2. Evaluating Transformative Innovation Policy Outcomes as Unfolding Processes Of Change In Socio-Technical Configurations

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2.1. Introduction

According to recent literature, a new, transformative innovation policy (TIP) paradigm is emerging, which implies a shift in focus from economic growth to addressing broad societal goals and 'grand challenges.'[3] The new paradigm

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3. Gijs Diercks, Henrik Larsen, and Fred Steward, 'Transformative innovation policy: Addressing variety in an emerging policy paradigm.' *Research Policy* 48, no. 4 (May 2019): 880–94. https://doi.org/10.1016/j.respol.2018.10.028; Jan Fagerberg, 'Mobilizing innovation for sustainability transitions: A comment on transformative innovation policy,' *Research Policy* 47, no. 9 (November 2018): 1568–76. https://doi.org/10.1016/j.respol.2018.08.012; Johan Schot and W. Edward Steinmueller, 'Three frames for innovation policy: R&D, systems of innovation and transformative change,' *Research Policy* 47, no. 9 (August 2018): 1554–67. https://doi.org/10.1016/j.respol.2018.08.011

comes with a broader view of the innovation process, building on writings on sustainability transitions (e.g., the multi-level perspective),[4] and additional rationales for policy intervention in innovation processes, such as transformational systems failures.[5] This indicates a shift in policy theory, which also needs to be reflected in policy evaluation.[6] However, evaluation practises are still very much based on a linear view of the innovation process,[7] with a focus on policy outputs rather than outcomes or final impacts.[8] As such, TIP implies several challenges for policy evaluation.[9] Most notably, a TIP-oriented evaluation framework would have to address (i) directionality and (ii) behavioural additionality.

Regarding directionality, TIP implies that there is a much clearer view of the intended impact of a policy intervention than in previous policy paradigms in that it targets a particular societal challenge or socio-technical transition rather than innovation in general. Indeed, the TIP paradigm implies a shift towards purposive and directional innovation.[10] Instead of considering all innovation outcomes as equally good, as in previous paradigms, TIP emphasises the need to assess whether achieved innovation outcomes are sustainable or not and whether innovation policy contributes to addressing specific societal

4. Frank W. Geels, 'Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study,' *Research Policy* 31, no. 8–9 (December 2002): 1257–74. https://doi.org/10.1016/S0048-7333(02)00062-8

5. K. Matthias Weber and Harald Rohracher, 'Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive "failures" framework,' *Research Policy* 41, no. 6 (July 2012): 1037–47. https://doi.org/10.1016/j.respol.2011.10.015

6. Jordi Molas-Gallart and Andrew Davies, 'Toward theory-led evaluation: The experience of European science, technology, and innovation policies,' *American Journal of Evaluation* 27, no. 1 (March 2006): 64–82. https://doi.org/10.1177%2F1098214005281701

7. Effie Amanatidou, et al., 'Using Evaluation Research as a Means for Policy Analysis in a 'New' Mission-Oriented Policy Context,' *Minerva* 52 (December 2014): 419–38. https://doi.org/10.1007/s11024-014-9258-x; Molas-Gallart and Davies, 'Toward theory-led evaluation.'

8. You-Na Lee, 'Evaluating and extending innovation indicators for innovation policy,' *Research Evaluation* 24, no. 4 (October 2015): 471–88. https://doi.org/10.1093/reseval/rvv017

9. Amanatidou, et al., 'Using Evaluation Research;' Carolina R. Haddad, et al., 'Transformative innovation policy: A systematic review,' *Environmental Innovation and Societal Transitions* 43 (June 2022): 14–40. https://doi.org/10.1016/j.eist.2022.03.002

10. Diercks, Larsen, and Steward, 'Transformative innovation policy;' Weber and Rohracher, 'Research, technology and innovation.'

needs, demands, and challenges.[11] Therefore, directionality is about addressing neglected questions such as 'which way?' 'who says?' and 'why?' and not only 'yes or no?' 'how much?' and 'how fast?'[12] However, how to incorporate directionality in policy evaluation remains understudied. While several authors acknowledge the need to address 'directionality failures,'[13] few provide any details on how to operationalise it apart from assessing the capacity of the actors in the targeted system to build a shared vision[14] or investigating the challenges that emerge from actors' interests and capabilities, networks, and institution.[15]

In turn, the concept of behavioural additionality refers to the assessment of actor changes (i.e., firm) behaviour following a policy intervention and was proposed to address perceived shortcomings of traditional input-output evaluation.[16] In a TIP context, behavioural change should, however, not only be studied at the level of firms but also at the system level.[17] Accordingly, evaluations should focus on explaining how specific interventions cause certain intended and unintended impacts on targeted systems and also take feedback loops between policy outputs, outcomes,

11. Jakob Edler and Wouter P. Boon, '"The next generation of innovation policy: Directionality and the role of demand-oriented instruments"—Introduction to the special section,' *Science and Public Policy* 45, no. 4 (August 2018): 433–34. https://doi.org/10.1093/scipol/scy026; Weber and Rohracher, 'Research, technology and innovation.'

12. Andy Stirling, *Direction, distribution and diversity! Pluralising progress in innovation, sustainability and development* (Brighton: STEPS Centre, 2009).

13. Weber and Rohracher, 'Research, technology and innovation.'

14. Markus Bugge, et al., 'Governing system innovation: assisted living experiments in the UK and Norway,' *European Planning Studies* 25, no. 12 (July 2017): 2138–56. https://doi.org/10.1080/09654313.2017.1349078; Markus M. Bugge, Lars Coenen, and Are Branstad, 'Governing socio-technical change: Orchestrating demand for assisted living in ageing societies,' *Science and Public Policy* 45, no 4 (February 2018): 468–79. https://doi.org/10.1093/scipol/scy010; Lisa Scordato, et al., 'Policy mixes for the sustainability transition of the pulp and paper industry in Sweden,' *Journal of Cleaner Production* 183 (May 2018): 1216–27. https://doi.org/10.1016/j.jclepro.2018.02.212

15. Markus Grillitsch, et al., 'Innovation policy for system-wide transformation: The case of strategic innovation programmes (SIPs) in Sweden,' *Research Policy* 48, no. 4 (May 2019): 1048–61. https://doi.org/10.1016/j.respol.2018.10.004

16. See for example: Timothy J. Buisseret, Hugh M. Cameron, and Luke Georghiou, 'What difference does it make? Additionality in the public support of R&D in large firms,' *International Journal of Technology Management* 10, no. 4–6 (1995): 587–600. http://bitly.ws/rnoq. Also check: Luke Georghiou and Bart Clarysse, 'Introduction and Synthesis,' in *Government R&D Funding and Company Behaviour: Measuring Behavioural Additionality*, ed. OECD (Paris: OECD Publishing, 2006), 9–38.

17. Abdullah Gök. *Evolutionary Approach to Innovation Policy Evaluation: Behavioural Additionality and Organisational Routines*. PhD diss. University of Manchester, 2011. http://bitly.ws/rnbz and impacts into account.[18] Some frameworks have already been proposed for performing such systems analysis in relation to individual policy programmes or more complex policy mixes, drawing on key transition-related frameworks such as the multi-level perspective (MLP), strategic niche management (SNM), the technological innovation systems (TIS) approach, and/or combinations of these.[19] These previous attempts have highlighted important evaluation aspects but have two main shortcomings. First, they do not explicitly capture behavioural changes in all three dimensions of a targeted socio-technical configuration, i.e., socio-technical systems, actor networks, and institutions,[20] but rather focus on one or a few of them. Second, the more comprehensive frameworks combine different existing frameworks without considering conceptual overlaps between them, which has resulted in unclear distinctions between processes as well as notable redundancies.

Against this background, the purpose of this chapter is to identify a set of non-overlapping key transformative processes, which captures both directionality and behavioural additionality. We suggest that this set of processes can be used as a framework to evaluate the outcomes of transformative innovation policy in terms of changes in all three dimensions of targeted socio-technical configurations. For this purpose, we draw on the literature on innovation system functions and socio-technical transitions (MLP and SNM).

18. Amanatidou, et al., 'Using Evaluation Research;' Erick Arnold, et al., 'How should we evaluate complex programmes for innovation and socio- technical transitions?' Technopolis Group, June 15, 2018, http://bitly.ws/rnqi; Florian Kern and Karoline S. Rogge, 'Harnessing theories of the policy process for analysing the politics of sustainability transitions: A critical survey,' *Environmental Innovation and Societal Transitions* 27 (June 2018): 102–17. https://doi.org/10.1016/j.eist.2017.11.001

19. Examples of this are: Matthijs J. Janssen, 'What bangs for your buck? Assessing the design and impact of Dutch transformative policy,' *Technological Forecasting and Social Change* 138 (January 2019): 78–94. https://doi.org/10.1016/j.techfore.2018.08.011; Florian Kern, 'Using the multi-level perspective on socio-technical transitions to assess innovation policy,' *Technological Forecasting and Social Change* 79, no. 2 (February 2012): 298–310. https://doi.org/10.1016/j.techfore.2011.07.004; Paula, Kivimaa, Hanna-Liisa Kangas, and David Lazarevic, 'Client-oriented evaluation of "creative destruction" in policy mixes: Finnish policies on building energy efficiency transition,' *Energy Research & Social Science* 33 (November 2017): 115–27. https://doi.org/10.1016/j.erss.2017.09.002; Paula Kivimaa and Florian Kern, 'Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions,' *Research Policy* 45, no. 1 (February 2016): 205–17. https://doi.org/10.1016/j.respol.2015.09.008; Paula Kivimaa and Venla Virkamäki. 'Policy mixes, policy interplay and low carbon transitions: The case of passenger transport in Finland,' *Environmental Policy and Governance* 24, no. 1 (January 2014): 28–41. https://doi.org/10.1002/eet.1629; Scordato, et al., 'Policy mixes.'

20. Frank W. Geels, 'From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory,' *Research Policy* 33, no. 6–7 (September 2004): 897-920. https://doi.org/10.1016/j.respol.2004.01.015

2.2. Main Theoretical Building Blocks

In a general sense, policy evaluation 'is about comparing the intended and actual effects of public policies and can refer to insights regarding policy outcomes and/or impacts.'[21] We adopt a 'realistic' approach to evaluation that focuses on understanding both the outcomes and impacts of policy intervention, including its underlying processes and mechanisms.[22] The realistic approach combines elements from 'positivist' and 'constructivist' views on evaluation. The former sees the evaluator as an objective analyst of events and stresses the importance of basing evaluations on facts rather than value judgements.[23] In contrast, the latter defends the idea of multiple realities and the importance of focusing on the 'claims, concerns and issues of stakeholders,'[24] and sees the evaluator as more of a mediator and co-producer of social constructs.[25] Realistic evaluations are also theory-led, which in the context of innovation policy implies that the goals, outcomes, and impacts of the focal policy should be assessed in relation to relevant conceptualisations of innovation and its underlying processes and mechanisms.[26] Regarding transformative innovation policy, our opinion is that the most relevant conceptualisations are the three main frameworks used in the field of sustainability transitions: the multi-level perspective, strategic niche management, and technological innovation systems.[27] This is also in line with

21. Christoph Knill and Jale Tosun, *Public Policy: A New Introduction*, 1st ed. (London: Red Globe Press, 2012), 175.

22. Pawson, Ray, 'Evidence-based Policy: The Promise of "Realist Synthesis,"' *Evaluation* 8, no. 3 (July 2002): 340–58. https://doi.org/10.1177%2F135638902401462448; Pawson, Ray, *The Science of Evaluation: a Realist Manifesto*, (London: SAGE Publications, 2013); Pawson, Ray, and Tilley, Nicholas, *Realistic Evaluation*, (London: SAGE Publications, 1997).

23. Amanatidou, et al., 'Using Evaluation Research;' Christina A. Christie and Marvin C. Alkin, 'An Evaluation Theory Tree,' in *Evaluation Roots: A Wider Perspective of Theorists' Views and Influences*, 2nd edition, ed. Marvin C. Alkin (Thousand Oaks: SAGE Publications, 2013), 20–74.

24. Egon G. Guba and Yvonna S. Lincoln, *Fourth Generation Evaluation*. Thousand Oaks: SAGE Publications, 1989, 50.

25. Amanatidou, et al., 'Using Evaluation Research.'

26. Molas-Gallart and Davies, 'Toward theory-led evaluation.'

27. Jonathan Köhler, et al., 'An agenda for sustainability transitions research: State of the art and future directions,' *Environmental Innovation and Societal Transitions* 31 (June 2019): 1–32. https://doi.org/10.1016/j.eist.2019.01.004; Jochen Markard, Rob Raven, and Bernhard Truffer, 'Sustainability transitions: An emerging field of research and its prospects,' *Research Policy* 41, no. 6 (July 2012): 955–67. https://doi.org/10.1016/j.respol.2012.02.013. A fourth sustainability transitions-related framework, some of the previous attempts to develop an evaluation framework, as mentioned in the introduction.

The Multi-level Perspective (MLP)

In the MLP framework, transitions are conceptualised as major changes in the socio-technical configurations through which important sectoral societal functions are fulfilled,[28] which unfold at multiple levels: niche, regime, and landscape.[29] Since policy can mainly influence the niche and regime levels, we focus on these. On the one hand, socio-technical transitions are dependent on the development and upscaling of new technologies and solutions. In the transition literature, this is assumed to happen through the gradual build-up and institutionalisation of socio-technical 'niches.' Niches can be thought of as 'protected spaces' that temporarily shelter emerging innovations from mainstream selection pressures.[30] As such, they allow promising technologies to be developed and used in an experimental setting, where technology, user practises, and regulations can be explored in a co-evolutionary way,[31] and they can, thus, be seen as 'local breeding spaces for new technologies.'[32] On the other hand, the transitions literature emphasises the stability and inertia of established socio-technical configurations, which originate from socio-technical systems, actor networks, and regime rules.[33] Socio-technical transitions, therefore, require 'windows of opportunity' to open up the regime

transitions management, was excluded here since it prescribes a set of activities that policymakers should use to shape transitions but does not provide much guidance on how to describe and analyse transition processes as such.

28. Geels, 'Technological transitions;' Geels, 'Sectoral systems of innovation.'

29. Geels, 'Technological transitions.'

30. Adrian Smith and Rob Raven, 'What is protective space? Reconsidering niches in transitions to sustainability,' *Research Policy* 41, no. 6 (July 2012): 1025–36. https://doi.org/10.1016/j.respol.2011.12.012; Adrian Smith, Jean-Peter Voß, and John Grin, 'Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges,' *Research Policy* 39, no. 4 (May 2010): 435–48. https://doi.org/10.1016/j.respol.2010.01.023

31. Johan Schot and Frank W. Geels, 'Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy,' *Technology Analysis & Strategic Management* 20, no. 5 (October 2008): 537–54. https://doi.org/10.1080/09537320802292651

32. René Kemp, Johan Schot, and Remco Hoogma, 'Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management,' *Technology Analysis & Strategic Management* 10, no. 2 (January 1998): 185. https://doi.org/10.1080/09537329808524310

33. Geels, 'Sectoral systems of innovation.'

to allow niche innovations to breakthrough.[34] This implies that some (or all) elements of the established socio-technical configurations, and in particular the regime, have to be weakened.[35]

Taken together, this means that we need to consider both niche development and regime destabilisation processes when assessing the behavioural additionality of transformative innovation policies. Niche development processes are described in more detail in the strategic niche management framework and will, therefore, not be discussed more here. Regime destabilisation has recently begun to receive increased attention in the literature, and there are now a few frameworks that address this issue in more detail. Some of these associate regime-level change primarily with a weakening (or reconfiguration) of core regime rules,[36] while others also include changes in actor networks and/or socio-technical systems.[37]

While the sustainability transition notion implies a direction towards a more sustainable socio-technical configuration, extant literature does not provide much guidance on how to assess that directionality. However, it has been suggested that one way forward could be to identify '"the right" transformation pathway(s) ... for relevant (sub-)systems.'[38] Such pathways can, for example, be described in terms of four archetypes: transformation (re-orientation), technological substitution, de- and re-alignment, and reconfiguration.[39] According to Geels et al., these

34. Geels, 'Technological transitions.'

35. Bruno Turnheim and Frank W. Geels, 'The destabilisation of existing regimes: Confronting a multi-dimensional framework with a case study of the British coal industry (1913–1967),' *Research Policy* 42, no. 10 (December 2013): 1749–67. https://doi.org/10.1016/j.respol.2013.04.009

36. Bipashyee Ghosh and Johan Schot, 'Towards a novel regime change framework: Studying mobility transitions in public transport regimes in an Indian megacity,' *Energy Research & Social Science* 51 (May 2019): 82–95. https://doi.org/10.1016/j.erss.2018.12.001; Turnheim and Geels, 'The destabilisation of existing regimes.'

37. Kern, 'Using the multi-level perspective;' Kivimaa and Kern, 'Destruction or niche support?' David Lazarevic, Petrus Kautto, and Riina Antikainen, 'Finland's wood-frame multi-storey construction innovation system: Analysing motors of creative destruction,' *Forest Policy and Economics* 110 (January 2020): 101861. https://doi.org/10.1016/j.forpol.2019.01.006

38. Michael P. Schlaile, et al., 'Innovation systems for transformations towards sustainability? Taking the normative dimension seriously,' *Sustainability* 9, no. 12 (December 2017): 6. https://doi.org/10.3390/su9122253

39. Frank W. Geels, et al., 'The enactment of socio-technical transition pathways: A reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–

differ regarding the type and degree of change they imply in the targeted socio-technical configuration with regard to technology (e.g., incremental vs modular vs architectural/radical innovation), actor networks (e.g., the relative importance of new entrants vs established actors and the relationship between them (competitive vs collaborative or complementary), and institutions (e.g., whether new institutions replace existing ones or are added to them).[40]

Strategic Niche Management (SNM)

The SNM framework is closely related to the MLP but focuses mainly on the niche level. It involves a clear governance aspect in that it suggests that strategically managing niches is 'a possible (or even necessary) strategy for governments to manage the transition process to a different regime.'[41] An overall argument is that protected spaces are required for entrepreneurs and system builders to experiment with new technology in relation to user practises, demonstrate its viability, and attract funding- This also entails achieving the institutional adaptations needed to eventually allow for a widespread diffusion.[42]

There are several conceptualisations of niche development, including the early work by Kemp, Schot, and Hoogma[43] as well as later elaborations of their framework by other scholars that identify three main niche development processes: learning processes, articulation of expectations and visions, and the enrolment of commitments from a growing network of actors.[44] In more recent literature, three

2014),' *Research Policy* 45, no. 4 (May 2016): 896–913. https://doi.org/10.1016/j.respol.2016.01.015; Frank W. Geels and Johan Schot, 'Typology of socio-technical transition pathways,' *Research Policy* 36, no. 3 (April 2007): 399–417. https://doi.org/10.1016/j.respol.2007.01.003

40. According to the original framework, the pathways differ in terms of the timing and nature of the multi-level interactions involved.

41. Kemp, Schot, and Hoogma, 'Regime shifts to sustainability': 185.

42. Schot and Geels, 'Strategic niche management.'

43. Kemp, Schot, and Hoogma, 'Regime shifts to sustainability.'

44. Examples of this are: Frank Geels and Rob Raven, 'Non-linearity and Expectations in Niche-Development Trajectories: Ups and Downs in Dutch Biogas Development (1973–2003),' *Technology Analysis & Strategic Management* 18, no. 3-4 (August 2006): 375–92. https://doi.org/10.1080/09537320600777143; Schot and Geels, 'Strategic niche management;' Smith, Voß, and Grin, 'Innovation studies and sustainability.' Kemp, Schot, and Hoogma identified three aims of strategic niche management: (i) to articulate necessary technological and institutional changes and adaptations; (ii) to set learning processes in motion in relation to different technological options; (iii) to stimulate the development and diffusion of these and other, complementary technologies; and (iv) to build a semi-coordinated constituency around a new technology.

properties of niches as protected spaces have been identified, namely: shielding, nurturing, and empowering.[45] Shielding implies that niches protect the emerging innovation from selection pressures in the mainstream market or other relevant selection environments[46] and, thus, create a space for experimentation.[47] Nurturing corresponds to the three main niche development processes described above.[48] Third, empowering refers to different processes that improve the competitiveness of niche innovations and remove shielding. This occurs either by adapting the niche innovation to fit current selection environments (fit-and-conform processes) or by institutionalising shielding to make mainstream selection environments more agreeable to the niche innovation (i.e., stretch-and-transform processes).[49] Based on this framework, a number of subsequent articles have described, operationalised, and analysed niche-level processes in more detail. We draw on these writings to develop our framework in the next section.

In spite of its governance focus, the SNM framework primarily describes niche development as a bottom-up process without much clear directionality. However, as mentioned above, it considers the development of a common vision among niche stakeholders as an important part of that process. It also sheds some light on how niches can contribute to modifying transition pathways as it highlights some of the non-technical factors that lead to changes in the regime.[50]

Technological Innovation Systems (TIS)

The TIS framework builds on earlier work on technological systems, which focuses on the innovation performance of 'a network of agents interacting in a

45. Smith and Raven, 'What is protective space?'

46. Ibid.

47. Bram Verhees, et al., 'The development of solar PV in The Netherlands: A case of survival in unfriendly contexts,' *Renewable and Sustainable Energy Reviews* 19 (March 2013): 275–89. https://doi.org/10.1016/j.rser.2012.11.011

48. Rolf Naber, et al., 'Scaling up sustainable energy innovations,' *Energy Policy* 110 (November 2017): 342–54. https://doi.org/10.1016/j.enpol.2017.07.056; Rob Raven, et al., 'Niche construction and empowerment through socio-political work. A meta-analysis of six low-carbon technology cases,' *Environmental Innovation and Societal Transitions* 18 (March 2016): 164–80. https://doi.org/10.1016/j.eist.2015.02.002; Verhees, et al., 'The development of solar PV.'

49. Raven, et al., 'Niche construction and empowerment;' Verhees, et al., 'The development of solar PV.'

50. Schot and Geels, 'Strategic niche management.'

specific economic/industrial area.'[51] In the context of sustainability transitions, this framework has primarily been used to analyse the development and diffusion of emerging technologies in the energy and transport sectors.[52]

In the TIS literature, innovation outcomes have been conceptualised in both structural and functional terms. Some literature describes processes that contribute to the structural build-up of new systems such as actor entry, network formation, and institutional adaptation.[53] Regarding functionality, seven key processes have been identified that contribute to the development, diffusion, and utilisation of new technologies and, thus, to changes in the socio-technical system of a sector: (1) knowledge development and diffusion, (2) entrepreneurial experimentation, (3) guidance of the direction of search, (4) market formation, (5) legitimation, (6) resource mobilisation, and (7) development of positive externalities.[54] These are closely related to niche nurturing, as described in the SNM.[55]

Several frameworks use the functions as a basis for analysing the impact of policy on the innovation outcomes of specific innovation systems.[56] However, these frameworks do not address changes in established socio-technical

51. Bo Carlsson and Rikard Stankiewicz, 'On the nature, function and composition of technological systems,' *Journal of Evolutionary Economics* 1 (June 1991): 93–118. https://link.springer.com/article/10.1007/BF01224915

52. Anna Bergek, 'Technological Innovation Systems: a review of recent findings and suggestions for future research,' in *Handbook of Sustainable Innovation*, eds. Frank Boons and Andrew McMeekin (Cheltenham: Edvard Elgar Publishing, 2019), 200–18; Köhler, et al., 'An agenda for sustainability.'

53. Staffan Jacobsson and Anna Bergek, 'Transforming the energy sector: the evolution of technological systems in renewable energy technology,' *Industrial and Corporate Change* 13, no. 5 (October 2004): 815–49. https://doi.org/10.1093/icc/dth032; Staffan Jacobsson and Anna Johnson, 'The Diffusion of Renewable Energy Technology: An Analytical Framework and Key Issues for Research,' *Energy Policy* 28, no. 9 (July 2000): 625–40. https://doi.org/10.1016/S0301-4215(00)00041-0. Some authors also include the accumulation of knowledge and artifacts among the structural processes. Take for example: Anna Bergek, Staffan Jacobsson, and Björn A. Sandén, '"Legitimation" and "development of positive externalities": Two key processes in the formation phase of technological innovation systems,' *Technology Analysis and Strategic Management* 20, no. 5 (September 2008): 575–92. https://doi.org/10.1080/09537320802292768

54. Anna Bergek, et al., 'Analyzing the functional dynamics of technological innovation systems: A scheme of analysis,' *Research Policy* 37, no. 3 (April 2008): 407–29. https://doi.org/10.1016/j.respol.2007.12.003

55. Smith and Raven, 'What is protective space?'

56. Staffan Jacobsson and Eugenia Perez Vico, 'Towards a systemic framework for capturing and explaining the effects of academic R&D,' *Technology Analysis and Strategic Management* 22, no. 7 (September 2010): 765–87. https://doi.org/10.1080/09537325.2010.511140; Janssen, 'What bangs for your buck?' Kivimaa and Virkamäki, 'Policy mixes, policy interplay.'

configurations. Moreover, like most other innovation system approaches, the current conceptualisation of the TIS framework does not contain any explicit element of directionality apart from the researcher's choice of which technologies to analyse. In fact, for the most part, it treats all innovation outcomes as essentially positive and does not necessarily consider their relevance for solving important societal challenges.[57] Recently, some attempts to conceptualise directionality have been made, for example in the form of mission-oriented innovation systems,[58] but, as discussed in the next section, these do not exploit the full potential of the functions framework to incorporate directionality.

Summary

As the review in this section shows, capturing behavioural additionality involves analysing a broad set of potential innovation outcomes that span several dimensions of the focal sectoral socio-technical configuration (i.e., socio-technical system, actor networks, and rules) as well as different levels of analysis (i.e., niche and regime). It also has both structural and functional features. MLP, SNM, and TIS have all identified relevant processes that can be used for this purpose, sometimes overlapping and complementing each other. Therefore, we suggest that it would be useful to integrate previous conceptualisations into one comprehensive evaluation framework.

2.3. Suggested Framework: Three Clusters of Transformative Processes

We define a transition as a reconfiguration of the socio-technical configuration that is associated with the social sector targeted by a particular transformative policy intervention, which is to be evaluated. Since this configuration is defined at the sectoral level, it might contain several more or less distinct technologies, actor networks, and sets of institutions, which can be analysed both as one system and as different sub-systems depending on the focus of the evaluation.

57. Schot and Steinmueller, 'Three frames for innovation;' Weber and Rohracher, 'Research, technology and innovation.'

58. Marko P., Hekkert, et al., 'Mission-oriented innovation systems,' *Environmental Innovation and Societal Transitions* 34 (March 2020): 76–79. https://doi.org/10.1016/j.eist.2019.11.011

In order to make a summative evaluation of the policy intervention in question, we need to assess its impact on the elements of the targeted socio-technical configuration – systems, actors, and institutions[59]– and compare it with the desired impact, as described in the implicit and explicit goals of the intervention and/or more general policy objectives. However, in a more formative evaluation setting – or an early transition phase – we argue that it is more relevant to trace the policy intervention's influence on a number of key intermediate transformative processes associated with each configuration element. As mentioned in the previous section, we have used insights from the MLP, SNM, and TIS frameworks to identify a set of such processes. The potential to combine the MLP, SNM, and TIS approaches has been explored elsewhere.[60] Still, what distinguishes our approach is that we scrutinise each conceptualisation at the level of individual processes in order to create an integrated (i.e., non-overlapping) list of relevant transformative processes that could be used to assess the outcomes of a transformative innovation policy programme. It should be noted that the functions framework mainly contributes to knowledge about processes related to changes in the socio-technical system dimension. In contrast, the MLP and SNM frameworks mainly boost knowledge about processes resulting in changes in actor networks and institutions.

We integrate directionality in two ways. First, we add a 'directionality filter' to each function in order to be able to capture innovation processes related to different socio-technical systems within the sectoral configuration (established as well as emerging). This enables us to assess the innovation dynamics of different technologies and, thus, their relative rate of improvement, diffusion, and/or decline. Second, by explicitly considering changes in actor networks and institutions related to emerging as well as existing sub-configurations, we can assess the relative importance of new versus established actors and the type and degree of change happening in the institutional framework. Based on these

59. Geels, 'Sectoral systems of innovation.'

60. Kivimaa, Kangas, and Lazarevic, 'Client-oriented evaluation;' Jochen Markard and Bernhard Truffer, 'Technological innovation systems and the multi-level perspective: Towards an integrated framework,' *Research Policy* 37, no. 4 (May 2008): 596–615. https://doi.org/10.1016/j.respol.2008.01.004; Weber and Rohracher, 'Research, technology and innovation.'

directionality considerations, a preliminary evaluation can be made of whether the transition seems to be going in the 'right' direction in relation to policy goals and objectives (although this is not in focus here).

Socio-technical Systems

We assume that, in many cases, the main goal of a TIP intervention is to induce changes in a focal socio-technical system that needs to be replaced or reconfigured in order for the targeted sector to become more sustainable. This requires innovation both in terms of improvements in established technologies and the development and diffusion of new technologies. As described in the second section, this is captured well by innovation system functions,[61] which can be applied at different system levels (i.e., sectors as well as individual technologies or groups of related technologies)[62] and might be used to analyse innovation processes related to both new and emerging technology fields.[63] In our framework, we use them to examine all technologies that (potentially) contribute to the overall societal function of the sector. In the energy sector, for example, we would consider innovation (or lack thereof) in established technologies such as coal, nuclear, or hydropower as well as various less established technologies such as wind, solar, and marine power.

61. Bergek, 'Technological Innovation Systems;' Bergek, et al., 'Analyzing the functional dynamics;' It should be noted that several authors, as mentioned in the second section, have already used the functions as a basis for assessing the effects of policy. See for example: Janssen, 'What bangs for your buck?' Kivimaa and Kern, 'Destruction or niche support?' Lazarevic, Kautto, and Antikainen, 'Finland's wood-frame.'

62. Anna Bergek and Staffan Jacobsson, 'The Emergence of a Growth Industry: A Comparative Analysis of the German, Dutch and Swedish Wind Turbine Industries,' in *Change, Transformation and Development,* eds. J. Stan Metcalfe and Uwe Cantner (Heidelberg: Physica-Verlag, 2003), 197–227; Anna Johnson and Staffan Jacobsson, 'Inducement and Blocking Mechanisms in the Development of a New Industry: The Case of Renewable Energy Technology in Sweden,' In *Technology and the Market: Demand, Users and Innovation*, eds. Rod Coombs, et al. (Cheltenham/Northhampton: Edward Elgar, 2001), 89–112.

63. See for example: Bo Carlsson, ed., *Technological Systems and Economic Performance: The Case of Factory Automation* (Dordrecht: Kluwer Academic Publishers, 1995); Ulrich Dewald and Matthias Achternbosch, 'Why more sustainable cements failed so far? Disruptive innovations and their barriers in a basic industry,' *Environmental Innovation and Societal Transitions* 19 (June 2016): 15–30. https://doi.org/10.1016/j.eist.2015.10.001; Daniel Gabaldón Estevan and Marko P. Hekkert, 'How does the innovation system in the Spanish ceramic tile sector function?' *Boletín de la Sociedad Española de Cerámica y Vidrio* 52, no. 3 (April 2013): 151–58. http://dx.doi.org/10.3989/cyv.202013. Nevertheless, this contrasts with perspectives comparing TISs with (global) niches (see Smith and Raven, 'What is protective space?') or arguing that the functions framework is only useful for analyzing emerging technologies (see Markard and Truffer, 'Technological innovation systems.')

We depart from the list of functions presented by Bergek et al.[64] and further developed by Bergek[65] and Bergek et al.[66], which includes (1) the development and diffusion of knowledge within the system; (2) entrepreneurial experimentation to reduce technological, market, and political uncertainty; (3) the formation of markets; (4) guidance of actors' search processes; (5) mobilisation of financial, human, and physical resources; (6) legitimation of technologies and actors; and (7) the development of positive external economies (see TABLE 2, second column, for a detailed definition of each function). By analysing these processes, analysts – or evaluators – can identify functional system weaknesses as well as the influence of policy on each process, i.e., behavioural additionality. In the words of Janssen, '... policy contributions to the building of technological innovation systems are in fact the 'bangs' [for the buck] auditors and evaluators should be looking for.'[67] The functions can also capture what is going on in an innovation system long before any concrete outputs in terms of new technologies, products, or processes become visible and, therefore, allow for formative evaluation.[68]

When comparing this list with the niche-level shielding, nurturing, and empowering processes identified in the SNM literature and the regime destabilisation processes described in relation to the MLP framework, we find that almost all processes that refer to change in the socio-technical system are covered by the functions (see Appendix A).[69] Regarding shielding, technology-

64. Bergek, et al., 'Analyzing the functional dynamics.'

65. Bergek, 'Technological Innovation Systems.'

66. Anna Bergek, et al., 'Sustainability transitions in coastal shipping: The role of regime segmentation,' *Transportation Research Interdisciplinary Perspectives* 12 (December 2021): 100497. https://doi.org/10.1016/j.trip.2021.100497

67. Janssen, 'What bangs for your buck?': 79.

68. Anna Bergek, et al., 'Functionality of innovation systems as a rationale and guide in innovation policy,' in *The Theory and Practice of Innovation Policy,* eds. Ruud E. Smits, Stefan Kuhlmann, and Phillip Shapira (Cheltenham: Edward Elgar, 2010), 117–46.

69. This contradicts previous claims that the functions underplay the importance of shielding against mainstream selection pressures and cannot explain mass-market diffusion (See Smith and Raven, 'What is protective space?'; Smith, Voß, and Grin, 'Innovation studies and sustainability.') – at least as far as the socio-technical system is concerned. Note also that the dynamics of market formation (including the importance of nursing markets) is a recurring topic in the TIS literature (see Björn A. Andersson and Staffan Jacobsson, 'Monitoring and assessing technology choice: the case of solar cells,' *Energy Policy* 28, no. 14 (November 2000): 1037–49. https://doi.org/10.1016/S0301-4215(00)00090-2; Anna Bergek, 'Technological dynamics and policy: how to derive policy prescriptions,' (lecture, 3rd Lundvall Symposium: Innovation specific RD&D support is covered by the 'resource mobilisation' function and possibly also by the 'knowledge development and diffusion' and 'entrepreneurial experimentation' if the mobilised resources are used for that.[70] The creation and exploitation of 'real'[71] and policy-induced[72] niche markets are covered by 'market formation.' With regard to nurturing, research, development, prototyping, piloting, and demonstration of niche innovations are covered by the 'knowledge development and diffusion' and 'entrepreneurial experimentation' functions; public support for such activities[73] by 'resource mobilisation;' and learning between niches (at the level of the 'global' niche)[74] by 'knowledge development and diffusion.' Regarding empowering, both infrastructure changes[75] and public support targeting price-performance improvements[76] are included in 'resource mobilisation.'[77]

Similarly, most of the regime-level processes related to changes in a socio-technical system can be connected to the functions. Changes and improvements in established socio-technical systems are mainly related to 'resource mobilisation.' For example, public investment support or loans for

Policy - Can it Make a Difference? Ålborg, DK: University of Aalborg, January 2014); Anna Bergek, 'The role of entrepreneurship and markets for sustainable innovation,' in *Creating a sustainable economy: an institutional and evolutionary approach to environmental policy*, ed. Gerardo Marletto (Abingdon: Routledge, 2012), 205–30.

70. Kern, 'Using the multi-level perspective;' Raven, et al., 'Niche construction and empowerment;' Smith and Raven, 'What is protective space?'

71. Smith and Raven, 'What is protective space?' Raven, et al., 'Niche construction and empowerment;' Verhees, et al., 'The development of solar PV.'

72. Kern, 'Using the multi-level perspective;' Raven, et al., 'Niche construction and empowerment;' Smith and Raven, 'What is protective space?'

73. Kern, 'Using the multi-level perspective;' Verhees, et al., 'The development of solar PV.'

74. Smith and Raven, 'What is protective space?'

75. Bugge, et al., 'Governing system innovation;' Raven, et al., 'Niche construction and empowerment.'

76. Raven, et al., 'Niche construction and empowerment;' Kern, 'Using the multi-level perspective;' Verhees, et al., 'The development of solar PV.'

77. It should be noted that from an innovation system perspective, price-performance improvement, product and process innovations (see Bruno Turnheim and Frank W. Geels, 'Regime destabilisation as the flipside of energy transitions: Lessons from the history of the British coal industry (1913–1997),' *Energy Policy* 50 (November 2012): 35–49. https://doi.org/10.1016/j.enpol.2012.04.060; Turnheim and Geels, 'The destabilisation of existing regimes') and efficiency improvements are considered outputs of the innovation process rather than as transformative processes in themselves.

efficiency improvements[78] are covered by (financial) 'resource mobilisation,' and changes in existing infrastructures and production plants[79] or investments in new complementary infrastructure[80] are both covered by (physical) 'resource mobilisation.' Aspects of a strategic reorientation of incumbent actors that are covered by the functions include a build-up of new competences and skills[81] and new operations[82] that are embedded in (human and physical) resource mobilisation. In turn, the build-up of new knowledge[83] and replacement of existing knowledge[84] could be seen as 'knowledge development and diffusion.' In addition, diversification to new product markets[85] and experimentation with new technologies[86] are covered by 'guidance of the direction of search' and 'entrepreneurial experimentation' respectively. Finally, reduced resource flows to established technologies in the form of declining markets or shifts in investment patterns[87] can be captured by 'market formation' or 'guidance of the direction of search,' depending on how and why the reduction occurs.

In order for the foregoing connections to become apparent, we need to explicitly account for directionality in the functions so that we can see whether they support emerging or established technologies or both. In the original framework, directionality is mainly accounted for in the function 'guidance of the direction of search,' which includes the processes by which actors decide in what direction to search for new opportunities and to what technologies and markets they allocate their resources.[88] Yet, this does not fully capture all aspects of direction-

78. Kern, 'Using the multi-level perspective.'

79. Ibid.

80. Ghosh and Schot, 'Towards a novel regime change.'

81. Kivimaa and Kern, 'Destruction or niche support?' Turnheim and Geels, 'The destabilisation of existing regimes.'

82. Turnheim and Geels, 'The destabilisation of existing regimes.'

83. Ibid.

84. Kivimaa and Kern, 'Destruction or niche support?'

85. Turnheim and Geels, 'The destabilisation of existing regimes.'

86. Kivimaa, Kangas, and Lazarevic, 'Client-oriented evaluation;' Lazarevic, Kautto, and Antikainen, 'Finland's wood-frame.'

87. Turnheim and Geels, 'Regime destabilization;' Turnheim and Geels, 'The destabilisation of existing regimes.'

88. Bergek, et al., 'Analyzing the functional dynamics.'

ality described in the second section, as it mainly refers to supply-side actors. We, therefore, propose that a directionality filter should instead be applied to each function, reflecting an understanding of directionality as an emergent property of the functional dynamics of the system (i.e., a bottom-up perspective on directionality).[89] For example, instead of just describing knowledge development related to a particular technology, all knowledge development processes in the focal sector could be analysed with regard to whether they support established technologies or niche technologies (and which niche technologies). Similarly, the market formation could include an analysis of for which technologies markets are formed (and how). Due to space limitations, we refrain from discussing all the functions in the text, but a summary of the main directionality aspects for each function is presented in TABLE 2 (see the third column).[90]

TABLE 2. Transformative Processes (Functions) Related to Socio-technical Change.

Function	Description	Examples of directionality aspects
Knowledge development and diffusion	Broadening and deepening of the knowledge base of a TIS, sharing of knowledge between actors within the system, and new combinations of knowledge because of these processes.	For which technologies is knowledge developed? What technological/societal problems are knowledge development efforts targeting? By and for whom is knowledge developed?

89. See for example: Xiao-Shan Yap and Bernhard Truffer, 'Shaping selection environments for industrial catch-up and sustainability transitions: A systemic perspective on endogenizing windows of opportunity,' *Research Policy* 48, no. 4 (May 2019): 1030–47. https://doi.org/10.1016/j.respol.2018.10.002

90. Thus, in contrast to Hekkert, et al., 'Mission-oriented innovation systems,' we do not think it is necessary to introduce an entirely new system concept. Our notion of a sector-level innovation system also differs in other ways from their concept of 'mission-oriented innovation systems.' Most notably, in contrast to MIS a sector-level TIS is not limited to innovation activities aimed at specific societal challenges but captures the main innovation- and transitions-related processes in a particular societal sector. It therefore captures developments in different directions (including recreating the regime) and does not require these developments to be coordinated by policy makers or other actors.

Function	Description	Examples of directionality aspects
Entrepreneurial experimentation	Problem-solving and uncertainty reduction through real-world trial-and-error experiments at different scales with new technologies, applications, and strategies.	Which technologies are experimented with and why? Who is experimenting with what and why? What sources of uncertainty are experiments targeting?
Market formation	The opening up of a space or an arena in which goods and services can be exchanged in (semi-) structured ways between suppliers and buyers, e.g., articulation of demand and preferences, product positioning, standard-setting, and development of rules of exchange.	Which segments are expanding vs declining and why? What customer needs are articulated vs ignored and by whom? Which segments and technologies do actors' market strategies target?
Guidance of the direction of search	Mechanisms that influence the decision-making processes to allocate resources in firms and other organizations to incentivise or pressure innovative work in a particular field.	To which technologies are actors allocating their resources and why? To which technologies, markets, and business models are actors allocating their resources and why?
Resource mobilisation	The system's acquisition of different types of resources for the development, diffusion, and utilisation of new technologies, products, and processes, most notably capital, competence and manpower, and complementary assets (e.g., infrastructure).	To what extent is resource mobilisation generic or technology-specific? Which technologies benefit the most from current resource endowments and why? To what extent and how can new technologies exploit existing infrastructures and complementary technologies?
Legitimation	The process of gaining regulative, normative, and cognitive legitimacy for the new technology, its proponents, and the TIS as such in the eyes of relevant stakeholders, i.e., increasingly being perceived as complying with rules and regulations, societal norms, and values, and cognitive frames.	Which technologies and actors are gaining vs. losing legitimacy in the eyes of which stakeholders and why? Which regulations and support systems are gaining vs. losing legitimacy in the eyes of which stakeholders and why?

Function	Description	Examples of directionality aspects
Development of positive externalities	The creation of system-level utilities (or resources), such as pooled labour markets, complementary technologies, and specialised suppliers, which are available also to system actors that did not contribute to building them up.	Which technologies benefit from which externalities and why? Which actors benefit from which externalities and why? Which self-reinforcing mechanisms support or hinder different technologies?

Source: The second column was prepared by authors based on Bergek[91] and Bergek et al.[92] (which draw on Bergek et al.[93]). The third column is our own conceptualisation.

Actor Networks

As mentioned in the second section, the TIS framework includes structural dynamics, including changes in an actor network, but has mainly focused on the emergence of new systems (primarily in terms of entry of actors along the entire value chain). We, therefore, build this part of our framework mainly on the MLP and SNM frameworks (see Appendix A TABLES 5 and 6).[94]

With regard to the regime level, the entry of new firms into the market (with a resulting redistribution of market shares) can rattle incumbent actors and challenge their stable position (potentially to the point that they are forced to exit the market entirely).[95] Such new entrants can come from niches[96] or other industries or countries. A new entry can also be enabled by more fundamental, policy-driven market reforms (e.g., the liberalisation of the electricity market).[97] In addition, new partnerships might be formed between new or

91. Bergek, 'Technological Innovation Systems.'

92. Bergek, et al., 'Sustainability transitions.'

93. Bergek, et al., 'Analyzing the functional dynamics.'

94. As can be seen in Tables 5 and 6 (Appendix A), the processes we identify here are related to the functions in that they may influence them (but they do not have to). It should also be noted that while 'guidance of the direction of search' covers the emergence of incentives for actors to enter a niche- or regime-level actor network, their actual entry and the subsequent formation of networks are structural rather than functional processes.

95. Kern, 'Using the multi-level perspective;' Kivimaa and Kern, 'Destruction or niche support?' Turnheim and Geels, 'The destabilisation of existing regimes.'

96. Kern, 'Using the multi-level perspective.'

97. Turnheim and Geels, 'Regime destabilization.'

established market actors as a result of business model innovation.[98] Finally, the literature highlights the need to reduce the power of incumbent actors in policy networks, either by deliberately breaking up established networks or by developing new ones dedicated to system change.[99] The creation of change advocates within established organisations can also be a way to stimulate destabilisation of the policy system.[100]

As for the niche level, the SNM especially highlights the importance of enrolling commitments from a growing network of actors. For shielding, key processes include the involvement of strong actors that provide support and protection,[101] provision of technology-specific business support to new actors,[102] and the establishment of demand-side collective initiatives such as buying cooperatives.[103] In relation to nurturing, the literature emphasises the entry of powerful actors,[104] the formation of broad and deep networks[105] as well as 'global' networks to support cross-niche learning,[106] and fostering of a wider societal engagement, for example in terms of NGOs or academics.[107] Finally, regarding empowering, the formation and strengthening of powerful advocacy coalitions and networks, which can prevent the niche from being captured by vested interests and ensure protection, are key processes.[108] They could include the involvement of government bodies that enable niche upscaling.[109]

98. Ibid.

99. Kivimaa and Kern, 'Destruction or niche support?' Lazarevic, Kautto, and Antikainen, 'Finland's wood-frame.'

100. Lazarevic, Kautto, and Antikainen, 'Finland's wood-frame.'

101. Bugge, et al., 'Governing system innovation;'

102. Kern, 'Using the multi-level perspective;' Smith and Raven, 'What is protective space?' Raven, et al., 'Niche construction and empowerment.'

103. Raven, et al., 'Niche construction and empowerment.'

104. Kern, 'Using the multi-level perspective.'

105. Naber, et al., 'Scaling up sustainable energy innovations;' Verhees, et al., 'The development of solar PV.'

106. Smith and Raven, 'What is protective space?'

107. Kern, 'Using the multi-level perspective.'

108. Smith and Raven, 'What is protective space?'

109. Bugge, et al., 'Governing system innovation.'

If we synthesise these insights from the MLP and SNM frameworks, we can identify four main transformative processes related to changes in actor networks, which are relevant for both the niche and the regime level: entry of new actors; formation of new knowledge, technology, and business networks; configuration (and de-configuration) of political networks; and development of political capacity and change advocacy (see TABLE 3). To account for directionality, each of these processes should be analysed from the point of view of whether they strengthen established actor networks or work towards the establishment of new or fundamentally reconfigured networks in the focal sector.

TABLE 3. Transformative Processes (Outcomes) Related to Actor Networks (Synthesis)

Processes (outcomes)	Niche-level processes	Regime-level processes
Entry of new actors	Entry/involvement of powerful actors (including policy) to get support and allow for up-scaling. Generation of (and support to) new firms and businesses.	Entry of niche actors. Entry of actors from other industries and countries. Replacement of incumbents by new actors.
Formation of new knowledge/ technology/business networks	Forging new relationships and networks and facilitating interaction. Formation (and maintenance) of broad networks, i.e., networks consisting of actors from different domains. Formation (and maintenance) of deep networks, i.e., networks with high resource commitment from network members. Development of 'global' networks that support the exchange and interpretation of specific lessons and experiences between niches.	New partnerships to enable business model innovation. The emergence of new customer groups/segments.
Configuration and de-configuration of political networks	Formation of 'discourse coalitions' including (industrial, administrative, and grassroots)	Balancing the power of incumbents, e.g., by inviting niche actors to advisory

Processes (outcomes)	Niche-level processes	Regime-level processes
	advocates accumulating resources and political power. Fostering wider societal engagement.	councils, etc. Breaking-up of existing policy networks.
Development of political capacity and change advocacy	Development of political capacity to avoid capture by vested interests.	Development of new fora/organisations to support policy change. Emergence/creation of change advocates in established (policy) organisations.

Source: Prepared by authors based on Bugge et al.; Kern; Kivimaa and Kern, Raven et al.; Smith and Raven; Ghosh and Schot; Turnheim and Geels; Naber et al., Verhees et al.; Lazarevic, Kautto, and Antikainen. (See Appendix A).[110]

Institutions

As for actors, the TIS framework recognises the importance of institutional change but has not given much explicit attention to it. We, therefore, build this part of our framework mainly on the MLP and SNM frameworks. (See Appendix A for a complete account of the identified processes.)

The literature highlights several processes of institutional change at the level of the regime. With regard to formal institutions, radical policy reforms (e.g., market liberalisation) or the implementation of control policies, such as taxes or bans, can exert direct destabilisation pressures on established technologies and actors.[111] According to these authors, withdrawal of support to established technologies and actors, such as the removal of subsidies, can also challenge their established position. Destabilisation can also be stimulated by changes in existing regulations and standards that (indirectly) favour incumbent

110. Bugge, et al., 'Governing system innovation;' Kern, 'Using the multi-level perspective;' Kivimaa and Kern, 'Destruction or niche support?' Raven, et al., 'Niche construction and empower ment;' Smith and Raven, 'What is protective space?' Ghosh and Schot, 'Towards a novel regime change;' Turnheim and Geels, 'The destabilisation of existing regimes;' Naber, et al., 'Scaling up sustainable energy innovations.'

111. Kivimaa and Kern, 'Destruction or niche support?' Lazarevic, Kautto, and Antikainen, 'Finland's wood-frame;' Turnheim and Geels, 'The destabilisation of existing regimes.'

technologies.[112] With regard to informal institutions, changes in belief systems, societal norms, and culture can result in the de-legitimation of established technologies and industries.[113] While such changes can be difficult to trace empirically, the articulation of new visions about the future and raised public awareness of the need for change,[114] changed user preferences (and buying patterns),[115] and active lobbying or public contestation against the regime[116] can be more visible signs that the regime is under pressure to change. Finally, changes in cognitive rules, including problem agendas,[117] industry identity and business models,[118] and organisational practises[119] are necessary for a transition to be realised.

At the niche level, key institutional processes related to shielding include framing the new technology to make it fit the values of key stakeholders or society in general,[120] lobbying to get political support or temporal exemptions from existing rules and standards,[121] or identifying technology-specific market stimulation.[122] With regard to nurturing, the articulation of clear and robust (i.e., shared) expectations and visions is one of the key niche development processes.[123] In addition, the literature discusses institutional aspects of learning, such as questioning established assumptions about the technology,[124] standardisation,[125] and

112. Lazarevic, Kautto, and Antikainen, 'Finland's wood-frame;' Kern, 'Using the multi-level perspective.'

113. Kern, 'Using the multi-level perspective;' Turnheim and Geels, 'The destabilisation of existing regimes.'

114. Kern, 'Using the multi-level perspective.'

115. Turnheim and Geels, 'The destabilisation of existing regimes.'

116. Ibid.

117. Kern, 'Using the multi-level perspective.'

118. Ibid.

119. Lazarevic, Kautto, and Antikainen, 'Finland's wood-frame;' Turnheim and Geels, 'The destabilisation of existing regimes.'

120. Smith and Raven, 'What is protective space?'

121. Ibid.; Verhees, et al., 'The development of solar PV.'

122. Kern, 'Using the multi-level perspective;' Raven, et al., 'Niche construction and empowerment;' Smith and Raven, 'What is protective space?'

123. Naber, et al., 'Scaling up sustainable energy innovations;' Verhees, et al., 'The development of solar PV.'

124. Verhees, et al., 'The development of solar PV;' Kern, 'Using the multi-level perspective.'

125. Verhees, et al., 'The development of solar PV;' Bugge, et al., 'Governing system innovation.'

overcoming different organisational practises.[126] Finally, regarding empowering, two strategies are highlighted: fit-and-conform and stretch-and-transform. The former includes the development of public policies aiming at price-performance improvements,[127] institutional reforms to transform the regime,[128] articulating flexible narratives,[129] and framing shielding and nurturing measures as temporary.[130] The latter comprises more far-going institutional changes such as the design of policy to incentivise actors to engage in niche solutions,[131] lobbying for institutional reform,[132] or the creation of new institutions.[133]

If we synthesise these insights from the MLP and SNM frameworks, we can identify four main transformative processes related to changes in institutions, which are relevant for both the niche and the regime level. These are the articulation of visions and expectations; framing and redefinition of values, norms, and practises; mobilisation and de-mobilisation of (political) support); and introduction of new regulations (see TABLE 4). To account for directionality, each of these processes should be analysed from the point of view of whether they strengthen established institutions or work towards the establishment of new or fundamentally reconfigured institutional frameworks.

TABLE 4. Transformative Processes Related to Institutions

Sub-dimensions	Niche-level processes	Regime-level processes
Articulation of visions and expectations	Articulation of clear, specific, and shared visions and expectations between members.	Articulation of new visions and expectations about the future.

126. Bugge, et al., 'Governing system innovation.'
127. Kern, 'Using the multi-level perspective;' Raven, et al., 'Niche construction and empowerment.'
128. Smith and Raven, 'What is protective space?'
129. Raven, et al., 'Niche construction and empowerment.'
130. Verhees, et al., 'The development of solar PV.'
131. Smith and Raven, 'What is protective space?'
132. Ibid.; Verhees, et al., 'The development of solar PV;' Raven, et al., 'Niche construction and empowerment.'
133. Raven, et al., 'Niche construction and empowerment.'

Sub-dimensions	Niche-level processes	Regime-level processes
Framing and redefinition of values, norms, and practises	Questioning assumptions about problem definitions, function, or desirability of the technology. Articulating narratives and enacting new discourses to fit contemporary objectives and values of (powerful) stakeholders. Framing shielding and nurturing as temporary and promoting that innovation will be competitive under conventional criteria.	Raised public awareness of the need for change. Broad cultural changes or changes in underlying values that challenge the regime. Changes in industry mission, identity, and confidence. Changes in organisational practises.
Mobilisation and de-mobilisation of (political) support)	Lobbying to achieve explicit political support. Overcoming initial reluctance. Arguing for temporal exemptions from existing rules and standards.	Reduction or removal of subsidies, funding, and protective measures. Changes in regulations that favour established technologies or hinder new ones (e.g., building codes or siting rules). Lobbying, framing, or public contestation against the regime. Attempts to influence policy development and change.
Introduction of new regulations	Development of institutional reforms. Identification and implementation of technology-specific policy instruments.	Restructuring of markets (e.g., liberalisation or regulation). Implementation of control policies (e.g., taxes, import restrictions, emissions regulations, bans, or plans for phase-out of specific technologies).

Source: Prepared by authors based on Naber et al.; Verhees et al.; Ghosh and Schot; Kern; Raven et al.; Smith and Raven; Turnheim and Geels; Lazarevic, Kautto, and Antikainen; Bugge et al.; Kivimaa and Kern. (See Appendix A). [134]

134. Naber, et al., 'Scaling up sustainable energy innovations;' Verhees, et al., 'The development of solar PV;' Ghosh and Schot, 'Towards a novel regime change;' Kern, 'Using the multi-level perspective;' Raven, et al., 'Niche construction and empowerment;' Smith and Raven, 'What is protective space?' Turnheim and Geels, 'Regime destabilization;' Turnheim and Geels, 'The destabilisation of existing regimes;' Lazarevic,

Summary

To sum up, we have identified three sets of transition-related processes that can be used as a means to analyse the transformative outcomes of an innovation policy programme. These include seven functions that describe processes related to changes in socio-technical systems, four processes related to changes in actor networks, and four processes associated with changes in institutions (see FIGURE 2). We have also argued that each of these processes should be scrutinised from a directionality point of view to determine whether they contribute to strengthen the existing socio-technical configuration, the development of new configurations, or both.

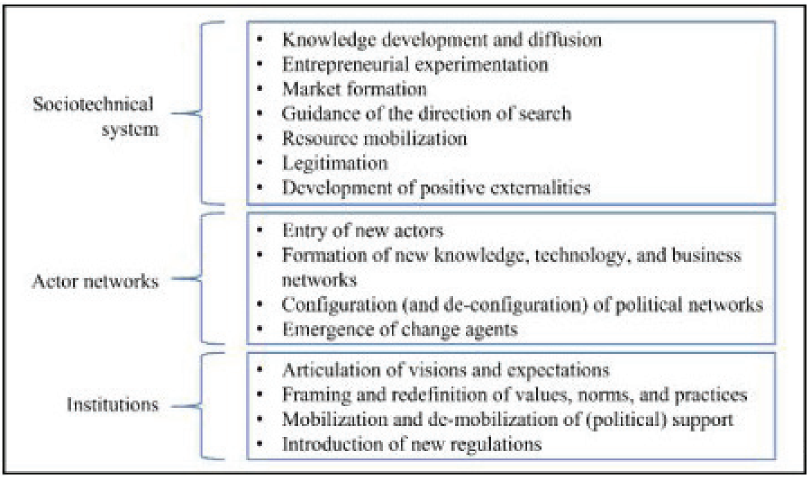

FIGURE 2. Three Sets of Transformative Processes

Source: Prepared by authors.

2.4. Concluding Discussion

The purpose of this paper was to identify a set of non-overlapping key transformative processes that capture both directionality and behavioural additionality and can be used as a framework to evaluate the outcomes of transformative

Kautto, and Antikainen, 'Finland's wood-frame;' Bugge, et al., 'Governing system innovation;' Kivimaa and Kern, 'Destruction or niche support?'

innovation policy. We drew on the literature on innovation system functions and socio-technical transitions (MLP and SNM) to achieve this purpose and took measures to avoid unnecessary overlaps between different frameworks.

The suggested evaluation framework is composed of three sets of transformative processes corresponding to the main elements of socio-technical configurations (see FIGURE 2). Regarding socio-technical systems, we argued that previously identified innovation functions (i.e., 'knowledge development and diffusion,' 'entrepreneurial experimentation,' 'market formation,' 'guidance of the direction of search,' 'resource mobilisation,' 'legitimation,' and 'development of positive externalities'), cover the most important processes both for emerging and established technologies. Still, a directionality filter needs to be added to understand which technologies benefit from the functional dynamics in a sector. Concerning actor networks and institutions, we identified four processes for each element, which are relevant for studying changes in both new and emerging configurations: 'entry of new actors,' 'formation of new knowledge, technology, and business networks,' 'configuration (and de-configuration) of political networks,' 'development of political capacity and change advocacy,' 'articulation of visions and expectations,' 'framing and redefinition of values, norms, and practises,' 'mobilisation and de-mobilisation of (political) support),' and 'introduction of new regulations.' Just as for the functions, analysts should pay special attention to whether these processes support existing configurations or result in a more radical reconfiguration of the focal sectoral socio-technical configuration.

A directionality-sensitive analysis focusing on the identified processes would pave the way for comparing emerging developments with the goals of the policy and broader societal expectations. Such comparisons should stress the pathway(s) the processes seem to be supporting and whether they seem to be driving the transition in the staked-out direction. This can be done even before it is possible to identify any real impacts in terms of a complete reconfiguration of the targeted sectoral socio-technical configuration or improvements in its sustainability performance. Policymakers could then use this information as part of their policy learning process, which could result in revised policy goals, changes in the overall policy mix, and/or redesign of the evaluated intervention.

This chapter has focused on the conceptual development of the framework. The next step is to test it on one or more empirical cases in order to identify operationalisation problems not yet considered. Likewise, testing it can indicate further conceptual and methodological developments needed. As for us, we will also consult policymakers and evaluation practitioners to get their perspectives on the practical applicability and usefulness of the framework.

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Appendix A: Niche- and Regime-level Processes Derived from the Reviewed Literature

TABLE 5. Niche-level Processes

Configuration element	Niche protection mechanism	Operationalisation/indicators or examples from empirical studies	Related function(s)*
Socio-technical system	Shielding	Dedicated (technology-/niche-specific) RD&D support (Kern; Raven et al. 2016; Smith and Raven)	• Resource mobilisation • Entrepreneurial experimentation
		Implementation of technology-specific investment subsidies, public procurement, and other market niche protection measures (Kern; Raven et al.; Smith and Raven)	• Market formation
		Exploitation of 'real' niche markets, e.g., segments willing to pay higher prices or accept lower performance or places outside the reach of existing infrastructures (Raven et al.; Smith and Raven; Verhees et al.)	• Market formation
	Nurturing	(Support to) Research, development, prototyping, piloting, and demonstration of niche innovations (e.g., RD&D funding, direct co-investment, technology acceleration projects) (Kern; Verhees et al.)	• Knowledge development and diffusion • Entrepreneurial experimentation • Resource mobilisation
		Exchange and interpretation of specific lessons and experiences between niches (at the level of the 'global' niche) (Smith and Raven)	• Knowledge development and diffusion
		Standardisation (to ensure interoperability) (Bugge et al.; Verhees et al.)	• *à Legitimation*

Configuration element	Niche protection mechanism	Operationalisation/indicators or examples from empirical studies	Related function(s)*
	Empowering	Infrastructural changes (Bugge et al.; Raven et al.)	• Resource mobilisation
		R&D and public support targeting or achieving price-performance improvements of niche innovations in terms of quality, functionality, production cost, etc. (Kern; Raven et al.; Verhees et al.)	• Resource mobilisation
Actor network	Shielding	Establishment of private technology-specific incubator units/programmes (Raven et al.; Smith and Raven)	• *à Entrepreneurial experimentation*
		Establishment of collective buying cooperatives (Raven et al.)	• *à Market formation*
		Support to help companies identify and exploit market opportunities (Kern)	• *à Market formation*
		Involvement of strong actors (that guarantee support) (Bugge et al.)	• *à Legitimation*
	Nurturing	Formation (and maintenance) of broad networks, i.e., networks consisting of actors from different domains (Naber et al.; Verhees et al.)	• *à Knowledge diffusion* • *à Guidance of the direction of search*
		Formation (and maintenance) of deep networks, i.e., networks consisting with high resource commitment from network members (Naber et al.; Verhees et al.)	• *à Resource mobilisation* • *à Guidance of the direction of search*
		Development of 'global' networks (that support exchange and interpretation of specific lessons and experiences between niches) (Smith and Raven)	• *à Knowledge development and diffusion*
		Entry of powerful actors (incl. policy) into the support network of the niche (Kern)	• *à Guidance of the direction of search*

Configuration element	Niche protection mechanism	Operationalisation/indicators or examples from empirical studies	Related function(s)*
		Business support to (new) companies (Kern)	
		Fostering wider societal engagement of, e.g., NGOs or academics (Kern)	• *à Legitimation*
	Empowering	Involvement of government bodies (to allow for upscaling) (Bugge et al.)	
		Development of political capacity to avoid protective space becoming captured by vested interests and to ensure protection stimulates the dynamic accumulation of innovative capabilities (Smith and Raven)	• *à Legitimation*
		Formation of networks of (industrial, administrative, and grassroots) advocates accumulating resources and political power (Smith and Raven)	• *à Resource mobilisation* • *à Legitimation*
		Create capabilities and attract resources that empower participation in political debates (Smith and Raven)	• Resource mobilisation
Institutions	Shielding	Re-framing the technology to fit contemporary political objectives or values of specific stakeholder groups (Smith and Raven)	• Legitimation
		Identification of technology-specific investment subsidies, public procurement, and other market niche protection measures (Kern; Raven et al.; Smith and Raven)	
		(Arguing for) Temporal exemptions from existing rules and standards (Smith and Raven; Verhees et al.)	• Legitimation

Configuration element	Niche protection mechanism	Operationalisation/indicators or examples from empirical studies	Related function(s)*
		Enacting new media discourses linking technologies with high-tech values in society (Smith and Raven)	• *à Legitimation*
		Lobbying to achieve explicit political support (Smith and Raven)	• Legitimation
	Nurturing	Questioning assumptions about problem definitions, function, or desirability of the technology (Kern; Naber et al.; Verhees et al.)	• *à Guidance of the direction of search* • *à Legitimation*
		Standardisation (to ensure interoperability) (Bugge et al.; Verhees et al.)	• *à Legitimation*
		Overcoming initial reluctance (Bugge et al.)	• Legitimation
		Overcoming different organisational practises (Bugge et al.)	• (Legitimation)
		Articulation of clear, specific, and shared expectations and visions between members (Naber et al.; Verhees et al.)	• *à Legitimation* • *à Guidance of the direction of search*
	Empowering	R&D and public support targeting or achieving price-performance improvements of niche innovations in terms of quality, functionality, production cost, etc. (Kern; Raven et al.; Verhees et al.)	• Resource mobilisation • Knowledge development • Entrepreneurial experimentation
		Development of institutional reforms that transform incumbent regimes (Smith and Raven)	
		Articulation of narratives in flexible ways (to attract powerful actors) (Raven et al.)	• *à Legitimation* • *à Guidance of the direction of search*

Configuration element	Niche protection mechanism	Operationalisation/indicators or examples from empirical studies	Related function(s)*
		Framing shielding and nurturing as temporary and promoting that innovation will be competitive under conventional criteria (Verhees et al.)	• Legitimation
		Policies (environmental regulations, fiscal measures, quotas, etc.) that incentivise (regime) actors to invest in niche solutions (Smith and Raven)	• Guidance of the direction of search
		Arguing for and achieving public or private institutional reform (e.g., changing regulatory frameworks) or creating new (technology-specific) institutions (Kern; Raven et al.; Smith and Raven; Verhees et al.)	

Source: Prepared by authors based on Kern; Raven et al.; Smith and Raven; Verhees et al.; Bugge et al.; Naber et al..[135]

(*) → means that the process in question might eventually contribute to the function in question but has no immediate influence on it.

135. Kern, 'Using the multi-level perspective;' Raven, et al., 'Niche construction and empowerment;' Smith and Raven, 'What is protective space?' Verhees, et al., 'The development of solar PV;' Bugge, et al., 'Governing system innovation;' Naber, et al., 'Scaling up sustainable energy innovations.'

TABLE 6. Regime Destabilisation Processes

Regime-level processes			
Configuration element	**Type of change**	**Operationalisation/indicators or examples from empirical study**	**Related function(s)***
Sociotechnical system	Changes in technical systems	Changes in existing production plants and infrastructure (Kern)	• Resource mobilisation
		Investments in new complementary infrastructure (Ghosh and Schot)	• Resource mobilisation
	Reduced resource flows to established technologies	Declining markets (export and domestic) (Turnheim and Geels)	• Market formation
		Shifts in investment patterns (Turnheim and Geels)	• Guidance of the direction of search • Market formation
	Improvements of established technologies	(Incremental) product and process innovation (Turnheim and Geels)	• *Innovation output*
		Efficiency improvements and modernisation of existing technologies and plants (Turnheim and Geels)	• *Innovation output*
		Public investment support or loans for efficiency improvements (Kern)	• Resource mobilisation
	Strategic reorientation incumbent actors wrt technology	Build-up of new technical knowledge, competences and operations (Turnheim and Geels)	• Knowledge development • Resource mobilisation
		Replacement of existing skills and knowledge (Kivimaa and Kern)	• Knowledge development) • Resource mobilisation
		Experimentation with new technologies (Kivimaa et al.; Lazarevic et al.)	• Entrepreneurial experimentation

Regime-level processes			
Configuration element	**Type of change**	**Operationalisation/indicators or examples from empirical study**	**Related function(s)***
		Diversification to new product markets (Turnheim and Geels)	• Guidance of the direction of search
Actor networks	Entry of new actors into mainstream market	Entry of niche actors (Ghosh and Schot; Kern; Turnheim and Geels)	
		Entry of actors from other industries and countries (Turnheim and Geels)	
		Replacement of incumbents by new actors (Kivimaa and Kern)	
	Development of new business networks	New partnerships to enable business model innovation (Turnheim and Geels)	
		Emergence of new customer groups/segments (Ghosh and Schot)	• Market formation
	Reconfiguration of policy networks	Balancing the power of incumbents, e.g., by inviting niche actors to advisory councils etc. (Kivimaa and Kern; Lazarevic et al.)	
		Breaking-up of existing policy networks (Kivimaa and Kern; Lazarevic et al.)	
	Emergence of change advocacy (within the regime)	Development of new fora/organisations to support policy change (Kivimaa and Kern; Lazarevic et al.)	• *à Legitimation*
		Emergence/creation of change advocates in established (policy) organisations (Lazarevic et al.)	• *à Legitimation*
Institutions	Introduction of new regulations that weaken the established socio-technical configuration	Restructuring of markets (e.g., liberalisation or regulation) (Ghosh and Schot; Kivimaa and Kern; Lazarevic et al.; Turnheim and Geels)	• *à Market formation*

Regime-level processes			
Configuration element	**Type of change**	**Operationalisation/indicators or examples from empirical study**	**Related function(s)***
		Implementation of control policies (e.g., taxes, import restrictions, emissions regulations, bans, or plans for phase-out of specific technologies) (Ghosh and Schot; Kivimaa and Kern; Lazarevic et al.; Turnheim and Geels)	• *à Market formation*
	Withdrawal of political support to established technologies and actors	Removal of subsidies, cuts in R&D funding or changes in tax laws (Kivimaa and Kern; Lazarevic et al.; Turnheim and Geels).	• *à Market formation* • *à Resource mobilisation*
		Reduction or removal of protective measures (Turnheim and Geels)	• *à Market formation*
	Changes in existing regulations and standards	Changes in regulations that favour established technologies or hinder new ones (e.g., building codes or siting rules) (Kern; Lazarevic et al.)	• *à Market formation*
		Attempts to influence policy development and change (Kern)	• *à Legitimation*
		Development of new (de facto) standards and technology specifications (Ghosh and Schot; Kern)	• Legitimation
	Changes in belief systems, societal norms, and culture	Raised public awareness of the need for change (Kern; Turnheim and Geels)	• *à Legitimation*
		Changes in user preferences (and buying patterns) (Ghosh and Schot; Turnheim and Geels)	• Market formation
		Lobbying, framing or public contestation against the regime (Turnheim and Geels)	• Legitimation

Regime-level processes			
Configuration element	**Type of change**	**Operationalisation/indicators or examples from empirical study**	**Related function(s)***
		Broad cultural changes or changes in underlying values that challenge the regime (Ghosh and Schot; Turnheim and Geels)	• *à Legitimation*
	Changes in cognitive rules	Articulation of new visions and expectations about the future (Ghosh and Schot; Kern)	• *à Legitimation*
		Changes in problem agendas (Kern)	• Guidance of the direction of search
		Changes in perceptions about stakeholders and relevant performance criteria (Ghosh and Schot)	• Guidance of the direction of search • Market formation
		Changes in industry mission, identity and confidence (Turnheim and Geels)	• *à Guidance of the direction of search*
		Changes in organisational practises (Lazarevic et al.; Turnheim and Geels)	• *à Guidance of the direction of search*

Source: Prepared by authors based on Kern; Ghosh and Schot; Turnheim and Geels; Kivimaa and Kern; Kivimaa, Kangas, and Lazarevic; Lazarevic, Kautto, and Antikainen.

(*) → means that the process in question might eventually contribute to the function in question but has no immediate influence on it.