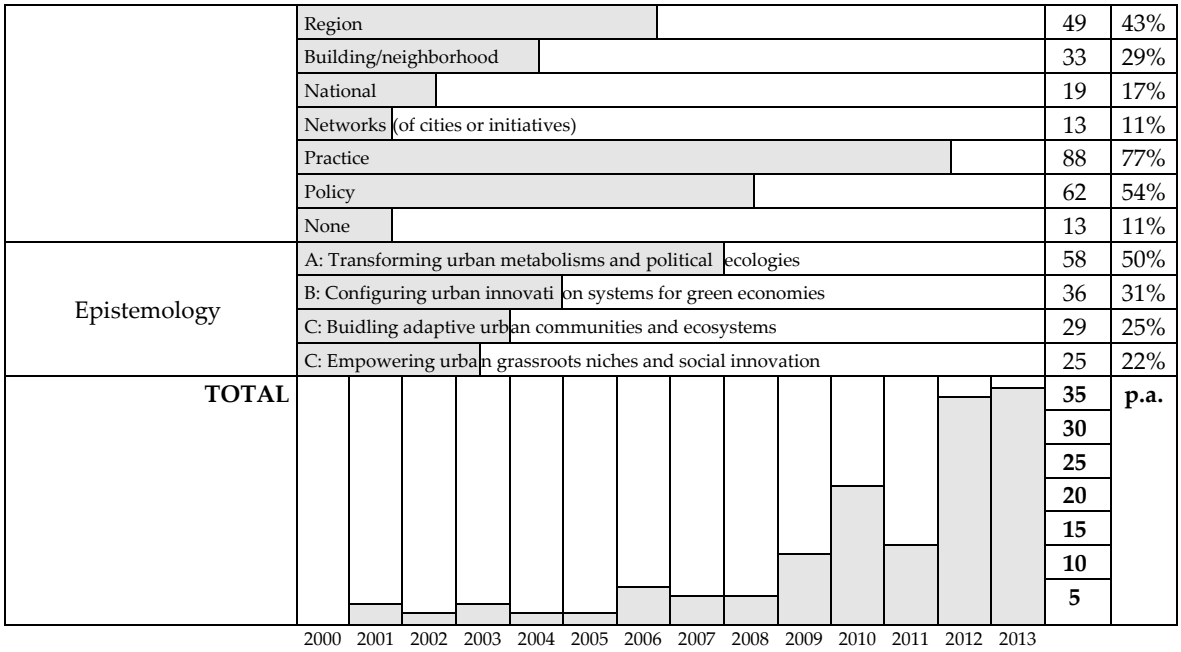
Among all findings, pertinent references were then selected by reviewing abstracts and conclusions, thereby excluding divergent understandings (e.g., "urban transition" as *urbanization*), references that did not *conceptually* engage with the search terms (e.g., invoking "system" without a substantive theoretical underpinning or "sustainability transition" merely as a label), as well as irrelevant findings (e.g., in nutrition studies). Additional references have been included through reviewing the reference lists (backward analysis) and on the basis of the author's own expertise, thus partly compensating for the narrow search terms. Finally, a total of 115 references have been retained for analysis (93 journal articles, 18 books, 4 book chapters—see Table S1). These can thus be claimed to form the core publications of an emergent epistemic community concerned with cities and systemic change for sustainability. The search has been conducted without restriction of the time period, but did not identify any contributions from before 2001. Therefore, it appears that the scientific conjunction of cities and systemic change indeed represents a relatively recent phenomenon, presumably linked to the growing importance of local to global sustainability concerns.

All references have been reviewed independently by at least two different researchers. The first review was conducted to derive categories from the corpus that describe five characteristics of the research reported: (1) Normative position: identifies whether the concept of "sustainability" forms a normative reference for the research undertaken (*i.e.*, urban/system change *should* pursue

sustainability). (2) Interdisciplinary trajectory: Recognizes how certain fields concerned with *urban* change have become interconnected with studies of *systemic* change and vice-versa. Four basic options have been distinguished here, combining the origin of the research *subject* (urban or systemic subject) with the origin of the *theory* adopted for analysis (urban or systemic change). In addition, where these distinctions have become blurred, the emergence of an integrated "urban transformation" approach has been recognized. (3) Theories and concepts used: Specifies the combination of conceptual frameworks adopted for analysis, drawing on key fields in urban studies (governance, planning, geography, ecology, sociology, design, other) and in systemic change studies (multi-level perspective, transition management, social-ecological resilience, innovation systems, co-evolution, social innovation, strategic niche management, other). (4) Methodology: Identifies characteristics of the research methodology used (deduction/hermeneutics, case study, data mining, modelling), as well as whether this implied a transdisciplinary approach (*i.e.*, research design and implementation were realized jointly with societal stakeholders). (5) Empiricism: Accounts for the unit(s) of analysis in terms of their spatial scale (building/neighborhood, city, region, national, networks) and institutional focus (policy, practice).

The categories derived on the basis of the first review have then been further calibrated in a second and third review round to strengthen their representativeness and complementarity. In addition, the focus was on characterizing the epistemologies adopted, considering underlying ontological assumptions and the role of basic drivers of change (see Section 4 for details). This bottom-up classification approach resulted in a total of 37 subcategories for differentiation (Figure 1). The review has thus allowed us to identify four prevailing epistemologies, rooted in certain strands of urban and systemic change studies that are partly converging towards each other through mutual engagement with the respective theories, subjects and methods. To illustrate this development, Sections 3.1 and 3.2 will first synthesize the main interdisciplinary trajectories recognized, while Section 3.3 highlights some patterns concerning methods and empiricism.

Category	Subcategory	No.	%
Normativity	Sustainability	100	87%
Interdisciplinarity	Urban transformation studies (integrated approaches)	31	27%
	Systemic change theory in urban studies	31	27%
	Urban subjects in systemic change theory	20	17%
	Urban theory in systemic change studies	19	17%
	Systemic change subjects in urban theory	14	12%
Urban theory/concepts	Urban Governance [1]	75	65%
	Urban Planning (incl. regional planning)	65	57%
	Urban Geography (incl. economic and political geography)	40	35%
	Urban Ecology (incl. polit. and industrial ecology)	31	27%
	Urban Sociology [2]	18	16%
	Urban Design (incl. architecture, building engineering)	15	13%
	Other (urban theory) [3]	14	12%
Systemic change theory/concepts	Multi-Level Perspective (MLP)	52	45%
	Transition Management (TM)	36	31%
	SES resilience [4]	27	23%
	Co-evolution	21	18%
	Innovation Systems (incl. regional-, local- and technological-)	20	17%
	Social innovation (incl. social practice theory, social movement theory)	19	17%
	Other (transition theory) [5]	11	10%
	Strategic Niche Management (SNM)	7	6%
Methodology	Deduction/Hermeneutics	82	71%
	Case study	75	65%
	Data mining	5	4%
	Modelling	2	2%
Transdisciplinarity		7	6%
Empiricism	City	78	68%



(1) Incl. multi-level governance, neo-institutionalism, regulation theory, discourse theory.

(2) Incl. organization and knowledge sociology, anthropology, culture theory.

(3) Incl. policy analysis, economics, information society studies, transport studies, rural studies, environmental justice.

(4) Incl. adaptive and transformative capacity, adaptive renewal cycle, panarchy.

(5) Incl. actor network theory, sustainability assessment, market transformation, complexity theory, spatial transition, sustainable consumption and production, ecological restructuring, social construction of technology.

Figure 1. Bottom-up classification of references and total incidence (n = 115).

3. Delineating Research Areas and Interdisciplinary Trajectories

3.1. Studies of Systemic Change Engaging with the City

Studies of systemic change already form a highly interdisciplinary scientific field, only loosely demarcated by a range of conceptual frameworks that theorize about the particular dynamics of such change. Although foundational contributions can be traced back to the early 20th century (esp. in systems theory and complexity theory), it is the growing recognition of the systemic character of societal *sustainability problems* that has brought about a renewed interest since the early 2000s, also leading to the development of novel theory and models. The normative concern for sustainability thus forms a shared feature of the strands identified here, using a focus on complex adaptive system change to address the particular role of *cities* in this regard. Most references thus adopt systemic change frameworks and concepts as a heuristic to explore patterns and dynamics of urban change. In addition, a prescriptive use of theory to develop new forms and methods for steering and intervention is frequent, given the orientation toward sustainability.

Two constitutive ontologies need to be distinguished in this regard. First, there is the notion of large-scale *socio-technical systems* (STS) that has informed an understanding of societal change as conditioned by co-evolution between particular technologies, institutions (policy, regulation, markets) and practices (users, routines) [11,12]. Drawing on insights from historical STS transformations e.g., regarding energy or transportation, the interest has thus been in identifying options to overcome the path-dependency and high inertia of existing STS that resist necessary sustainability innovations. This has informed the conception of the *multi-level perspective* (MLP), a heuristic framework that maps interactions between incumbent socio-technical configurations (*regimes*), alternative solutions in an early stage (*niches*), and developments in the system environment (*landscape*) [13]. Moreover, new frameworks have also been conceived to inform policy intervention.

Transition management (TM) builds on the enabling role of governance, foresight, experimentation and learning in system innovation processes [14]. S*trategic niche management* (SNM) targets especially the formation, selection and empowerment of promising niches [15].

Finally, *technological innovation systems* (TIS) offer an analytical grid for understanding actor constellations, institutions and processes that help or hinder (green) technology breakthrough and mainstreaming [16]. These frameworks provide the principal conceptual references for the observed progressive engagement with cities and urban development.

The second constitutive strand forms the study of *social-ecological system* (SES) and their de- and re-stabilization, conceptualizing in particular the systemic property of *resilience* [17]. From an SES perspective, it is *ecological* functions and services such as the provision of fresh water, green space or biomass that are constitutive for the identification of the systemic relations studied, then considering the role of cultures, institutions, practices and technologies in forming and/or transforming the system. The concept of resilience has been used here primarily to identify variables that together condition the ability of an SES to *preserve* a desirable state, namely the latitude of its stability domain, the diversity and redundancy of components and feedbacks, and its capacity for learning, adaptation and self-organization [18]. However, scholars have increasingly underlined the need to "create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable […]" [19]. Similar to STS studies, SES studies have thus also recognized the need for governance innovations, foresight processes, knowledge transfers and learning-by-doing across scales as critical conditions for enabling systemic change [20,21], increasingly also linked to urban contexts [22].

Within our corpus, the most widely adopted conceptual frame is the "multi-level perspective" (MLP), followed by "transition management" (TM), "resilience" and "innovation systems" (see Figure 1). "Co-evolution" and "social innovation" concepts are hardly employed independently from these, see e.g., [23,24], with the combination between "social innovation" and "strategic niche management" (SNM) forming a more persevering pattern. Also, very few researchers draw on both the MLP (SNM, TM) *and* "resilience", see e.g., [7,25], which reflects a clear divide between the respective epistemic communities rooted in either STS or SES scholarship. Thus, apart from the prevailing use of the MLP, we distinguish two related research trajectories informed by TM or SNM/"social innovation", and two more independent ones building on "innovation systems" or "resilience" theory. Each of these will be briefly expanded on in the following.

The *MLP* highlights how the co-evolution between a dominant socio-technical regime and innovations emerging in niches affects the creation and unfolding of pathways for transformation that (can) result in new system configurations. By adopting the MLP, new basic questions have thus been raised for urban policy and planning that address the role of cities as purposeful *actors* in socio-technical transitions and their possible influence on (national) regime transformation, and/or as *seedbeds* for local innovation niches [26,27], especially with a view to urban infrastructures [28]. But also cities themselves have been interpreted as *urban regimes*, configured through strategic work by incumbent urban actors [29]. However, the MLP has only rarely served to directly derive new approaches for urban policy and planning that address niches-regime constellations, see e.g., [30], but mostly required a combination with other system innovation and/or urban theory to meaningfully address intervention options, *cf*. [31].

Here, especially *TM* has been helpful as a heuristic to examine the characteristics of urban governance and planning processes. Based on its postulations concerning actor types (frontrunners, border-crossers, incumbents), interaction forms (transition arena) and activities (orientating, agenda setting, activating, reflecting) [32,33], TM has been largely employed for empirical assessment and/or development of urban policy guidance. Focused on single domains such as water management [34] or information infrastructures [35], or regarding broader development strategies such as waterfront regeneration [36], this has provided deeper insights concerning the role of agency and leadership, as well as pilots and experiments for enabling transformative governance and social learning in urban contexts. It has equally informed the conception of action research in "urban transition labs" *i.e*., transdisciplinary interaction spaces that complement existing governance arenas [37]. Moreover, the

specific design of foresight processes within TM has generated suggestions for modifying urban planning methods [38,39].

Other studies have invoked *SNM* as a conceptual reference in order to "zoom in" on the requirements of local niches and their relations to socio-technical regimes. While this has largely confirmed the importance of general success factors identified in the SNM literature such as shared stakeholder expectations, enabling actor networks and experiential learning [40,41], it has also illustrated the need for a better understanding of locally *embedded* niches. Some scholars have therefore linked SNM with social innovation theories in order to also trace the implications of practical know-how, physical activities and cultural meanings for the transformative impact of community initiatives and "grassroots niches" [42–44]—yet often without a clear differentiation of their urban and spatial contexts. By contrast, others have strongly underlined the need to acknowledge for the *place-specific* constitution of niches and related options for strategic urban planning [45], or a less antagonistic but more relational understanding of locally shaped niche-regime configurations [46]. Furthermore, the focus on urban niches has also led to recognize the necessity to develop new approaches to public participation in urban planning with a view to enable civil society and private sector actors to effectively contribute to urban transformations [47].

A different direction has been pursued by those drawing on (technological) *innovation systems* studies and their concern for the institutions and actor networks that shape the creation, adoption and diffusion of new technologies or products, *cf.* [48]. While the vast majority of studies using the TIS framework does not reflect on the spatial or urban dimension of the systems analyzed [49], the crucial importance of place had already been recognized by earlier approaches for managing the transformation of local socio-economic systems [38]. Embedded actor strategies and institutional structures in urban contexts can thus form vital factors for the breakthrough of "green" technologies, industries and markets [50]. Empirical studies illustrate this for specific technologies [51,52] or clusters of eco-innovation [53–56], while simultaneously highlighting the multi-level character of the processes observed. This underlines the unique position of cities as the places that connect consumers, producers and policy, thus co-shaping urban lifestyles and global consumption patterns [57].

Last not least, SES studies have generated another rich strand of research addressing urban transformations, mainly with a view to identify vulnerabilities, unsustainable performances and dynamics of change. Based on the concept of resilience, there is a strong concern here for governance innovations, experimentation and social learning [21,22]. This is reflected in the resulting spectrum of research subjects and interests, aiming to interpret overall urban transformation dynamics and identify options for steering [58–61], develop orientation and practical guidance for urban planning and design [62–64] or related foresight [65], explain the emergence and impact of local sustainability innovations [66], as well as related lifestyle changes [67]. Overall, these studies coincide in underlining the need for making *ecological* system functions and services a cornerstone for redefining stakeholder interactions, altering cognitive and normative frameworks and thereby enhancing the self-organizing capacity of SES for sustainability.

3.2. Urban Studies Engaging with Systemic Change

Constituted only by the shared subject of "cities", also the scientific field of "urban studies" is a highly interdisciplinary one with fuzzy edges. It comprises all scientific perspectives on cities, examining their condition and development across time and space. Since the discursive construction of cities as a subject of science was driven by individual disciplines there has been a corresponding epistemological and methodological diversity from the outset. This included not only a concern for analysis and interpretation, but also for developing and implementing new forms of intervention, as represented by the subfield of *planning*, *cf.* [68,69]. It is here that the evolving modes of urban governance and requirements for steering urban development have been discussed extensively, see e.g., [70–72].

Despite all diversity, urban studies have gradually started to develop a more widely shared ontology since the 1970's, informed by post-structuralist thinking. Based on the perspective of

relational geography, cities became increasingly framed as local nodes within multiple overlapping social, economic, ecological, political and physical networks, continuously shaping and shaped by flows of people, matter and information across scales [73,74]. This post-structuralist shift acknowledged for the crucial role of places in (re-)configuring "glocal" power relations and patterns of exploitation [75–77]. It has also been an important catalyst for a broader engagement with the normative concept of sustainability, following the 1992 Rio summit. Central epistemological axes in urban studies appeared to resonate particularly well with key tenets of sustainability that demanded holistic thinking and action, including the basic concern for human needs and justice ("inter-/intragenerational equity"), for linked social, ecological and economic dynamics ("triple-bottom line"), for power and institutions ("good governance"), as well as for place, communities and culture ("Local Agenda 21"). Hence, a broad diversity of boundary disciplines, a relational understanding of space and place, and an orientation at intervention for sustainability are main characteristics of the field that have become important for a growing engagement with studies of systemic change.

Most references draw on concepts from urban governance and planning studies, thus reflecting the related concerns of STS and SES scholarship, but offering further insights regarding the multi-level governance and institutional thickness of cities. An important number of contributions invokes notions from urban geography or ecology, and a significant fraction also from urban sociology or design. This has allowed to not only recognize the crucial role of space in mainstream conceptions of system transformation. Most importantly, it has enabled a more differentiated account for the specific dynamics resulting for and from cities considering urban metabolisms, built environs and forms of agency. Four principal sub-strands can be distinguished here by the nature of their subjects and the theoretical references used, respectively rooted in urban *economic geography*, *political ecology*, *planning studies* or *sociology*.

Research informed by *economic geography* has been particularly instrumental to acknowledge for the spatial implications of STS transitions and to also provide adequate concepts to capture these. Following earlier calls for a "geography of sustainability transitions" [78], the endeavor has been here to foreground the role of *place* and *scale*, thereby enhancing the utility of the MLP. Drawing on relational geography, regime and niche actors have thus been framed within cross-scale spatial and institutional contexts that produce enabling and constraining effects for socio-technical transitions in terms of identity, legitimacy, actor coalitions and resources. Consequently, the impacts of embeddedness and territorial power relations on shaping socio-technical trajectories and patterns of uneven distribution have been disclosed [50,79], especially looking at energy systems [80,81]. Regarding cities, this has served to illustrate their ambivalent role in shaping STS transitions both as places of innovation and as a local manifestations of multi-scalar socio-technical regimes.

A second central motive for using urban theory in transition studies has been the *political ecology* of resource flows underpinning urban development. Through the lens of urban governance- and regime theory, new insights have been obtained into the ongoing reconfiguration of the networked infrastructures that mediate those flows [82,83]. Focused on the public and private key stakeholders, their interactions and the institutional shifts they create, this perspective has illustrated the multi-level and multi-sectoral character of urban socio-technical change [84–86], but also the crucial role of strategic local planning processes and new intermediaries [28,87–91]. It has equally underlined how urban experiments and civil society participation contribute to articulate new system configurations in concrete settings [92,93]. In order to orient socio-technical transformations towards sustainability and avoid new elitist forms of steering [94], different new requirements have been identified for urban governance and planning [95–97]. Especially participatory foresight and novel forms of intermediation turn out to be critical elements in transition processes grounded in urban contexts with a view to their contribution to create shared visions, operational capacity to act, and opportunities for social learning [98,99].

Third, *planning studies* have increasingly turned towards systemic change as well, both conceptually and empirically. Starting from earlier engagements with complexity theory and its lessons for planning in terms of handling uncertainty, thresholds and emergence [72,100], requirements for planning processes to explicitly address system transformation have gradually

become further specified. This has underlined the pertinence of the theoretical debates on collaborative-, adaptive- and/or strategic urban planning, especially regarding their emphasis on participation, knowledge co-creation, long-term foresight, experimentation and flexibility [87,101,102]. While some authors have sought to substantiate their conceptual considerations empirically through analyzing strategies and measures in current planning practice [103,104], others have discussed conceptual ambiguities when applying systemic change theory to cities. This refers especially to the constitution of cities out of multiple coalescing subsystems, both socio-technical and socio-ecological, that require to conceive of "multi-regimes" and to develop different strategies for managing place-based niches in a highly inert built environment [45,105].

Finally, drawing on urban *sociology* and anthropology increasing attention has been paid to the influence of social practices, communities and grassroots initiatives on socio-technical transitions. While recognizing the steering attempts of urban regime actors, this perspective acknowledges especially for the time- and space-specific constituents of everyday practices as equally basic conditions for system innovations [106]. Hence, differences between places in terms of discourses, cultural frames and identity result to be critical factors for transition governance that require attention through foresight, community participation and empowerment approaches [107–110]. The case of the UK Transition Town movement and its diffusion has received much attention from this perspective, giving rise to critical questions regarding transition visions, politics and culture [111–113]. These studies clearly recognize that cities provide far better opportunities for scaling up the impacts of grassroots initiatives than the villages and small towns that currently prevail in this particular movement. Especially the capacity to empower communities and to draw on translocal and cross-scale networks appears to be a crucial asset of cities [114,115].

3.3. Method, Empiricism and Transdisciplinarity

Regarding the research designs used across all references analyzed, it is first of all the high proportion (1/3) of purely deductive and/or hermeneutic approaches that draws our attention, apparently reflecting lively and ongoing theoretical development in this field. The empirical work is almost exclusively based on qualitative case studies, with only a few methodological exceptions (surveys, modeling, data mining). Although the majority of these case studies focus on the scale of the city, there are also a number of cross-scale studies that address either relations between the urban/regional and/or urban/national scales, or relations within cities and their subscales of districts, blocks or buildings.

However, there are a number of significant empirical gaps emerging. The case studies invariably deal with *individual* cities—comparative research dealing with several cities has hardly been undertaken, although this would be particularly informative (esp. if realized within the same nation-state to control context variables). Studies on trans-local relations of cities and the role of city networks have also been rare so far. Moreover, regarding the geographical location of the cities studied, the empirical basis appears to be largely concentrated in Western Europe, thus (implicitly) assuming specific political, cultural and socio-economic conditions. Likewise, despite all interdisciplinarity, there is still a lack of genuine contributions from key fields in urban studies such as planning, political science, engineering, economics or sociology. These disciplines would however be important to further illuminate the interplay of cities and systemic change regarding e.g., approaches for intervention and related power and equity effects, specific forms of agency in urban contexts, or the obduracies of built environs and infrastructures.

Above all, the proportion of *transdisciplinary* research—*i.e.*, interdisciplinary studies defined and realized together by science *and* society stakeholders—is surprisingly low. Although the crucial importance of transdisciplinarity for collective knowledge production and learning processes in system transformations has been repeatedly emphasized and illustrated [116–119], and although the urban context provides ideal conditions for transdisciplinary research (proximity, institutional thickness), practical implementation appears to fall short of meeting this requirement. Yet, without continued involvement of practitioners throughout all process phases, including a broad diversity of knowledge types and high intensity of interactions, research hardly leads to empowerment and

transformational impacts [120,121]. The cases of an international "network for sustainable urban development" formed by research institutes *and* cities [122] or the adoption of a lab approach in the city of Ghent [123] represent pioneering exceptions here, but also point to the continued lack of adequate concern in mainstream policy (e.g., funding mechanisms and requirements) and research.

4. Prevailing Epistemologies

Drawing on the interdisciplinary trajectories outlined above, this section provides a more cross-cutting and foresighted reading of the corpus with a view to inform a future agenda for research. It discusses four prevailing epistemologies that appear to dominate the debate so far, and are therefore also well substantiated both empirically and conceptually. Considering the classifications adopted for the analysis, we recognize a widely shared normative orientation at sustainability. In this, affinities exist between studies pertaining to *different* interdisciplinary strands. These affinities are partly characterized by the underlying ontologies (STS or SES), but also by an emphasis on particular *drivers of change* and their role in shaping urban and systemic transformations towards sustainability. Following Pacione [124], seven basic drivers of societal change can be distinguished: political, economic, ecological, social, cultural, technological and demographic drivers, *cf*. [125]. More specifically, McCormick *et al*. [7] identify three main drivers for "sustainable urban transformation" that align with this categorization, although surprisingly leaving out technological and ecological drivers: "governance and planning" (political, social), "innovation and competitiveness" (economic, social), "lifestyle and consumption" (social, cultural, economic, demographic). We refer to the above typology of seven basic drivers to underpin the four salient epistemologies identified (Figure 1 and Table 1). Without claiming comprehensive coverage or unique attribution of all references analyzed, these epistemologies will be briefly sketched in the following to illustrate their different assumptions regarding pertinent basic drivers and their interrelations to explain and predict systemic change. This implies to highlight their different focus on particular action domains, stakeholders and their motives and interactions, as well as emphasis on different forms of intervention required for pursuing sustainability. In so doing, we aim to sharpen the respective profiles of these prevailing epistemologies in order to enable the subsequent recognition of critical gaps and potential synergies.

Table 1. Prevailing epistemologies in research on cities and systemic change for sustainability—emphasis on drivers of change.

Epistemology/Drivers	Political	Economic	Ecological	Social	Cultural	Technological	Demographic
A: Transforming urban metabolisms and political ecologies (STS)	●●●	●●●	●●●			●●●	
B: Configuring urban innovation systems for green economies (STS)		●●●	●●●	●	●	●●●	
C: Building adaptive communities and ecosystems (SES)	●●		●●●	●●●	●		●
D: Empowering urban grassroots niches and social innovation (STS)			●●●	●●●	●●●	●	●

● = low, ●● = medium, ●●● = high.

4.1. A: Transforming Urban Metabolisms and Political Ecologies

This perspective focuses on the strategic responses that powerful urban actors create to the challenge of a shifting political ecology and economy of cities in times of global resource scarcity and climate change. It recognizes that especially local governments and major infrastructure and technology providers increasingly engage in novel forms of place-specific interaction and socio-technical experimentation concerning urban energy, water, waste or transport. To secure long-term access to vital resources for continued economic growth and safeguarding local assets and living standards, these actors form new alliances that aim to significantly reduce a city's carbon and ecological

footprints. New technologies, services and usages are therefore tested in urban settings, involving various stakeholders, from industry to NGO's and citizens. This perspective is also wary of scalar relations and multi-level interactions in this regard with a view to state institutions, resource markets or (inter-) national companies, and accounts for the role of intermediaries and their capability to facilitate change by supporting new visions, discourses, networks and coalitions. Particular attention is paid here to emerging deficits in terms of legitimacy, accountability and openness. Hence, this perspective strongly focuses on STS that condition the urban metabolism and its changing (multi-level) governance. Drawing on the MLP, cities represent complex socio-technical *niches* that can challenge large-scale resource regimes, but also place-based *urban regimes* for small-scale experiments. Together, the agency involved in both constellations is deemed to enable or constrain wider sustainability innovation dynamics. This also suggests particular forms of intervention, like strategic networking, intermediation and/or participatory foresight in order to influence or counterbalance the direction and speed of these processes, *cf.* [28,83,87,88,90,92,126].

4.2. B: Configuring Urban Innovation Systems for Green Economies

While the central motif of the key actors in this perspective is similar to the previous one (*i.e.*, adjustment to global environmental change in order to stay competitive), "transformations" primarily concern production and consumption patterns here, not (only) infrastructures. However, cities are equally vital for this: the focus is on private companies, consumers and markets for high/low carbon products, and the place-specific requirements, strategies and networks for "greening" the related parts of the economy. Actor constellations are recognized that bring together government agencies, industry, SMEs and academic institutions, jointly initiating and driving innovation processes that improve their competitiveness, while also contributing to reduction of the resource-intensity of certain products and services. In this, knowledge transfers and innovation activities are conditioned by the formal and informal networks among these actors, and the associated formation of shared value systems and cooperation-cultures. However, issues of legitimacy or accountability are not necessarily a particular concern here. In this perspective, change for sustainability thus takes place through local innovation systems for selected markets and socio-technical practices anchored in cities. This points towards a proactive pursuit of local "public-private-research" co-operations facilitated through certain types of intermediaries (e.g., economic promotion agencies, cluster managers), as well as specific forms of experimentation and open innovation (e.g., Living Labs) *cf.* [38,51,52,55–57].

4.3. C: Building Adaptive Urban Communities and Ecosystems

Climate change, resource scarcity and biodiversity loss form the combined drivers in this perspective, especially with a view to the resulting vulnerabilities of cities. Diverse urban stakeholders respond to this challenge, aiming to create a dynamic socio-ecological system balance while controlling the local impacts of global environmental change. The system relations and contexts considered are thus defined essentially through ecosystem services. Therefore, water supply and catchment areas, building material imports and exports, food provision and agriculture, or green infrastructures and their different functions (carbon sink, water resorption, species protection, shading, recreational space, *etc.*) are important starting points for future pathways. In this regard, a broad variety of locations and typologies also needs to be considered (e.g., for green infrastructures: riverbanks, parks, gardens, brownfields, roofs, facades, streets, squares). Correspondingly, the socio-ecological interactions and actor constellations are rather diverse but highly inclusive, ranging from the vegetable garden at the scale of the block to material recycling and urban mining in metropolitan areas. Pertinent communities may thus include citizens (as dwellers, owners, and users) and civil society groups, (local) government agencies as well as private companies and research institutions. New system configurations can be enabled by fostering self-organization capabilities and creating diverse and redundant solutions. Thus, participation, knowledge co-production, learning-by-doing and adaptive governance become necessary cornerstones of urban policy making and planning *cf.* [58–63,66,67].

4.4. D: Empowering Urban Grassroots Niches and Social Innovation

In this perspective, change for sustainability is driven by heterogeneous approaches and initiatives of civil society actors in cities and their environmental concerns. Global environmental change thus plays an equally crucial role, but responses are rather justified ethically, and also need to be seen in relation to other individual and group-specific needs (e.g., employment, housing, mobility) and motives (e.g., identity, self- achievement, recognition, cohesion, solidarity). Correspondingly, there is a wide range of activity fields addressed, including, e.g., food, education, health, but also green space or renewable energy. This implies that characteristics of urban structure and design such as density, typology, functional mix and accessibility are of considerable importance here since they have a direct or indirect bearing upon stakeholders' means and ends. On the other hand, this interweaving with the built environment also conditions an integrated handling of socio-technical and socio-ecological problem dimensions (e.g., as in street rehabilitation or residential and roof gardens). The focus is on the ability and opportunity of the respective initiatives to promote and scale their innovative practices, both through replication and through translation into policies and regulation, or new markets. The transformative potential of such urban niches is seen to depend on the local institutional cultures and practices, but also trans-local relations (peer-to-peer). Cities may thus prove to be either innovation incubators, actively empowering and promoting grassroots initiatives and networks, or regimes that offer structural resistance, or possibly both at once *cf.* [43,110,111,114,115,127].

5. Conclusions: Towards a Future Research Agenda

Based on a methodical literature review, this paper has discussed the interconnections emerging between the two broad interdisciplinary research fields of urban studies and systemic change studies. Acknowledging the shared concern for urban implications of complex adaptive system changes for sustainability, it has described the particular range of interdisciplinary trajectories that have so far favored the articulation of four epistemologies, currently prevailing in this field. These clearly underline the added value and necessity to conceive of and study urban and systemic change for sustainability in an integrated way. However, they equally reflect a number of blind spots that future action in science, policy and practice should aim to address. In order to move from complementarity to synergy, and from emergence to strategy, the following issues require particular attention:

(1) Studies that have engaged with cities and systemic change have so far largely drawn on *selected* theoretical concepts to conceive of and explain transformations. This implied a more fragmented account for the urban and its role in system transformation(s): Our corpus shows how cities are largely framed either as protagonists of infrastructure transformations, as local innovation ecosystems, as nodes of adaptive ecosystem governance, or as seedbeds for grassroots innovation. While these perspectives remain valid and useful, much could be gained from conceptualizing and exploring *interdependencies* between the different change dynamics they address—without aspiring to create a "great unified theory". For this, relational geography and (multi-level) governance theory provide shared frameworks that facilitate a crossover, including between the various underlying ontologies, *cf.* [128]. Such a multifaceted approach is required to adequately account for the (spatial, temporal and institutional) coincidence of various systemic change dynamics in cities. Particular attention should thus be paid to emerging synergies and conflicts between the articulation of different sets of drivers (e.g., regarding urban political ecology, innovation systems and grassroots innovations), between orientations at resilience (stabilization) or transformation (destabilization), *cf.* [129], and between phasing out *old* and building up *new* systemic configurations [130]. It would equally allow to identify *new tipping points* that effectively *couple* different innovation dynamics in cities.

(2) Adopting the above research perspective necessarily entails a shift in terms of the subjects and questions dealt with. As recognized by various STS scholars already, looking at cities implies to acknowledge for "multi-regime" configurations that interconnect various socio-technical systems (e.g., energy, water, buildings, transport). The mutually de-/stabilizing influences of such

interconnected regimes have hardly been explored so far, but appear to be vital for guiding urban development towards sustainability. In addition, cities can equally be depicted as a set of coalescing SES that govern diverse resource stocks, flows and ecosystem services. Therefore, it becomes crucial to empirically explore how institutions, discourses, actor constellations and practices avoid or embrace this "hybrid" reality of cities as *social-ecological-technological systems* (SETS), *cf*. [131]—and with what implications for sustainability transformations. Emphasis needs to be put here on the role of *urban place* as a key entity, since it is through particular physical landscapes, built environments, identities and socio-cultural practices that such hybrid configurations become manifest in cities. Across the spectrum of epistemologies identified, this raises new questions about how multiple transformation dynamics play out in *different* places, accounting for their local constitution, as well as translocal and scalar relations.

(3) Having recognized the critical role all epistemologies attribute to agency, leadership and intermediation, particular efforts need to be undertaken with a view to develop suitable *urban* approaches for intervention to help initiate, accelerate and navigate sustainability transformations. Transition management and its local adaptation, including "urban transition labs", provide only first orientations here. In addition, especially capacity building and civil society empowerment form equally important approaches, especially considering the diversity of context conditions and starting points of cities from across the globe. Most importantly, the gap towards urban planning and policy making practice must be closed in theory and practice. Instruments and techniques applied in this domain (e.g., strategic planning, SEA, foresight, community participation, urban regeneration) offer considerable potential regarding their integrative, governance and experimental functions, but would require more tailored modifications considering systemic change requirements. Therefore, transcending the available approaches to develop new forms of urban governance, intermediation and institutional entrepreneurship in cities is a necessity that would also help facing the legitimacy challenge of TM.

(4) The current empirical basis, range of research methods and role of transdisciplinarity require strategic extensions. Identifying lessons and patterns regarding the multitude of individual case studies carried out so far seems an immediate requisite. Correspondingly, more emphasis needs to be put on *comparative research*, including both qualitative case study and quantitative analysis of larger urban data sets. In this, the growing diffusion and application of concepts from research on cities and systemic change in policy and practice should form a key concern for evaluating impacts and policy mobility. Moreover, the empirical basis should more thoroughly embrace the global South and East, enabling an exploration of different transition dynamics and the influence of key context variables, as well as interconnections between particular cities and/or cities within particular regions. Last not least, the role of transdisciplinarity needs to be strengthened substantially, using especially research policy and programs as a lever to co-develop and mainstream new approaches for transformative interaction between science and society in cities.

Supplementary Materials: The following are available online at www.mdpi.com/http://www.mdpi.com/2071-1050/8/2/144/s1, Table S1: List of references reviewed (sorted by interdisciplinarity).

Acknowledgments: The authors would especially like to thank Junhan Kim, Seung Beom Kang and Joy Fangzhou for their invaluable support in the reference analysis. This research has been co-funded by the 7th European Research Framework Programme, grant agreement No. 603654, ARTS project (Accelerating and Rescaling Transitions to Sustainability) (www.acceleratingtransitions.eu).

Author Contributions: The research reported in this publication has been jointly designed and realized by Marc Wolfram and Niki Frantzeskaki. Both authors have contributed equally to the conception and formulation of the manuscript.

Conflict of Interest: The authors declare no conflict of interest.

References

1. UN Sustainable Development Solutions Network. *The Urban. Opportunity: Enabling Transformative and Sustainable Development*; UN Sustainable Development Solutions Network: Bangalore, India; New York, NY, USA, 2013.
2. Open Working Group. *Open Working Group Proposal for Sustainable Development Goals*; Open Working Group of the UN General Assembly on SDG's: New York, NY, USA, 2014.
3. Weinstein, M.P.; Turner, R.E. *Sustainability Science: The Emerging Paradigm and the Urban Environment*; Springer: New York, NY, USA, 2012.
4. Elmqvist, T.; Fragkias, M.; Goodness, J.; Güneralp, B.; Marcotullio, P.J.; McDonald, R.I.; Parnell, S.; Schewenius, M.; Sendstad, M.; Seto, K.C.; *et al*. *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*; Springer: Berlin, Germany, 2013.
5. Vojnovic, I. Urban sustainability: Research, politics, policy and practice. *Cities* **2014**, *41*, S30–S44.
6. Collier, M.J.; Nedović-Budić, Z.; Aerts, J.; Connop, S.; Foley, D.; Foley, K.; Newport, D.; McQuaid, S.; Slaev, A.; Verburg, P. Transitioning to resilience and sustainability in urban communities. *Cities* **2013**, *32*, S21–S28.
7. McCormick, K.; Anderberg, S.; Coenen, L.; Neij, L. Advancing sustainable urban transformation. *J. Clean. Prod*. **2013**, *50*, 1–11.
8. Frantzeskaki, N.; Coenen, L.; Castán Broto, V.; Loorbach, D. *Urban. Sustainability Transitions*; Routledge Studies in Sustainability Transitions; Routledge: New York, NY, USA, 2016.
9. Petticrew, M.; Roberts, H. *Systematic Reviews in the Social Sciences a Practical Guide*; Blackwell Publishers: Oxford, UK, 2006.
10. Gough, D.; Thomas, J.; Oliver, S. Clarifying differences between review designs and methods. *Syst. Rev.* **2012**, doi:10.1186/2046-4053-1-28.
11. Bijker, W.; Hughes, T.P.; Pinch, T. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*; MIT Press: Cambridge, MA, USA, 1987.
12. Elzen, B.; Geels, F.W.; Green, K. *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy*; Edward Elgar Publishing: Cheltenham, UK, 2004.
13. Geels, F.W. Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Res. Policy* **2002**, *31*, 1257–1274.
14. Rotmans, J.; Kemp, R.; van Asselt, M. More evolution than revolution. Transition management in public policy. *Foresight* **2001**, *3*, 15–31.
15. Kemp, R.; Schot, J.; Hoogma, R. Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technol. Anal. Strateg. Manag.* **1998**, *10*, 175–198.
16. Bergek, A.; Jacobsson, S.; Carlsson, B.; Lindmark, S.; Rickne, A. Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Res. Policy*. **2008**, *37*, 407–429.
17. Holling, C.S. Resilience and stability of ecological systems. *Annu. Rev. Ecol. Syst.* **1973**, *4*, 1–23.
18. Folke, C.; Carpenter, S.; Elmqvist, T.; Gunderson, L.; Holling, C.; Walker, B. Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations. *AMBIO J. Hum. Environ*. **2002**, *31*, 437–440.
19. Walker, B.; Holling, C.S.; Carpenter, S.R.; Kinzig, A. Resilience, Adaptability and Transformability in Social-ecological Systems. *Ecol. Soc.* **2004**, *9*, Article 5.
20. Gunderson, L.H.; Holling, C.S. *Panarchy: Understanding Transformations in Human and Natural Systems*; Island Press: Washington, DC, USA, 2002.
21. Folke, C.; Carpenter, S.R.; Walker, B.; Scheffer, M.; Chapin, T.; Rockström, J. Resilience Thinking: Integrating Resilience, Adaptability and Transformability. *Ecol. Soc.* **2010**, *15*, Article 20.
22. Ernstson, H.; Leeuw, S.E. van der Redman, C.L.; Meffert, D.J.; Davis, G.; Alfsen, C.; Elmqvist, T. Urban Transitions: On Urban Resilience and Human-Dominated Ecosystems. *Ambio* **2010**, *39*, 531–545.
23. Mader, C. Sustainability process assessment on transformative potentials: The Graz Model for Integrative Development. *J. Clean. Prod.* **2013**, *49*, 54–63.
24. Roggema, R.; Vermeend, T.; Dobbelsteen, A. Incremental Change, Transition or Transformation? Optimising Change Pathways for Climate Adaptation in Spatial Planning. *Sustainability* **2012**, *4*, 2525–2549.
25. Newton, P.W. *Transitions: Pathways Towards Sustainable Urban Development in Australia*; CSIRO Pub: Collingwood, UK, 2008.

26. Geels, F.W. The role of cities in technological transitions—Analytical clarifications and historical examples. In *Cities and Low Carbon Transitions*; Bulkeley, H., Castán Broto, V., Hodson, M., Marvin, S., Eds.; Routledge: New York, NY, USA, 2011; pp. 13–28.
27. Raven, R.; Schot, J.; Berkhout, F. Space and scale in socio-technical transitions. *Environ. Innov. Soc. Transit.* **2012**, *4*, 63–78.
28. Bulkeley, H.; Castán Broto, V.; Hodson, M.; Marvin, S. *Cities and Low Carbon Transitions*; Routledge: New York, NY, USA, 2011.
29. Quitzau, M.-B.; Jensen, J.S.; Elle, M.; Hoffmann, B. Sustainable urban regime adjustments. *J. Clean. Prod.* **2013**, *50*, 140–147.
30. De Graaf, R.; van der Brugge, R. Transforming water infrastructure by linking water management and urban renewal in Rotterdam. *Technol. Forecast. Soc. Chang.* **2010**, *77*, 1282–1291.
31. Burch, S.; Shaw, A.; Dale, A.; Robinson, J. Triggering transformative change: A development path approach to climate change response in communities. *Clim. Policy* **2014**, *14*, 467–487.
32. Rotmans, J. A Complex Systems Approach for Sustainable Cities. In *Smart Growth and Climate Change: Regional Development, Infrastructure and Adaption.*; Ruth, M., Ed.; Edward Elgar: Cheltenham, UK, 2006; pp. 155–180.
33. Loorbach, D.; Rotmans, J. The practice of transition management: Examples and lessons from four distinct cases. *Futures* **2010**, *42*, 237–246.
34. Brown, R.R.; Farrelly, M.A.; Loorbach, D.A. Actors working the institutions in sustainability transitions: The case of Melbourne's stormwater management. *Glob. Environ. Chang.* **2013**, *23*, 701–718.
35. Wolfram, M.; Vogel, R. Governance and Design of Urban Infostructures: Analysing Key Socio-Technical Systems for the Vulnerability and Resilience of Cities. *Raumforsch. Raumordn.* **2012**, *70*, 323–336.
36. Frantzeskaki, N.; Wittmayer, J.; Loorbach, D. The role of partnerships in "realising" urban sustainability in Rotterdam's City Ports Area, the Netherlands. *J. Clean. Prod.* **2013**, *65*, 406–417.
37. Nevens, F.; Frantzeskaki, N.; Gorissen, L.; Loorbach, D. Urban Transition Labs: Co-creating transformative action for sustainable cities. *J. Clean. Prod.* **2012**, *50*, 111–122.
38. Wiek, A.; Scholz, R.; Lang, D.; Stauffacher, M.; Walter, A. *Grundlagen des Transition-Managements von Regionen. Systemanalyse, Variantenkonstruktion, Bewertung Ein Handbuch*; Natural and Social Science Interface; Swiss Federal Institute of Technology: Zürich, Switzerland, 2003.
39. Eames, M.; Egmose, J. Community foresight for urban sustainability: Insights from the Citizens Science for Sustainability (SuScit) project. *Technol. Forecast. Soc. Chang.* **2011**, *78*, 769–784.
40. Bai, X.; Roberts, B.; Chen, J. Urban sustainability experiments in Asia: Patterns and pathways. *Environ. Sci. Policy* **2010**, *13*, 312–325.
41. Schreuer, A.; Ornetzeder, M.; Rohracher, H. Negotiating the local embedding of socio-technical experiments: A case study in fuel cell technology. *Technol. Anal. Strateg. Manag.* **2010**, *22*, 729–743.
42. Davies, A. *Enterprising Communities: Grassroots Sustainability Innovations*; Advances in Ecopolitics; Emerald: Bingley, UK, 2012.
43. Seyfang, G.; Haxeltine, A. Growing grassroots innovations: Exploring the role of community-based initiatives in governing sustainable energy transitions. *Environ. Plan. C Gov. Policy* **2012**, *30*, 381–400.
44. Smith, A.; Seyfang, G. Constructing grassroots innovations for sustainability. *Glob. Environ. Chang.* **2013**, *23*, 827–829.
45. Quitzau, M.-B.; Hoffmann, B.; Elle, M. Local niche planning and its strategic implications for implementation of energy-efficient technology. *Technol. Forecast. Soc. Chang.* **2012**, *79*, 1049–1058.
46. Maassen, A. Heterogeneity of Lock-In and the Role of Strategic Technological Interventions in Urban Infrastructural Transformations. *Eur. Plan. Stud.* **2012**, *20*, 441–460.
47. Aylett, A. Networked urban climate governance: Neighborhood-scale residential solar energy systems and the example of Solarize Portland. *Environ. Plan. C Gov. Policy* **2013**, *31*, 858–875.
48. Hekkert, M.P.; Negro, S.O. Functions of innovation systems as a framework to understand sustainable technological change: Empirical evidence for earlier claims. *Technol. Forecast. Soc. Chang.* **2009**, *76*, 584–594.
49. Truffer, B.; Murphy, J.T.; Raven, R. The geography of sustainability transitions contours of an emerging theme. *Environ. Innov. Soc. Transit.* **2015**, *17*, 63–72.
50. Coenen, L.; Benneworth, P.; Truffer, B. Toward a spatial perspective on sustainability transitions. *Res. Policy* **2012**, *41*, 968–979.

51. Carvalho, L.; Mingardo, G.; van Haaren, J. Green Urban Transport Policies and Cleantech Innovations: Evidence from Curitiba, Göteborg and Hamburg. *Eur. Plan. Stud.* **2012**, *20*, 375–396.
52. Dewald, U.; Truffer, B. The Local Sources of Market Formation: Explaining Regional Growth Differentials in German Photovoltaic Markets. *Eur. Plan. Stud.* **2012**, *20*, 397–420.
53. Cooke, P. Regional innovation systems: Development opportunities from the "green turn". *Technol. Anal. Strateg. Manag.* **2010**, *22*, 831–844.
54. Cooke, P. Transition regions: Regional–national eco-innovation systems and strategies. *Prog. Plan.* **2011**, *76*, 105–146.
55. Lahlou, S. *System Innovation for Sustainability 4: Case Studies in Sustainable Consumption and Production—Energy Use and the Built Environment*; Greenleaf Pub.: Sheffield, UK, 2011.
56. McCauley, S.M.; Stephens, J.C. Green energy clusters and socio-technical transitions: Analysis of a sustainable energy cluster for regional economic development in Central Massachusetts, USA. *Sustain. Sci.* **2012**, *7*, 213–225.
57. Reusswig, F. Sustainability Transitions Through the Lens of Lifestyle Dynamics. In *Sustainable Production Consumption Systems*; Lebel, L., Lorek, S., Daniel, R., Eds.; Springer: Berlin, Germany, 2010; pp. 39–59.
58. Pincetl, S. Nature, urban development and sustainability—What new elements are needed for a more comprehensive understanding? *Cities* **2012**, *29*, S32–S37.
59. Wilson, G.A. Community resilience, globalization, and transitional pathways of decision-making. *Geoforum* **2012**, *43*, 1218–1231.
60. Pickett, S.T.A.; Boone, C.G.; McGrath, B.P.; Cadenasso, M.L.; Childers, D.L.; Ogden, L.A.; McHale, M.; Grove, J.M. Ecological science and transformation to the sustainable city. *Cities* **2013**, *32*, S10–S20.
61. Cole, R.J.; Oliver, A.; Robinson, J. Regenerative design, socio-ecological systems and co-evolution. *Build. Res. Inf.* **2013**, *41*, 237–247.
62. Desouza, K.C.; Flanery, T.H. Designing, planning, and managing resilient cities: A conceptual framework. *Cities* **2013**, *35*, 89–99.
63. Jabareen, Y. Planning the resilient city: Concepts and strategies for coping with climate change and environmental risk. *Cities* **2013**, *31*, 220–229.
64. Lu, P.; Stead, D. Understanding the notion of resilience in spatial planning: A case study of Rotterdam, The Netherlands. *Cities* **2013**, *35*, 200–212.
65. Van der Voorn, T. Combining backcasting and adaptive management for climate adaptation in coastal regions: A methodology and a South African case study. *Futures* **2012**, *44*, 346–364.
66. Boyd, E.; Ghosh, A. Innovations for enabling urban climate governance: Evidence from Mumbai. *Environ. Plan. C Gov. Policy* **2013**, *31*, 926–945.
67. Peters, M.D.; Fudge, S.; Jackson, T. *Low Carbon Communities: Imaginative Approaches to Combating Climate Change Locally*; Edward Elgar: Cheltenham, UK, 2012.
68. Fainstein, S. S.; Campbell, S.; (Eds.) *Readings in Planning Theory*, 3rd ed.; Wiley-Blackwell: Malden, MA, USA, 2012.
69. Harding, A.; Blokland, T. *Urban Theory*; SAGE Publication Ltd: Thousand Oaks, CA, USA, 2014.
70. Healey, P. Planning through Debate: The Communicative Turn in Planning Theory. *Town Plan. Rev.* **1992**, *62*, 143–162.
71. Albrechts, L. Strategic (spatial) planning reexamined. *Environ. Plan. B Plan. Des.* **2004**, *31*, 743–758.
72. de Roo, G.; Silva, E.A. *A Planner's Encounter with Complexity*; Ashgate: Farnham, UK; Burlington, VT, USA, 2010.
73. Murdoch, J. *Post-Structuralist Geography: A Guide to Relational Space*; SAGE: London, UK; Thousand Oaks, CA, USA, 2006.
74. Davoudi, S.; Strange, I.; (Eds.) *Conceptions of Space and Place in Strategic Spatial Planning*; Routledge: New York, NY, USA, 2009.
75. Sassen, S. *The Global City?: New York, London, Tokyo*, 2nd ed.; Princeton University Press: Princeton, NJ, USA, 1991.
76. Castells, M. *The Rise of the Network Society*; 2nd ed.; Blackwell Publishers: Oxford, UK, 2000.
77. Brenner, N. *New State Spaces: Urban Governance and the Rescaling of Statehood*; Oxford University Press: Oxford, UK, 2004.
78. Smith, A.; Voß, J.-P.; Grin, J. Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Res. Policy* **2010**, *39*, 435–448.

79. Truffer, B.; Coenen, L. Environmental Innovation and Sustainability Transitions in Regional Studies. *Reg. Stud.* **2012**, *46*, 1–21.
80. Essletzbichler, J. Renewable Energy Technology and Path Creation: A Multi-scalar Approach to Energy Transition in the UK. *Eur. Plan. Stud.* **2012**, *20*, 791–816.
81. Gavin Bridge; Bouzarovski, S.; Bradshaw, M.; Eyre, N. Geographies of energy transition: Space, place and the low-carbon economy. *Energy Policy* **2013**, *53*, 331–340.
82. Guy, S.; Marvin, S.; Moss, T. *Urban Infrastructure in Transition: Networks, Buildings, Plans*; Earthscan Publication: London, UK; Sterling, VA, USA, 2001.
83. Monstadt, J. Conceptualizing the political ecology of urban infrastructures: Insights from technology and urban studies. *Environ. Plan. A* **2009**, *41*, 1924–1942.
84. Burch, S.; Schroeder, H.; Rayner, S.; Wilson, J. Novel multisector networks and entrepreneurship: The role of small businesses in the multilevel governance of climate change. *Environ. Plan. C Gov. Policy* **2013**, *31*, 822–840.
85. Späth, P.; Rohracher, H. Local Demonstrations for Global Transitions—Dynamics across Governance Levels Fostering Socio-Technical Regime Change Towards Sustainability. *Eur. Plan. Stud.* **2012**, *20*, 461–479.
86. Uyarra, E.; Gee, S. Transforming urban waste into sustainable material and energy usage: The case of Greater Manchester (UK). *J. Clean. Prod.* **2012**, *50*, 101–110.
87. Truffer, B.; Störmer, E.; Maurer, M.; Ruef, A. Local strategic planning processes and sustainability transitions in infrastructure sectors. *Environ. Policy Gov.* **2010**, *20*, 258–269.
88. Hodson, M.; Marvin, S. Can cities shape socio-technical transitions and how would we know if they were? *Res. Policy* **2010**, *39*, 477–485.
89. Guy, S.; Marvin, S.; Medd, W.; Moss, T. *Shaping Urban Infrastructures: Intermediaries and the Governance of Socio-Technical Networks*; Earthscan: London, UK; Washington, DC, USA, 2011.
90. Bulkeley, H.; Castán Broto, V.; Edwards, G. Bringing climate change to the city: Towards low carbon urbanism? *Local Environ.* **2012**, *17*, 545–551.
91. Hamann, R.; April, K. On the role and capabilities of collaborative intermediary organisations in urban sustainability transitions. *J. Clean. Prod.* **2013**, *50*, 12–21.
92. Castán Broto, V.; Bulkeley, H. A survey of urban climate change experiments in 100 cities. *Glob. Environ. Chang.* **2013**, *23*, 92–102.
93. Rydin, Y.; Turcu, C.; Guy, S.; Austin, P. Mapping the coevolution of urban energy systems: Pathways of change. *Environ. Plan. A* **2013**, *45*, 634–649.
94. Khan, J. What role for network governance in urban low carbon transitions? *J. Clean. Prod.* **2013**, *50*, 133–139.
95. Domènech, L.; Saurí, D. Socio-technical transitions in water scarcity contexts: Public acceptance of greywater reuse technologies in the Metropolitan Area of Barcelona. *Resour. Conserv. Recycl.* **2010**, *55*, 53–62.
96. Young, R. The greening of Chicago: Environmental leaders and organisational learning in the transition toward a sustainable metropolitan region. *J. Environ. Plan. Manag.* **2010**, *53*, 1051–1068.
97. Scerri, A.; Holden, M. Ecological Modernization or Sustainable Development? Vancouver's "Greenest City Action Plan": The City as "manager" of Ecological Restructuring. *J. Environ. Policy Plan.* **2014**, *16*, 261–279.
98. Späth, P.; Rohracher, H. "Energy regions": The transformative power of regional discourses on socio-technical futures. *Res. Policy* **2010**, *39*, 449–458.
99. Hodson, M.; Marvin, S.; Bulkeley, H. The Intermediary Organisation of Low Carbon Cities: A Comparative Analysis of Transitions in Greater London and Greater Manchester. *Urban Stud.* **2013**, *50*, 1403–1422.
100. Innes, J.E.; Booher, D.E. Consensus Building and Complex Adaptive Systems: A Framework for Evaluating Collaborative Planning. *J. Am. Plan. Assoc.* **1999**, *65*, 412–423.
101. Healey, P. *Urban Complexity and Spatial Strategies: Towards a Relational Planning for Our Times*; Routledge: London, UK; New York, NY, USA, 2007.
102. Rauws, W.S.; de Roo, G. Exploring Transitions in the Peri-Urban Area. *Plan. Theory Pract.* **2011**, *12*, 269–284.
103. Portney, K.E. Sustainability in American Cities: A comprehensive look at what cities are doing and why. In *Toward Sustainable Communities, Transition and transformations in Environmental Policy*; MIT Press: Cambridge, MA, USA, 2009.
104. Hagelskjær Lauridsen, E.; Stissing Jensen, J. The strictest energy requirements in the world: An analysis of the path dependencies of a self-proclaimed success. *Energy Policy* **2013**, *53*, 97–104.

105. Næss, P.; Vogel, N. Sustainable urban development and the multi-level transition perspective. *Environ. Innov. Soc. Transit.* **2012**, *4*, 36–50.
106. Shove, E.; Walker, G. Governing transitions in the sustainability of everyday life. *Res. Policy* **2010**, *39*, 471–476.
107. Cooke, P.; Rehfeld, D. Path Dependence and New Paths in Regional Evolution: In Search of the Role of Culture. *Eur. Plan. Stud.* **2011**, *19*, 1909–1929.
108. Mulugetta, Y.; Jackson, T.; van der Horst, D. Carbon reduction at community scale. *Energy Policy* **2010**, *38*, 7541–7545.
109. Marsden, T. Sustainable place-making for sustainability science: The contested case of agri-food and urban–rural relations. *Sustain. Sci.* **2013**, *8*, 213–226.
110. Späth, P. Understanding the Social Dynamics of Energy Regions—The Importance of Discourse Analysis. *Sustainability* **2012**, *4*, 1256–1273.
111. Mason, K.; Whitehead, M. Transition Urbanism and the Contested Politics of Ethical Place Making. *Antipode* **2012**, *44*, 493–516.
112. Neal, S. Transition culture: Politics, localities and ruralities. *J. Rural Stud.* **2013**, *32*, 60–69.
113. Brown, G.; Kraftl, P.; Pickerill, J.; Upton, C. Holding the future together: Towards a theorisation of the spaces and times of transition. *Environ. Plan. A* **2012**, *44*, 1607–1623.
114. Taylor, P.J. Transition towns and world cities: Towards green networks of cities. *Local Environ.* **2012**, *17*, 495–508.
115. North, P.; Longhurst, N. Grassroots Localisation? The Scalar Potential of and Limits of the "Transition" Approach to Climate Change and Resource Constraint. *Urban Stud.* **2013**, *50*, 1423–1438.
116. Wiek, A.; Binder, C.; Scholz, R.W. Functions of scenarios in transition processes. *Futures* **2006**, *38*, 740–766.
117. Scholz, R.W. *Environmental Literacy in Science and Society: From Knowledge To Decisions*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2011.
118. Mieg, H.A.; Töpfer, K. *Institutional and Social Innovation for Sustainable Urban Development*; Routledge: Abingdon, UK; New York, NY, USA, 2013.
119. North, P. Knowledge exchange, "impact" and engagement: Exploring low-carbon urban transitions. *Geogr. J.* **2013**, *179*, 211–220.
120. Brandt, P.; Ernst, A.; Gralla, F.; Luederitz, C.; Lang, D.J.; Newig, J.; Reinert, F.; Abson, D.J.; von Wehrden, H. A review of transdisciplinary research in sustainability science. *Ecol. Econ.* **2013**, *92*, 1–15.
121. Lang, D.J.; Wiek, A.; Bergmann, M.; Stauffacher, M.; Martens, P.; Moll, P.; Swilling, M.; Thomas, C.J. Transdisciplinary research in sustainability science: Practice, principles, and challenges. *Sustain. Sci.* **2012**, *7*, 25–43.
122. Childers, D.L.; Pickett, S.T.A.; Grove, J.M.; Ogden, L.; Whitmer, A. Advancing urban sustainability theory and action: Challenges and opportunities. *Landsc. Urban Plan*. **2014**, 125, 320–328.
123. Nevens, F.; Roorda, C. A climate of change: A transition approach for climate neutrality in the city of Ghent (Belgium). *Sustain. Cities Soc.* **2014**, *10*, 112–121.
124. Pacione, M. *Urban Geography: A Global Perspective*, 3rd ed.; Routledge: London, UK; New York, NY, USA, 2009.
125. Mieg, H.A. Introduction. In *Institutional and Social Innovation for Sustainable Urban Development*; Mieg, H.A., Töpfer, K., Eds.; Routledge: Abingdon, UK; New York, NY, USA, 2013; pp. 1–21.
126. Hodson, M.; Marvin, S. Mediating Low-Carbon Urban Transitions? Forms of Organization, Knowledge and Action. *Eur. Plan. Stud.* **2012**, *20*, 421–439.
127. Seyfang, G.; Smith, A. Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environ. Polit.* **2007**, *16*, 584–603.
128. Geels, F.W. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Res. Policy* **2010**, *39*, 495–510.
129. Smith, A.; Stirling, A. The Politics of Social-ecological Resilience and Sustainable Sociotechnical Transitions. *Ecol. Soc.* **2010**, *15*, Article 11.
130. Loorbach, D. *To Transition! Governance Panarchy in the New Transformation*; Dutch Research Institute for Transitions: Rotterdam, NL, USA, 2014.
131. McGinnis, M.D.; Ostrom, E. Social-ecological system framework: Initial changes and continuing challenges. *Ecol. Soc.* **2014**, doi:10.5751/ES-06387-190230.