



Walking the talk? Innovation policy approaches to unleash the transformative potentials of the Nordic bioeconomy

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Abstract

This article explores whether and how innovation policies promote transitions to more sustainable configurations in socio-technical systems. Empirically it departs from an analysis of the bioeconomy policy strategies and instruments in four Nordic countries. The analysis highlights that while a transformative approach is present at the policy strategy level in the Nordic countries, the bioeconomy policy instruments implemented are significantly less transformative. The article argues that a bioeconomy transition that contributes to sustainable development will require a redirection of policies towards transformative failures (directionality, policy coordination, demand articulation, and reflexivity). In this regard, it is important that policymakers experiment with and explore ways of balancing between traditional market and innovation system approaches and new policy approaches for transformative change.

Key words: bioeconomy; innovation policy; transformative change; Nordic countries

1. Introduction

Transformative Innovation Policy (TIP) represents an emerging and new approach to science, technology, and innovation (STI) policy (Schot and Steinmueller 2018; Weber and Rohracher 2012). The term transformation reflects the need for policies to address sustainability transitions, defined as processes of fundamental social change in response to societal challenges, such as climate change, resource depletion, population growth, health, and energy security (Grin et al. 2010; Markard et al. 2012). A distinctive feature of TIP is the recognition that neoliberal economic and market approaches cannot be the only or dominating components of decision-making in innovation policies addressing social change. TIP thus places an emphasis on the need to address a number of transformative failures implying that policymakers proactively set a direction for a sustainable societal development, articulate demand underpinning this direction, coordinate relevant policy areas, and ensure reflexivity across stakeholders involved (Schot and Steinmueller 2018; Weber and Rohracher 2012). A salient characteristic of TIP is the recognition that societal challenges are complex, involving multiple factors and high levels of contestation about the nature of (and solutions to) their problems (Meadowcroft 2011; Stirling 2014).

Rather than a focus on technological innovation or competitive growth in specific industries and sectors, the main concern of TIP is thus to achieve sustainability transitions or socio-technical system transformation in vital societal

services, such as energy, mobility, food production, and consumption (Schot and Steinmueller 2018). However, to the best of our knowledge, research has so far not analysed empirically whether STI policies that address such transformative challenges actually follow the TIP approach, or rather resemble more traditional STI approaches focussed on correcting market failures or supporting existing innovation systems. Furthermore, existing empirical research on the TIP approach tend to focus on single policy instruments (Grillitsch et al. 2019; Diercks et al. 2019; Janssen 2019) rather than broader policy mixes.

In this paper we focus on bioeconomy policy mixes in four Nordic countries (Denmark, Finland, Norway, and Sweden). The selection of the bioeconomy as an empirical case for our study is motivated by several reasons. Since the mid-2000s the promotion of the bioeconomy, defined as an economy in which the basic components of materials, chemicals, and energy are derived from renewable biological resources (McCormick and Kautto 2013), has increasingly gained attention by governments worldwide. In the beginning of 2018 over 50 countries, including the Nordics, had published bioeconomy policy strategies and intentions (Fund et al. 2018; OECD 2018). The bioeconomy has been promoted not only from a climate change perspective, but also for achieving policy objectives related to food security, health, industrial restructuring, and energy security (Bugge et al. 2016; Klitkou et al. 2019; Morone 2016). Since about 2015, bioeconomy objectives are frequently being aligned to the achievement

of the United Nations Sustainable Development Goals (UN SDGs) and the Paris Agreement on climate change (European Commission 2018; EUBA 2018; Fund et al. 2018; Fritsche et al. 2020).

However, a bioeconomy transition that contributes to sustainable development will require a redirection of policies towards TIP. Previous studies have shown that bioeconomy policies are frequently underpinned by traditional market and system change rationales and that its development is made difficult by several factors which in our view largely reflect the transformative failures justifying a TIP approach. Examples of such obstacles are the lack of consensus on the goals and interpretations of the bioeconomy, challenges with policy coordination of a broad range of actors with different interests (Fund et al. 2018), loose connection of bioeconomy policies to social and environmental concerns (Giljum et al. 2016; Kitchen and Marsden 2011; Staffas and McCormick 2013), and that many policy instruments focus on technology development (Patermann and Aguilar 2018; Schmid et al. 2012). As Birch suggests, the policy visions of a bioeconomy typically represent a future that is based on biological rather than fossil inputs, but that is otherwise not radically different from the present in terms of social institutions, infrastructure, and consumption patterns (Birch 2019; Ponte and Birch 2014).

Investigating the innovation policy approaches for the bioeconomy in the four Nordic countries is interesting for several reasons. Firstly, in the countries' bioeconomy policy strategies, the development of the bioeconomy is explicitly expected to achieve social and environmental change (e.g. FORMAS 2012). Secondly, natural resource industries within forestry (Norway, Sweden, and Finland), fisheries (Norway), and agriculture (Denmark) have traditionally played important roles in the national economies of the Nordic countries and continue to do so (Johansen et al. 2019; Schou 2020; The Royal Swedish Academy of Agriculture and Forestry 2015). Third, the natural resource industries have negative environmental impacts (Kettunen et al. 2012; Prestvik et al. 2013) which create contestation in these countries over the sustainability of bioeconomy development, such as the utilisation and exploitation of biological resources (Scordato et al. 2017). Finally, the four Nordics are frontrunners in several bioeconomy fields, such as bioenergy, biochemicals, and biotechnology, and in green technology more generally (Gregg et al. 2017; Hansen et al. 2017; Näyhä and Pesonen 2012), and the analysis of their policy mixes for the bioeconomy may hold important lessons for other countries.

Consequently, the main research objectives of our paper are:

- (1) to investigate whether and how the TIP approach is applied in bioeconomy policies addressing societal challenges and
- (2) to analyse whether the suggested and implemented bioeconomy policy instruments are in accordance with the orientation of the innovation policy approaches of the bioeconomy policy strategies.

In terms of methods, we analyse bioeconomy policy strategies and instruments based on a review of policy documents and interviews with policy experts in the four countries.

The remaining of this article proceeds as follows. Section 2 presents the theoretical background and framework of the

analysis before Section 3 discusses the data and methods used in the empirical case study. Section 4 presents the empirical results, followed by a discussion of the key findings across the four countries in Section 5. The last section presents the conclusions of our analysis as well as the implications for further research.

2. Theoretical background and framework for analysis

In this section, we present the analytical background of our paper and explain the main features of three different approaches to innovation policy. We also present some of the key conclusions and observations made in previous studies analysing bioeconomy policies and explain why the TIP approach is particularly relevant for analysing policies for bioeconomy transitions.

2.1 Three innovation policy approaches: innovation for growth, systems of innovation, and transformative change

The politics and governance of sustainable socio-technical transitions have become a key field in innovation studies over the last few years. Building on multiple disciplines including evolutionary economics, institutional theory, and innovation studies, several research contributions have examined policy processes towards transformations of socio-technical systems such as energy, mobility, food, and water (Davies and Evans 2019; Diercks et al. 2019; Rogge et al. 2017; Sovacool and Axsen 2018).

Given the complexity of sustainability transition processes, single policy instruments are unlikely to facilitate such transitions. Consequently, innovation studies acknowledge that paying attention to policy mixes, i.e. the combination of policy strategies, policy instruments, and the processes through which such strategies and instruments emerge, is important (Flanagan et al. 2011; Kivimaa and Kern 2016; Rogge and Reichardt 2016). This has been observed in a number of empirical studies in the fields of energy production (Falcone et al. 2017; Kern et al. 2017; Reichardt et al. 2016), mobility (Bakker and Trip 2013; Van Der Vooren 2015), and industry (Huttunen et al. 2014).

A further trend in this field of study is the observation that the urgent societal challenges addressed by policymakers since the mid-2000s represent a break from conventional innovation policies implemented during the previous thirty years (Kallerud et al. 2013; Kuhlmann and Rip 2014). Departing from the historical unfolding of innovation policies since World War II, Schot and Steinmueller (2018) have presented an interpretation of innovation policies as subject to three framings or generations of innovation policy approaches: (1) *innovation for growth*, (2) *systems of innovation*, and (3) *transformative change*. We suggest that they represent useful analytical categories for better understanding how different policy approaches are combined. Policy strategies and instruments are likely to look very different in each of the three approaches. Building on Weber and Rohracher's (2012) conceptualisation of policy failures in the three different approaches, Table 1 provides a summary of the specific failures in focus.¹

Table 1. Summary of failures addressed in the three innovation policy approaches.

Innovation for growth <i>Market failures</i>	Systems of innovation <i>Structural system failures</i>	Transformative change <i>Transformational system failures</i>
Information asymmetries: Uncertainty about outcomes and short time horizon of private investors lead to undersupply of funding for R&D	Infrastructural failure: Lack of physical and knowledge infrastructures	Directionality failure: Lack of shared vision regarding the goal and direction of the transformation process; lack of targeted funding for research, development and demonstration projects and infrastructures
Knowledge spill-over: Public good character of knowledge and leakage of knowledge lead to socially sub-optimal investment in (basic) research and development	Institutional failures: Hard institutional failure: Absence, excess, or shortcomings of formal institutions such as laws, regulations, and standards (in particular regarding Intellectual Property Rights (IPR) and investment) Soft institutional failure: Informal institutions (e.g. social norms and values, culture, entrepreneurial spirit, trust, and risk-taking) that hinder innovation	Demand articulation failure: Insufficient spaces for anticipating and learning about user needs to enable the uptake of innovations by users. Absence of orienting and stimulating signals from public demand. Lack of demand-articulating competencies
Externalisation of costs: The possibility to externalise costs leads to innovations that can damage the environment or other social agents	Interaction or network failure: Strong network failure: Intensive cooperation in closely tied networks leads to lock-in into established trajectories and a lack of infusion of new ideas, due to too inward-looking behaviour, and lack of weak ties to third actors. Weak network failure: too limited interaction and knowledge exchange with other actors inhibits exploitation of complementary sources of knowledge and processes of interactive learning	Policy coordination failure: Lack of multi-level policy coordination across different systemic levels (e.g. regional–national–European or between technological and sectoral systems); lack of horizontal coordination between research, technology, and innovation policies on the one hand and sectoral policies (e.g. transport, energy, and agriculture) on the other; lack of vertical coordination between ministries and implementing agencies
Over-exploitation of commons: Public resources are over-used in the absence of institutional rules that limit their exploitation (tragedy of the commons)	Capabilities failure: Lack of appropriate competencies and resources at actor and firm level prevent the access to new knowledge and lead to an inability to adapt to changing circumstances, to open up novel opportunities, and to switch from an old to a new technological trajectory	Reflexivity failure: Insufficient ability of the system to monitor, anticipate, and involve actors in processes of self-governance; lack of distributed reflexive arrangements to connect different discursive spheres, provide spaces for experimentation and learning; no adaptive policy portfolios to keep options open and deal with uncertainty

Source: Adapted from [Weber and Rohracher 2012](#).

In the first approach (*innovation for growth*), the rationale for policy intervention is to address market failures leading to underinvestment in research and development (R&D) by the private sector. The underlying assumption is that innovation is necessary to sustain long-term economic growth. Governments are expected to intervene only to mitigate deficiencies in markets, such as compensating for too little investment in R&D, non-desired externalities and asymmetric information, as well as eliminating barriers to entry ([Chaminade and Edquist 2010](#)). The innovation model is essentially technology and science-driven and emphasises the commercialisation of scientific discoveries, particularly by large private firms. In this approach, there is a clear division of labour among scientists, private firms, and public actors. Each have the responsibility for advancing scientific discovery, transforming discovery into innovations, and regulating eventual externalities, respectively ([Schot and Steinmueller 2018](#)). Policy instruments typically provide subsidies for R&D and tax exemptions for private R&D investments.

The second approach (*systems of innovation*) understands innovation as a systemic and interactive process influenced by institutional settings, which have important implications

for the design and implementation of innovation policy. Thus, innovation processes are characterised by interaction and dynamic feedback loops, which is opposed to the linear model of innovation emphasised in the first innovation policy approach ([Schot and Steinmueller 2018](#)). However, like the first, the second approach departs from an understanding whereby STI are necessary for maintaining competitiveness, and it emphasises the importance of strengthening the competitive advantage of domestic firms in terms of global competition. The central rationale for policy intervention is to address failures in the components that constitute systems of innovation: actors, networks, and institutions. Thus, policy intervention may strengthen the interaction, alignment, and cooperation between actors such as universities, industries, and governments, but also facilitate the entry of entrepreneurs and small- and medium-sized enterprises in networks. Various authors ([Smith 2000](#); [Woolthuis et al. 2005](#)) have identified several structural system failures, which this approach may address. Examples of such failures are the lack of appropriate *competences and resources* at the firm level which hamper the access and exploitation of knowledge; the absence, excess, or shortcoming of *formal institutions* such as laws, regulations,

and standards but also *informal institutions* such as social norms and values, culture, and entrepreneurial spirit which impeded collaboration for innovation. Moreover, structural system failures are also found in relation to *networks* which may be too closely tied leading to myopia. Interaction may also be too limited and thus inhibiting complementary knowledge and interactive learning. There may also be failures with regard to a lack of physical and knowledge *infrastructure* due to large scale, long time horizon of operation and ultimately too low return on investment for private investors. Following this line of argument, the choice of policy instruments is determined in relation to the actual problems identified in the innovation system.

The third and emerging innovation policy approach (*transformative change*) calls for the transformation of large socio-technical systems (Schot and Steinmueller 2018). ‘Socio-technical system transformation (or transition) is about changing skills, infrastructures, industry structure, products, regulations, user preferences and cultural predilections’ (Schot and Steinmueller 2018: 1562). Characterise transitions as long-term processes that often last forty-fifty years. For this reason, the importance of long-term strategic orientation in sustainability transitions is acknowledged as having a fundamental role in giving direction to system change.

The third approach draws on the four transformative system failures identified by Weber and Rohracher (2012): (1) directionality failure, (2) demand articulation failure, (3) policy coordination failure, and (4) reflexivity failure. Directionality failure refers to a lack of ability in steering innovation efforts and collective priorities in a specific direction in order to meet societal challenges. Demand articulation failure refers to insufficient uptake of innovations, and a lack of anticipating and learning about user needs. Policy coordination failure refers to a deficit in managing and synchronising the inputs from different policy areas to meet societal challenges. Such coordination might include coherence between policies at international, national, regional, and municipal levels (vertical coordination failure), or across different sectors (horizontal coordination failure). Reflexivity failure refers to missing learning feedback loops and the lack of ability to continuously monitor the progress of ongoing innovation processes and to subsequently adjust the course of action. A key feature of TIP is its focus on experimentation and the exploration of different options.

The policy rationales of the third approach thus differ quite substantially from those of the first and second approaches. The fundamental difference starts from the explicit critique that stimulating innovation is not always positive and that ‘many technologies are deeply implicated in persistent environmental and social problems’ (Schot and Steinmueller 2018: 1562). In this manner, it is argued that a re-examination of the two earlier approaches and that a new approach, represented by the emerging third approach, is necessary to meet the societal challenges of our time. It is important to mention, however, that the first two approaches, *innovation for growth* and *systems of innovation*, are not entirely dismissed in the third transformative approach but are instead viewed as valid and relevant to many aspects. In fact, Weber and Rohracher (2012) explicitly state that a TIP approach does not entail that it is irrelevant to correct market and structural system failures. The point here is that innovation policies addressing societal challenges need to do much more than that. Thus, a TIP policy

approach does not exclude attention to e.g. over-exploitation of commons and capabilities failures, but it does necessitate attention to transformative system failures. Schot and Steinmueller also acknowledge that real-life policies will in fact reflect a combination of approaches and stress that ‘a deeper discussion and confrontation of frames and a process of critical frame reflection both by academics and policy makers is, however, important’ (Schot and Steinmueller 2018: 1555). Moreover, they make clear that ‘Real world policy contexts will also always involve a wide range of policy instruments drawing on several rationales’ (ibid: 1565). Table 1 provides a summary of the failures addressed respectively by each of the three innovation policy approaches.

More recently, the TIP approach has been discussed. Diercks et al. (2019) argue that ‘the emerging paradigm of transformative innovation policy is still a heavily contested discursive space’ (Diercks et al. 2019: 881). Giuliani (2018) has argued that Schot and Steinmueller’s (2018) three frames assign little attention to the unintended consequences of technology on society and the environment. She adds that the transformative change framing needs to pay much more attention to the ‘dark side’ of multinational companies (Giuliani 2018: 1579). In a recent contribution, Fagerberg (2018) argues that the third frame pays too little attention to the role of firms in transformative innovation and adds that the policy advice, which the authors bring to the table, is rather vague (however, see Grillitsch et al. 2019).

In our view, the three innovation policy approaches constitute a useful analytical framework for exploring whether and how innovation policy approaches coexist and to trace the features of the emerging transformative approach in policy strategies with transformative ambitions. We nevertheless acknowledge that the differences between the three approaches are perhaps more subtle, nuanced, and not as clear-cut as suggested by Schot and Steinmueller. For instance, the societal impact of innovation was also to some extent emphasised by proponents of the first and second approaches (Grillitsch et al. 2020).

2.2 Bioeconomy policy and its relevance for transformative innovation policy

As mentioned in the introduction the concept of the bioeconomy has increasingly gained interest in both policy and academic debates since about the mid-2000s. During this period, bioeconomy policy strategies have increasingly been oriented towards an ambition to contribute to sustainable development. However, previous studies suggest they largely continue to pursue traditional innovation policy paradigms. Considering the theories reviewed in the previous section, a bioeconomy transition that contributes to sustainable development will require a redirection of policies towards TIP. In this section we illustrate why, in our view bioeconomy policy development may require a stronger attention on transformative failures.

From the literature it emerges that the policy drivers for promoting bioeconomic development have evolved significantly over the last ten-fifteen years. While initially closely connected to *life sciences* and *biotechnology* development (see OECD 2009) or to the ‘knowledge-based bio-economy’ concept emphasising organic raw materials (McCormick and Kautto 2013; Straffas and McCormick 2013), the

bioeconomy has increasingly been aligned to meeting major societal challenges (Fund et al. 2018). At the same time, policy strategies for the bioeconomy have increasingly turned to recognise the importance of the *circular* bioeconomy concept which underlines the importance of maintaining the value of products, materials, and resources for as long as possible and supporting a societal development based on the principles of the waste hierarchy (Stegmann et al. 2020). These objectives imply large societal changes involving behavioural changes from consumers and producers rather than a purely techno-economic endeavour (Fritsche et al. 2020; Morone 2016). However, studies show that despite changes in policy drivers, most bioeconomy policy strategies continue prioritising production and utilisation of biological resources to generate high value bio-based products and services, and propose policy measures based on traditional market and system failure rationales (e.g. research programmes) (Fund et al. 2018; Töller et al. 2021). For example, while a broad conceptualisation of the bioeconomy was promoted in the EU bioeconomy strategy from 2012, bioeconomy policy instruments had a considerably narrower focus on techno-scientific solutions to societal problems (see also Patermann and Aguilar 2018; Schmid et al. 2012), which is raised as an area of concern (Birch 2016; Mukhtarov et al. 2016).

Interestingly, Töller et al. (2021) argue that bioeconomy policy is still to be viewed ‘as a somewhat diffuse and loose constellation of differently established partial policy fields in the area of biomass production, processing and use’ (Töller et al. 2021: 159). Moreover, “that bioeconomy policy still lacks specific and long-term constellation of interrelated problems, actors, institutions and measures” (Töller et al. 2021: 159). In sum, they pointed at the following recurring problems characterising bioeconomy policy:

- (1) Fragmentation of the institutional and regulatory landscape,
- (2) Ambiguity, inconsistency and contestation of its overarching goals,
- (3) Fragile supportive bioeconomy actor constellations,
- (4) Lack of bioeconomy-specific policy instruments (Töller et al. 2021).

On a similar note, other studies illustrate how the bioeconomy is subject to different and divergent interpretations and ideas in terms of spatial focus, scale, and scope. On the one hand, the bioeconomy is proposed as a rationale for an increased exploitation of global value chains and large-scale centralised production systems, and on the other as a rationale for an economy based on local, small-scale decentralised production systems. In agriculture, these conflicting rationales may be exemplified by preferences for, respectively, a continued emphasis on mass production and monoculture, and small-scale organic practices. These different and sometimes competing interpretations create contestations and difficulties for the design and formulation of bioeconomy policy (Bugge et al. 2016; Levidow et al. 2012a,b) and hence call for a stronger political attention on issues related to directionality and policy coordination. In fact, empirical studies have shown that national bioeconomy policy strategies are often written as broad frameworks and thus often merge environmental concerns such as protecting ecosystems, biodiversity, and land use change with socio-economic objectives such as

ensuring jobs and growth (Dubois and Gomez San Juan 2016; Püzl et al. 2014). Birch (2016) argues that policy visions defined by broad policy frameworks, based on a ‘catch all agenda setting’, risk making actions difficult and implementation uncoordinated and fragmented. Moreover, attention on reflexivity by monitoring progress and effects of the bioeconomy transition is needed in bioeconomy policy as the positive effects of the bioeconomy on environmental sustainability are often taken for granted in bioeconomy policies, despite empirical evidence, showing that the opposite may in some cases occur (Bugge et al. 2016; Cavicchi 2016; Ponte 2009; Richardson 2012).

2.3 Analytical framework

In order to fulfil the article’s research objectives, we develop an analytical framework (Table 2) that provides a stylised account of different approaches (following Schot and Steinmueller 2018) to developing the bioeconomy. We make a distinction between policy strategies and policy instruments as core components of policy mixes (Rogge and Reichardt 2016). Here, (Rogge and Reichardt 2016: 1623) a policy strategy is ‘a combination of policy objectives and the principle plans for achieving them’ and policy instruments are ‘the tools policy makers have to achieve determined objectives’. The policy-making process is referred to as a ‘political problem-solving process among constrained social actors in the search for solutions to societal problems’ thus involving ‘power, agency and politics’ (ibid: 1625). It is emphasised that policy learning in policy processes is a particularly important component.

While the purpose of our article is not to carry out an exhaustive analysis of the countries’ policy instruments of relevance for the bioeconomy, we nevertheless find it important (following the insights of Schmid et al. (2012) described above) to make a distinction between the countries’ visions for bioeconomy development at the strategic level and the main emphasis of bioeconomy policy instruments that actually are in place.

3. Methodology

This article examines the bioeconomy-related strategies and instruments in the four Nordic countries: Denmark, Finland, Norway, and Sweden. The selection of multiple cases was made to provide a better test of the analytical framework than could have been done from analysing a single case (Yin 2014).

3.1 Data sources

The empirical analysis is based on two types of data sources: bioeconomy-related strategy documents and interviews. First, we identified and selected 20 official policy documents in total by searching official web pages and through recommendations from national experts. The documents consulted were official governmental documents or other types of documents treated by the countries as primary documents related to the promotion of the bioeconomy. Hence, the reviewed documents were of different natures and scope and included specific and overarching bioeconomy policy strategies, as well as policy strategies related to specific bioeconomy relevant sectors such as forestry, food, agriculture, and fisheries. We limited our analysis to documents published between 2006 and 2019 (see Appendix 1). Second, we conducted 21 semi-structured

Table 2. Overview of analytical framework.

	Innovation for growth	Systems of innovation	Transformative change
Strategy: <i>What is the most important policy approach underpinning the bioeconomy strategies?</i>	Compensate for under-investment in R&D by private-sector actors in the bioeconomy	Ensure the build-up and development of effective systems of innovation around bio-based sectors and technologies	Proactive and transformative change of existing systems towards a sustainable bioeconomy; focus on wide societal changes
<i>How are the bioeconomy strategy development processes organised and who was involved?</i>	Traditional top-down policy process involving a narrow set of actors from the science and technology domain	Sectoral and/or silo-based policy approaches involving actors across supply and demand in the respective sectoral domains	Broad, bottom-up, coordinated, and open-ended policy process involving diverse actors across industry, policy academia, and civic sector. Reflexivity and continuous adjustments around goals and working practices
Instruments: <i>What types of policy instruments are most important to promote the bioeconomy?</i>	Ensure tax incentives, R&D support schemes, strengthening of IPRs, and commercialisation strategies for new bio-based technologies	Support capability development of actors working with the bioeconomy, develop infrastructures (e.g. waste sorting facilities), attention to institutions preventing innovation in bio-based technologies, and support for collaboration and networking	Set goals and targets for bioeconomy development that other policy instruments must contribute to, stimulate demand for bio-based products, and establish bodies in charge of coordination of bioeconomy policy and monitoring of progress and effects of the bioeconomy transition

interviews with key policy experts (see [Appendix 2](#)). We selected interviewees by contacting the organisations listed as primary authors of the strategy documents, and through snowball sampling. In this way we managed to interview experts that were centrally placed in relation to the development and formulation of bioeconomy policies and that were very well positioned to provide their expert opinion on the current policy approaches to the bioeconomy in their respective countries.

To account for the diversity of individual responses, we sampled actors within different organisations (ministries, research and innovation funding agencies, universities, research institutes, and industry associations). At the start of our field research, we strived to reach a similar number and profile of interviewees across the four countries by contacting equivalent organisations. However, we did not fully succeed in our attempt and we acknowledge this as a limitation of the research findings. The reason for the dissimilarity of interviewee profiles can mainly be explained by two factors: by a dissimilar type of policy actors involved in the development of the bioeconomy strategies and, in some cases, by the unavailability of the contacted experts at the time of conducting the research. The interviews were carried out in the autumn and winter of 2017. Interviews were carried out face to face or by telephone and lasted approximately 1 h each. Interviews were recorded and transcribed. The interview protocol was structured in three parts (see [Appendix 3](#)). The objective of the first part was to identify the interviewees' understanding of the bioeconomy, including which bio-sectors were considered central in each country. The second part aimed at identifying the policy actors' views on key barriers and drivers, and preferred/implemented policy instruments for achieving a transition to a bioeconomy. The third part aimed to assess stakeholder involvement and processual challenges. Although all interviews followed the same structure they were treated as semi-structured, as they were open for new perspectives raised by the interviewees.

3.2 Data analysis

We performed a directed content analysis ([Hsieh and Shannon 2005](#)) of the key documents on bioeconomy policy in the four Nordic countries. A directed content analysis is advantageous when the aim is to validate existing theory or as in our case assess the use of various innovation policy approaches in promoting the bioeconomy. The starting point for the content analysis was to develop an initial coding scheme (see [Table 3](#)) aiming to identify typical features (or failures) of the three innovation policy approaches. As explained in [Section 2](#), attention to market and structural system failures is not in itself incongruent with a TIP approach. Rather, more traditional approaches to innovation policy are characterised by strong attention to market and structural system failures and lack or little attention to transformative system failures. Subsequently the national policy documents were coded and analysed following the coding scheme. To improve the coding process regarding reliability and consistency across the used categories, the coding was first carried out by the four researchers individually and then discussed and compared jointly. See [Appendix 4](#) for exemplar quotes used in the coding.

We acknowledge that the analysed policy documents in each country are shaped by the socio-economic contexts, industrial specialisations, and established institutional cultures ([Rogge and Reichardt 2016](#)) and the result of policymaking processes involving actors with different interests, political preferences, and agendas ([Meadowcroft 2011](#)). Nevertheless, our theory-informed coding scheme provides us with a comparable lens whereby we can analyse the different elements making up each country's innovation approach.

The content analysis of the policy documents were important starting points for the interviews, providing an in-depth understanding of the situation in each case country. After conducting the interviews, we wrote short summaries for

Table 3. Operationalisation of the analytical framework.

Innovation policy approach	Failures	Policy strategy and instruments in country <i>x</i> , <i>y</i> , <i>z</i>
Innovation for growth	Information asymmetries (MF1) Knowledge spill-over (MF2) Externalisation of costs (MF3) Over-exploitation of commons (MF4)	<i>Weak/Strong/ Absent</i>
Systems of innovation	Infrastructural failures (SF1) Hard/soft institutional failures (SF2) Interaction or network failures (SF3) Capabilities failures (SF4)	<i>Weak/Strong/ Absent</i>
Transformative change	Directionality failure (TF1) Demand articulation failure (TF2) Policy coordination failure (TF3) Reflexivity failure (TF4)	<i>Weak/Strong/ Absent</i>

each case using the inputs from the document analysis and from the interview transcriptions. The case study summaries were then commented on and discussed between the authors. By doing so we gained deeper insight about the combination of innovation policy approaches in each of the four countries.

4. Analysis: innovation policy approaches in the Nordic countries' policy strategies and instruments for the bioeconomy

In this section, we present our analysis of the Nordic countries' bioeconomy strategies and instrument profile considering the three innovation policy approaches described in Section 2. Each country section begins with an analysis of the policy documents forming the respective country's bioeconomy strategy before analysing their profiles on policy instruments.

4.1 Denmark

4.1.1 Policy strategy

Denmark's strategic work related to a bioeconomy is expressed across several documents (see list in Appendix 1). The basis for this work was created as early as 2004, where the Advisory Council for Food Research (RUFF), introduced the vision of making Denmark a 'leading player in the future knowledge-based bio-economy through high technology research into food, non-food and feed' (RUFF 2006a: 4). RUFF worked under the mandate of the Ministry of Food, Agriculture and Fisheries and the Ministry of Family and Consumer Affairs. More recently, strategic elements on bioeconomy development in Denmark has been expressed in various governmental documents: the Growth Plans from 2013 (Danish Government 2013a,b,c,d), Action Plan for New Sustainable Proteins (Ministry of Environment and Food 2018), Strategy for Circular Economy (Ministry of the Environment

and Ministry of Industry, Business and Financial Affairs 2018), and in the national research strategy FORSK2025 (Styrelsen for Forskning og Uddannelse 2017). FORSK2025 prioritised bio- and life science in relation to food, feed, health, and materials, all of which are defined as Danish positions of strengths.

The policy development processes behind the strategic documents reflect involvement and coordination across diverse actors connected to the bioeconomy. The strategic documents are all based on recommendations from multi-stakeholder advisory boards constituted by the Government at the time (e.g. RUFF 2004, 2006a; Danish Government 2013a,b,c,d; Ministry of Environment and Food 2018; Ministry of the Environment and Ministry of Industry Business and Financial Affairs 2018). Most advisory boards were composed of actor types like firms, universities, and public sector authorities; however also labour market unions, non-governmental organisations (NGOs), grassroots movements, etc. were represented on for example the early National Bioeconomy Panel (NBP). If the civic sector was not formally represented on the board, these were often involved indirectly in the strategy process through meetings and workshops.

The bioeconomy strategy documents reflect all three policy rationales. The *innovation for growth* approach is mainly emphasised through a strong focus on research and innovation support. The strategies also consider increasing research coordination and collaboration between innovation system actors in line with the *systems of innovation* approach (Danish Government 2013a,b,c,d; RUFF 2004, 2006b).

The documents express a shift towards TIP thinking in certain aspects. For instance, the strategic work is developed in tandem with the work of the European Commission (European Commission 2004, 2012) and continually calls for the need for vertical and horizontal *coordination* (Danish Government 2013a,b; Ministry of Environment and Food 2018; RUFF 2004, 2006b). As part of setting the direction for change, the government has persistently aimed to influence the EU to ensure a sustainable bioeconomy based on sustainably produced biomass (Danish Government 2013d). Nevertheless, a recurrent theme in the strategic documents as well as in the public debate about a bioeconomy future in Denmark is the conflicting interests of the agricultural industry and environmental considerations. Some respondents argue that even though they perceive this antagonistic relationship as false because the bioeconomy potentially can make a large agricultural and food industry more sustainable, the tension between the agriculture and the environment is a central hindrance for explicitly setting direction and targets in Denmark (D2 and D4). The idea that the bioeconomy can solve the sustainability challenges while increasing profit throughout the whole value chain, from primary producers to retailers, is also a theme in some policy documents (Danish Government 2013a; RUFF 2006a; Styrelsen for Forskning og Uddannelse 2017). However, it has not gained widespread acceptance, and throughout the timeframe studied in this paper, the government has instead prioritised a traditional pro-agricultural policy direction. It is likely that the ambition of considering both the agricultural industry and the environment will continue to cause hindrances to the bioeconomy agenda in Denmark.

Demand-articulation was addressed in the early RUFF strategies (2004, 2006a,b) and to a limited degree in the

growth plans (Danish Government 2013b; d). Focus was on ensuring security, transparency, and ethical considerations in the use of biotechnology in food and non-food products in order to create legitimacy and thereby improve demand articulation.

In sum, the transformative change perspective seems to be more apparent in earlier strategy documents (Danish Government 2013a,b; RUFF 2004, 2006b) than in later strategy documents (Ministry of Environment and Food 2018; Ministry of the Environment and Ministry of Industry, Business and Financial Affairs 2018). In the later strategic documents, the government hesitates to commit to the bioeconomy vision and calls for further analysis before developing a national strategy and implementing the policy tools called for by the NBP and the Advisory Board for Circular Economy (ABCE).

4.1.2 Policy instruments

When examining the bioeconomy policy instruments in Denmark it is clear that the market failure and the system of innovation approach still dominate and that the TIP instruments are more challenging to design and implement. The most relevant policy instruments in Denmark related to the bioeconomy are the R&D funding support (e.g. FORSK2025), bioenergy subsidy schemes, support for innovation networks, and the NBP.

The interviewees confirm that the current configuration of policy instruments is inadequate within all three policy rationales (D1–D6). For example, some respondents stress the need for using stronger market failure policy instruments like tax on fossil-based resources or unused or downgraded side-streams (D3 and D4). Existing market failure policies are implemented through subsidy schemes for bioenergy production² (e.g. biogas, electricity and heat produced from biomass) and are assessed by some respondents as counterproductive for a bioeconomy transition because it downgrades biomass value (D4). ‘We need a level playing field so biomass won’t be used in places where it is downgraded, but should be used to its highest possible value. The only two government approved subsidies targeting the bioeconomy are counterproductive because it creates artificial high prices for using biomass in bioenergy production and attracts biomass that could have been used somewhere else to create higher value products’ (D4).

Other interviewees openly reflect on the challenges related to promoting the new type of high value-added sustainable bio-based products: ‘the system is challenged and has to rethink everything. It is easier to talk about the biofuel blending requirement, but we need an innovative space in terms of what tools we can use to promote high-value biobased products’ (D2). Such instruments, it is argued (D4), need to set targets for utilisation of biomass and subsequently tax unused or downgraded use of biomass.

In line with the system of innovation approach, interviewees argue for strengthening coordination across new value chains and public–private partnerships (PPPs) (D2, D4, and D6). An example of this is the established innovation network The Danish Innovation Network for Biomass (INBIOM), funded partly by the Ministry of Higher Education and Science. INBIOM has been successful in stimulating an experimental start-up environment for utilising bioresources. However, respondents also call for mitigating the risk for new initiatives through PPP (D4 and D5).

Regarding transformative change policy instruments, most interviewees call for a stronger commitment by the government and industry associations in order to set direction and clear targets for realising the transition to a bioeconomy (D4, D2, and D6). The lack of an overarching national bioeconomy strategy has been criticised from various entities, including the ABCE (2017), the NBP (2014), Danish Agriculture and Food Council, The Danish society for Nature Conservation, and The partnership for Sustainable Biorefining (Altinget 2019).

An example of a TIP instrument that has been implemented is the NBP, which was established for the first time in 2013 as a result of the recommendations in the EU bioeconomy strategy. The objective of the NBP has been to coordinate efforts across ministries³ and to unite the voices and actions of scientists, firms, interest organisations, and authorities in addressing a bioeconomy transition. After a change of government in mid-2015, a new panel was launched in 2017 with changes to its constellation but with a much narrower mandate. The new NBP only had members from universities and the private sector and no longer representatives from NGOs, ministries, and public agencies, which improved the panel’s ability to agreeing (D1, D2, and D4). However, the new NBP has been limited in its mandate to only consider recommendations related to proteins, which according to one interviewee is too narrow. Because the panellist of the former NBP never heard any response on their recommendations, the relaunched NBP worked under a new principle of ‘follow or explain’, which means that the government should either follow the recommendations of the panel or explain why it chose not to do so. Although the NBP is an example of a coordinating instrument that encourages involvement and representation across public and private sector actors in Denmark, the lack of realisation of the NBP’s recommendations show that such panels require a strong political will to follow and implement the proposed recommendations.

Overall, the policy instruments are guided by traditional market failure and systems of innovation rationales and only when it comes to coordination failure instruments (e.g. NBP) follow the rationale of transformative change. Still, the interviews reveal that although there is a wish to improve coordination horizontally across ministries and sectors, disagreements and opposing perceptions of the role a bioeconomy transition should play in Denmark has led to a lock-in in the political space. Other indications of a transformative change approach have been found in the early strategy work and in the fact that the strategy development processes show high degree of involvement across multiple sectors. However, the lack of political will to set directionality hampers these good intentions in earnest to redirect and accelerate a transformation to a bioeconomy in Denmark.

4.2 Finland

4.2.1 Policy strategy

The National Resource Strategy of Finland introduced the concept of the bioeconomy to Finnish policy discourse (Davies et al. 2016). It takes a wide perspective on natural resources use across all sectors of society and acknowledges the need for wide systemic changes. Initiated by the prime minister in office and compiled by the Finnish Innovation Fund Sitra, the strategy development process involved a broad range of experts including politicians, administrators, business

representatives, researchers, NGOs, and the media. The strategy also stressed the need to ensure an open and multi-actor approach in bioeconomy policy coordination more generally. It stresses that: ‘To achieve change, the public sector, businesses and civil society must work together towards a shared vision’ (Finnish Innovation Fund 2009: 4). In this regard, it recognised the need to create a permanent high-level body to oversee the implementation of the strategy and the coordination policies. Thus, strong attention is paid to both horizontal and vertical policy coordinations, which are important features of the transformative change approach. The need to pay attention to reflexivity is also clearly identifiable in the strategy. It puts high emphasis on the need for recognising barriers, conducting experiments, and learning from evaluation in a continuous process. While the underlying rational of the strategy clearly builds on transformative change perspectives, this coexists with perspectives of the systems of innovation approach. This is evident through the importance attributed to creating and maintaining favourable and attractive operating environment for firms, attention to physical infrastructure and on providing economic incentives, and for how it gives attention to issues of legislation and administration which are to provide the necessary conditions for firms. Moreover, it recognises the importance of providing consumers with the right information and incentives for making efficient choices (The Finnish Innovation Fund 2009).

Finland’s first over-arching national bioeconomy strategy was published by the government in 2014. Similar to the strategy from 2009, it combines innovation system approaches with elements of the transformative change approach. The underlying policy rational of the national strategy is clearly emphasising the potentials for a sustainable economic growth and well-being. The strategy is explicitly defined as being a ‘growth strategy’ and ‘the transition from a fossil economy to a bioeconomy [as] a new wave of economic development’ (Ministry of Employment and the Economy 2014). The policy objectives are underpinned by typical innovation system approaches which are illustrated by the strategy’s four strategic goals: the promotion of a competitive operating environment, the creation of new businesses, a strong competence base from cross-sectoral cooperation and the creation of well-functioning markets for bio-based raw materials.

Transformative change perspectives were also identified in the strategy and from the interviews. Policy coordination was highlighted as well as the need to pay attention to potential tensions and conflicts in the bioeconomy. The policy strategy process was initiated and led by three ministries (the Ministry of Employment and the Economy, in cooperation with the Ministry of Agriculture and Forestry and the Ministry of the Environment) with different sector responsibilities and with traditionally different perspectives pertaining to the bioeconomy. Citizens were also invited to submit suggestions and views through digital platforms. Interviewees (F2 and F3) recognised that the initial strategy development process had been open to multiple actors and mitigated initial tensions and conflicts regarding the overarching objectives and understanding of the bioeconomy: ‘[...] we had some different viewpoints and emphasis regarding bioeconomy, and in that of course we had many discussions about how to take into consideration also for example biodiversity issues and things not just like boosting business opportunities’ (F3). At the same time,

interviewees acknowledged that the tensions between different views on the bioeconomy continued to persist and affect public and policy debates: ‘[...] now there is lots of criticism around the increased use of forest biomass [...]’ (F3). ‘I think one of the conflicts that has been discussed is how much forest we should cut, how much wood we should use [...], this is one of the areas where there is a lot of public discussion going on’ (F4). In a previous study it was found that despite efforts at transparency and interactive public debate in relation to the transition towards a bioeconomy in Finland, it has been challenging for in particular citizens to meaningfully participate in the strategic decision-making (Mustalahti 2018). Moreover, an interviewee (F1) acknowledged that existing silos in the Finnish policymaking system was a significant barrier to efficient policy coordination and implementation.

4.2.2 Policy instruments

Overall, bioeconomy policy in Finland was placed at a high political level and represented a strategic priority of the Finnish government thus attracting substantial allocation of public funding (Antikainen et al. 2017, and interviewee F2). Regarding the policy instruments interviewees emphasised traditional market failure and systems of innovation perspectives to support bioeconomy development. As mentioned by one interviewee: ‘In the government programme there are specific spearhead projects which focus on different aspects of the bioeconomy, all the way from logistical kind of considerations about how circulation of forest raw materials can be enhanced all the way to promote new types of cross industrial ecosystems and new funding models from the government side relating to demonstration plants’ (F1). Strong attention was given to increased public funding for R&D programmes managed and coordinated by the Academy of Finland and Business Finland.⁴ R&D support and support for technology development for start-ups and large companies were viewed as essential for reaching the strategy’s economic growth objectives. The national bioeconomy strategy highlighted the importance of increasing cooperation across boundaries of bioeconomy sectors through the Strategic Centres for Science, Technology and Innovation (SHOKs) and the INKA—Innovative Cities programme, development of standards as well as new types of industrial ecosystems. The SHOKs in particular have become one of the main instruments of Finnish innovation policy and one of its ‘flagship’ programmes. The two most relevant bioeconomy SHOKs were the Finnish Bioeconomy Cluster FIBIC and CLEEN (later merged into the CLIC Innovation cluster). The increased focus on cross-sectoral cooperation in bioeconomy sectors was highlighted by an interview: ‘it is new this idea of developing symbiotic systems across the sector and borders [of the bioeconomy] and I can see that all the sectors fishery, agriculture, forestry are interested and developing ideas on this regard’ (F3). Funding for pilot and demonstration plants is managed by Business Finland who has funded several bioeconomy-related programmes the last decade including a number of pilot and demonstration projects.⁵ In 2018, the agency launched a €300 million ‘Bio and Circular Finland programme’ aiming at accelerating growth and internationalisation of Finnish companies. The Academy of Finland has had dedicated funding to the bioeconomy sector through its applied research programmes. Amongst these, ‘The

Competence Centre for the Materials Bioeconomy' (CERES) has been considered particularly important (Business Finland 2018).

While it was clear that many policy instruments belonged to traditional market and innovation system approaches, an interviewee expressed the view that changes in the mindset of policymakers were emerging: 'the bioeconomy [in Finland] has started to be viewed as a transition/system change which requires not only R&D and processing of biomass, but that changes are needed in economical, institutional and social systems' (F1). In terms of instruments addressing transformative change, we found that these foremost addressed policy coordination, reflexivity, and demand articulation. A dedicated NBP was established as a policy coordination instrument to ensure the inclusion of different perspectives and interests in the implementation, follow-up, and updation of the national bioeconomy strategy.⁶ In terms of reflexivity, a monitoring system for assessing the achievement of bioeconomy policy objectives has been established using indicators related to *output, value added, investments, employment and exports*.⁷ Regarding demand articulation, interviewees (F1 and F3) mentioned an increased attention to the role of public procurement in creating demand for bio-based products and solutions and for providing incentives replacing non-renewable resources by renewables. An 'Accelerator for low-carbon and circular economy public procurements' was launched in 2018 and is managed by the Finnish Environment Institute in cooperation with the Competence Centre for Sustainable and Innovative Public Procurements (KEINO).⁸ Still, an interview stressed that despite the considerable attention on the role of procurement and on new government resolutions in this field, challenges remained related to training and advisory functions for using the procurement instruments strategically at the local level of municipalities and for increasing consumer awareness (F3).

4.3 Norway

4.3.1 Policy strategy

The Norwegian government presented the first national bioeconomy strategy, 'Familiar resources – undreamt of possibilities', in November 2016. The strategy stresses opportunities in more conscious exploitation and use of bioresources, in particular on circularity (waste prevention, reuse, material recovery, and recycling of waste), and to apply biotechnology onto bioresources in order to create innovative and high-value products. The document excluded specific policies for the traditional bio-industries, and the focus of the strategy is on the potential for growth in synergies across established value chains, industries, and disciplines. In the Norwegian context, this means creating new linkages across blue (fisheries and fish farming) and green (forestry and agriculture) bio-sectors.

Due to a parallel policy process of developing a climate strategy, according to one of our respondents climate as such did not become a core issue in the bioeconomy strategy: 'Our bioeconomy strategy did not address this as a major issue, it became too complicated and there would have been too many fights' (N6). However, although not playing a vital role in the official policy process and final strategy, our informants stress how the bioeconomy 'is also a mindset, it is a change of attitude. [...] It represents an opportunity to link different industries, different value chains, different side streams,

different residual raw materials, one industry into another industry so that it gives economic returns' (N1).

The strategy document reflects all three policy rationales. The *innovation for growth* approach is dominant in economic and industrial policy in Norway, and the document includes explicit discussions of market failure-based policies and instruments. It argues that 'correct pricing of climate- and environmental externalities is an efficient way to promote the bioeconomy. The authorities also play a role in providing expedient regulations and correct for different forms of market failure' (Ministry of Trade Industry and Fisheries 2016: 39–40). There is a persistent call for sector neutral instruments (financial system, taxes, property structure, and information flows) and supply-oriented funding of innovative development where the innovation for growth approach is evident. However, several informants stressed the need to accompany research funding (i.e. market failure) with other policy measures in order to bring out the full potential of the bioeconomy. We also found elements of a system failure rationale, i.e. innovative public procurement and improved interaction and coordination along value chains, between firms, research institutions, and public agencies. The transformative approach is indicated by the main policy goal of developing radically new products, value chains, and industries which combine objectives of increasing added value (growth and jobs) with sustainability aims (climate change and resource limitations). This would be the outcome of processes based on combinations of elements of existing bio-industries, resulting in a 'circular and environmentally friendly low emission economy' (Ministry of Trade Industry and Fisheries 2016: 9, 57) with continuous resource management to ensure that environmental impacts are kept within sustainable boundaries. Nonetheless, sustainability seems to be secondary to business as usual. 'Our mandate is primarily Norwegian business [...] but we will still do it in a sustainable and socially responsible way' (N2).

The process of developing the strategy was characterised by broad anchoring and collaboration across several types of stakeholders. The process involved eight ministries, and representatives from the Ministry of Trade, Industry and Fisheries and the Ministry of Agriculture and Food constituted the secretariat for the strategy process.

A core intention (of the secretariat) was to provide all stakeholders with a shared understanding of how to operationalise 'bioeconomy' in the Norwegian context. The process included an openness to inputs from external and non-governmental stakeholders, with several conferences and written submissions welcoming expressions of interest from diverse stakeholders. Interviewees expressed that: 'This was really a very good process. [...] it is rare that one is so open in such kind of work. [...] This was very new, like pioneering work in the ministries' (N6), and 'It is no doubt the most complex area I have developed a strategy for' (N3).

4.3.2 Policy instruments

By limiting the bioeconomy to transformative processes involving the development of new value chains and industries as cross-sectoral innovation processes, the strategy defines the bioeconomy as a new 'policy niche'. This is not the responsibility of any single ministry, and the strategy does not suggest positioning the coordinating function of the strategy at governmental policy level. The strategy is therefore not anchored

in existing sector-based policies or in the traditional policy-making system: no individual ministry is expected to take responsibility for the follow-up of the strategy process and ensure cross-sectoral policy coordination.

Rather, the strategy document proposes a bottom-up approach where the coordinating role is the responsibility of the three main public funding agencies for innovation (Innovation Norway, the Research Council of Norway, and SIVA). They were asked to follow up on the bioeconomy strategy by developing a joint action plan including how to improve coordination of and balance between relevant instruments (from R&D to demonstration, pilot and upscaling, and market orientation). In February 2019 this action plan was released (NFR 2019) and which outlines the respective responsibilities across the three funding agencies Innovation Norway, Research Council Norway, and SIVA. The action plan has a technocratic character and focusses upon increasing collaboration, coordination, and clarity in responsibilities across existing policy measures in the three funding agencies. It is also stressed that the action plan is to be implemented within existing budgetary frames. Moreover, the strategy outlines how different policy measures in place spreads out across the value chain from research to market introduction.

Norway has a rather weak tradition of cross-sectoral coordination in innovation policies, and the implementing agencies have *de facto* fulfilled this role (Smith and Wicken 1990). We may thus perceive the strategy as a new policy niche and a systematic experiment to engage a broad set of actors including firms, research institutions, local communities, and other stakeholders at project or programme level, reflecting an idea of ‘coordination from below’.

Although the bioeconomy strategy can be perceived as a transformative niche, it is based on existing and more traditional policy instruments targeting the bioeconomy.

‘Producing biofuels, for example, can have an effect in terms of reducing climate emissions from the transport sector. But it doesn’t necessarily have to be any increased circularity in it’ (N3).

The main current policy instruments targeting the bioeconomy in Norway comprise the R&D programmes Bionær, MarinForsk, Biotek2021, Energix, and Havbruk, all operated by the Research Council of Norway. Another central initiative is Foods of Norway, a Centre for Research-based Innovation (CRI) at the Norwegian University of Life Sciences, funded by the Research Council of Norway and industry partners. In addition, the more generic support measure SkatteFUNN (tax deduction for R&D investments) is also potentially important for the bioeconomy. Innovation Norway has had several measures targeting the bioeconomy in particular, such as the Marine Value Creation Program, the Biorefinery Program, or the Program for the Development of Environmental Technologies (Bruvoll et al. 2015).

The measures operated by the Research Council of Norway can be categorised as a supply-oriented and science-driven approach towards the development of new technologies (market failure). The measures operated by Innovation Norway have a systems approach oriented towards supporting networks, clusters, and demonstration fields (system failure). Central building blocks for developing the bioeconomy are thus cross-sectoral knowledge and technology platforms with new forms of coordination mechanisms.

In terms of specific policy instruments, the strategy calls for active policy bringing changes in demand and the role of public procurement (e.g. the construction industry), as well as experimentation with new products (e.g. biogas and new types of fertilisers), and production methods radically different from monoculture (multi-trophic aquaculture). In this way there are clear discrepancies between existing policy measures targeting the bioeconomy and the policy instruments prescribed by the bioeconomy strategy. According to one of our respondents there is a lack of market-pull instruments targeting the bioeconomy in Norway. The prevalence of market neutrality in innovation policy support measures hinders proactive innovation policy measures. However, despite this structural barrier towards a proactive approach towards the bioeconomy, the support apparatus to some extent still manages to act proactively through its close dialogue with and counselling and coupling function with industry actors (N1 and N2).

4.4 Sweden

4.4.1 Policy strategy

The central bioeconomy policy document in Sweden is the Swedish Research and Innovation Strategy for a Bio-based Economy, published by FORMAS (2012). As the key national-level strategic document on bioeconomy in Sweden, the policy does not take a narrow research-push approach to the development of the Swedish bioeconomy, even if the areas of research and innovation are naturally assigned considerable importance (Coenen et al. 2017). Straffas and McCormick (2013: 2762) state that the strategy ‘clearly has a broad approach to the BBE [bio-based economy] and addresses numerous aspects of both the BBE itself and the ways to reach it’.

The Swedish Government assigned the task of drafting the strategy to FORMAS, the Swedish Research Council for Sustainable Development, in consultation with VINNOVA (Sweden’s Innovation Agency) and the Swedish Energy Agency. Interviewees highlighted that the strategy development process was not very open and inclusive (S2): ‘It was some individuals who created a very nice product [...] it was a product of work carried out behind a desk.’ Even contrasting opinions between representatives from the three involved public organisations were not really resolved (S3): ‘there were three agencies with different missions and different ideas about what they should do in this area and no-one would like to give up their own degree of freedom’. Thus, the strategy development process involved a narrow set of actors and was carried out in a rather traditional top-down manner.

The underlying policy rationale of the strategy combines an innovation system approach with a transformative change perspective. An innovation system perspective is evident through, firstly, the importance attributed to collaboration across sectoral and industrial boundaries, since the bioeconomy ‘necessitate[s] widespread collaboration between companies, sectors, universities, colleges, research institutes and public sector organisations’ (FORMAS 2012: 31). Secondly, the strategy also calls for capability development in multiple fields, covering biomass cultivation and development, production, consumption, and recycling of bio-based products. Thirdly, the strategy acknowledges the need for better

understanding how regulatory and administrative barriers hinder the transition towards a bioeconomy. Fourthly, attention is also given to the need for improving infrastructures in the form of demonstration facilities for new bio-based products.

The transformative change perspective is very clearly identifiable in [FORMAS \(2012\)](#) (see also [Coenen et al. 2017](#)). The strategy highlights the importance of constantly giving attention to issues related to prioritisation, since a development towards a bioeconomy may have unanticipated negative environmental and social effects, i.e. ensuring that the direction of development is in fact desirable from a wider societal perspective. In this way, potential tensions and conflicts associated with the bioeconomy transition are acknowledged and highlighted, rather than assumed to not exist. Demand articulation is also extensively addressed in the strategy, with significant consideration devoted to the need for learning about and influencing consumption habits and attitudes. The strategy also calls for increased coordination between different policy areas, in particular horizontally across industry sectors and along value chains.

Conversely, a traditional market failure approach is not very evident in the Swedish strategy. In fact, contrary to the neo-classical approach, the difficulty of pricing all externalities associated with a transition towards a bioeconomy is openly acknowledged. However, it should be noted that another central bioeconomy policy document ([The Swedish Government 2014](#)) emphasises the importance of improving assessments of economic value of ecosystem services in order to ensure long-term sustainable development. However, in general, a market failure approach does not appear to be central in Swedish bioeconomy strategies.

4.4.2 Policy instruments

Moving from policy strategy to policy instruments, we observe a considerable change in the dominant policy rationale. Our informants unanimously stated that the [FORMAS \(2012\)](#) strategy has in fact had very limited impact on the actual instruments supporting the bioeconomy transition, and it was characterised as ‘a very theoretic product [...] just something on paper’ (S2) and ‘some kind of policy document without any real impact’ (S3).

Thus, a transformative policy perspective has not been firmly anchored in the system, which continues to emphasise rather traditional technology-push instruments. This includes research support through different funding instruments operated by in particular FORMAS, the Swedish Research Council for Sustainable Development, but also commercialisation support from sector agencies such as the Swedish Board of Agriculture. In between research and commercialisation, it was also highlighted that ‘when it comes to test-beds, I think this has developed a lot in recent years’ (S2) with increasing financial and coordination support (e.g. through the Swedish Testbed Programme) from agencies such as the Swedish Energy Agency and Vinnova, which supported facilities of core relevance to the bioeconomy such as LignoCity (a test facility for development of products based on lignin).

Conversely, all informants agreed that instruments focusing on demand articulation are underrepresented in the Swedish bioeconomy instrument mix. As expressed by one interviewee, ‘there is a lot of [technology] push in Sweden but not so much [demand] pull’ (S3). This also follows from a

lack of a shared vision regarding the transition to a bioeconomy. Responsibility for policy instruments to a large extent resides with sectorial agencies that have a rather traditional view of how to promote innovation and the development of a bioeconomy. As expressed by an interviewee (S2), ‘[t]hey are extremely linear and they, in the sectorial agencies like [agency name], [university name], [agency name], [agency name], their view on this transition is very traditional going from basic... we need basic research’, while another interviewee acknowledged that: ‘we are still very focused on research and academia’ (S1). A third interviewee stated that ‘except support for research and innovation, we haven’t seen much from the last government’ (S4).

Related to this, policy coordination is generally considered insufficient. Swedish bioeconomy policy instruments were described as ‘fragmented’ (S2). Thus, while [FORMAS \(2012\)](#) emphasises the need for policy coordination, this has not been implemented in the instrument mix. Still, interviewees suggested that increasing awareness of the need for policy coordination was found in the system, but progress is hampered by the lack of a shared vision for the bioeconomy transition and limited attention to reflexivity in policymaking: ‘I think it is a process that is developing in a positive way. I think people are becoming aware of the need of coordination [...] So it’s getting better. But I think the main problem is that we don’t really have a shared vision’ (S2). Regarding reflexivity, according to interviewees, considerations and responsibilities for monitoring and policy learning are still unarticulated for bioeconomy policy: ‘I don’t know if anyone has asked for this monitoring or who should be responsible for it’ (S3). Thus, the overall emphasis of Swedish bioeconomy policy instruments is on traditional technology-push instruments, which is rather different from the bioeconomy strategies. However, interviewees did highlight that changes in policy instruments were occurring, however only ‘in isolated spots’ (S3). Firstly, a systemic perspective is found at the regional level, where a number of Swedish regions clearly draw on innovation systems thinking in their efforts to develop a bioeconomy. However, these efforts still have a clear link to the national level where Vinnväxt, Vinnova’s cluster excellence programme, was central in establishing influential regional bioeconomy intermediaries in regions such as Scania (emphasis on food) and Värmland (emphasis on forestry) ([Jolly et al. 2020](#)). Secondly, the establishment of so-called strategic innovation programmes, which explicitly target system-wide transformation in order to address grand challenges and increase Swedish international competitiveness, represents an important step towards a transformative policy rationale ([Vinnova 2017](#)). Interviewees highlighted the strategic innovation programme focussed on the bioeconomy, BioInnovation, as a prime example of a move towards more transformative policy instruments (see [Grillitsch et al. 2019](#) for a detailed analysis of BioInnovation). This is also reflected in the policy processes established around the strategic innovation programmes: priority setting and the use of resources are to a large extent left to consortia spanning industry, academia, and interest organisations, which have been formed through bottom-up processes: ‘the stakeholders of BioInnovation they have a lot of responsibility themselves to design the strategy and implement it [...] they really take full responsibility’ (S2) Thirdly, the Swedish Government has recently established so-called Strategic Collaboration Programs for five priority areas, including a circular bio-based economy. A

central aim is to increase policy coordination across sectorial boundaries. However, the effects of this aim are still not clear.

5. Discussion

This section presents a cross-country discussion on how and whether the TIP approach is applied and coexists with traditional innovation policy approaches in the four countries' bioeconomy strategies and instruments.

5.1 Policy strategies

As expected, the analysed bioeconomy policy strategies in the four Nordic countries incorporate all three innovation policy approaches (*innovation for growth, systems of innovation, and transformative change*). For all countries, we found evidence of a move towards policies for transformative change, i.e. the need to address societal and environmental problems with STI policies. However, we see clear variations in the way the transformative change perspectives are expressed in the countries' strategies and instruments.

We found that the strategies combine the features of the innovation system and transformative change approaches, although they also place some emphasis on innovation for growth rationales. In all strategies, we found strong attention to priorities such as improved collaboration across sectoral and industrial boundaries, coordination across value chains, commercialisation of new bio-based products in demonstration facilities, and knowledge creation across sectors. The strategies provide evidence of a move towards transformative change perspectives by paying attention to vision creation (Norway, Finland, and Sweden), broad involvement of civil society actors (Finland and Norway), the importance of prioritisation, niche experimentation, demand articulation through public procurement (Finland), and the need for active policy influencing consumption habits and attitudes (all countries).

Overall, we do not see that the market failure rationale plays a unique role in the four countries' strategies, except for a recognised need for R&D investments as an essential ingredient in developing a bioeconomy.

The policy goals of fostering a bioeconomy are underpinned by a growth objective of increasing added value in terms of economic growth and job creation, in combination with environmental sustainability concerns (climate change, resource limitations, clean energy, etc.). While some of the strategies address directionality failure by including a vision for long-term policies, we did not see that social and environmental sustainability aims were embedded in strategic motivations, which is an essential element of the TIP approach. In fact, only the Swedish strategy explicitly recognises issues of prioritisation and unintended effects of bioeconomy policies, however without addressing how to deal with such conflicts. In the Danish case, bioeconomy strategies assumed positive relations between industry development and environmental sustainability. The Norwegian case gave central importance to business development in the form of creating new value chains across bio-based sectors without having to address the potential unsustainability of existing value chains. In Finland, while the first strategy from 2009 stressed the negative environmental impacts of current economic practices, these concerns were not explicitly addressed in the

national bioeconomy strategy from 2014. In summary, this suggests that contestations related to the negative environmental impacts of the natural resource industries do not occupy a central place in the four countries' bioeconomy strategies.

The analysis also showed variation regarding the position and role of the bioeconomy in the existing policy landscape. While the bioeconomy is a high-level policy field in Sweden and Finland, it represents a rather new policy area and has so far not achieved a strong position in policymaking in Norway. Here, the main national discourse on the economic future relates to the strong position and economic dependence of the oil and gas sector. As part of an early phase of strategy formation, we argue that the Norwegian bioeconomy strategy may be a first step towards establishing a common understanding of the contents and direction of the bioeconomy. Moreover, it represents a new way of organising policy development and innovation across a wider group of stakeholders in the Norwegian policy system. In Denmark, the tension between a large agricultural and food industry and environmental concerns runs deep in the Danish political system and results in a lack of high-level policy support and commitment to a bioeconomy transition. Danish civil servants have played a major role in keeping the bioeconomy on the political agenda by moving it forward in the EU system as well as during times of governmental change.

An important feature of the TIP approach is the need to pay attention to policy coordination. In each country, we found that policy coordination failures were addressed in different ways. In Denmark, Finland, and Norway the drafting of bioeconomy strategies were initiated jointly by multiple sector ministries and the strategy development processes were open to and involved a diverse set of actors and stakeholders through open hearings and stakeholder meetings. On the other hand, we found that the process in Sweden was more bureaucratic and top-down. In all four countries we noticed that the traditional innovation system actors, such as research and innovation funders, played a key role in developing and following up the strategies.

We also found that the strategies acknowledge the heterogeneity of the bioeconomy and calls for horizontal coordination across sectoral policies and alignment of regulatory and administrative settings. However, most interviewees reported that actual coordination mechanisms for system change remained inadequate even in countries like Finland and Denmark, where new *ad hoc* advisory boards or national bioeconomy councils or panels were established to support coordination and to follow up on strategies.

When looking at how reflexivity failures were addressed, we found initiatives expressing the need to address this aspect, but also indications of barriers hindering such reflexivity. In Finland, the national resource strategy placed emphasis on the need to continuously recognising barriers and explicitly addressed the importance of evaluation and policy learning. In addition, the later national strategy included initiatives such as the establishment of monitoring systems with the inclusion of sustainability indicators and the use of foresight in support of policy development. In Denmark, the NBP was adjusted underway and adapted to better equip the civil service system to bridge and coordinate recommendations and initiatives guiding the bioeconomy. In Norway, a particular challenge was the lack of a formal organisation responsible for the

follow-up of the cross-sectoral bioeconomy strategy as well as the lack of mechanisms for regular evaluation or monitoring of the progress of a national bioeconomy. In a similar way, we found that efforts in Sweden were hampered by the lack of a shared vision for the bioeconomy transition and limited attention to reflexivity in policymaking, as well as unarticulated responsibilities for monitoring and policy learning.

5.2 Policy instruments

While we found some evidence of an emerging rationale for *transformative change* in the policy strategies in all four countries, a different picture emerged from the interviews. Interviewees expressed that the policy instruments in place in the four countries were predominantly reflecting the innovation for growth and systems of innovation approaches and favouring a technology-push perspective. On this point, the interviewees expressed that the current policy instruments were inadequate to achieve significant social change, an ambition which they nevertheless clearly saw as spelled out in the strategies. It was made clear that the societal change ambitions set out in the policy strategies had not yet translated into instruments fit for the purpose. We did however find a few instruments indicating a turn towards the TIP approach such as the establishment of so-called Strategic Innovation Programmes in Sweden or the Accelerator for Low-carbon and Circular Economy Public Procurement in Finland.

What we observe in relation to the four Nordic countries' policy development processes for the bioeconomy may be regarded as expressions of policy *layering*, which 'refers to the process of adding new policy goals and instruments to existing policy mixes without discarding previous measures' (Kern and Kivimaa 2017) or policy *drift* which 'occurs when new goals replace old ones without changing the instruments used to implement them'. According to Howlett and Rayner (2013) the development of policies through layering or drift (in addition to *conversion*, and *replacement*) is quite common and that this often results in incoherent and inconsistent policy mixes (Howlett and Rayner 2013). Whether and how the policymakers in the Nordics can find ways to effectively balance the existence of diverse innovation policy approaches remains an open question. However, the lack of bioeconomy instruments for supporting systemic change might be explained by the weak anchoring of TIP in the broader innovation system beyond the domain of research and innovation. This may also explain the dominating role of targeted public funding for R&D and instruments supporting market creation for innovative bio-based products and services. Table 4 illustrates the coexistence of the three innovation policy approaches in the Nordic countries' bioeconomy strategies and instruments.

6. Conclusion

In STI policy discussions amongst both policy actors and academics, there is an increasing interest in understanding how STI can more effectively contribute to confront major social and environmental challenges. In this context, the TIP approach has recently been identified as an emerging innovation policy approach which can offer guidance for policymakers in exploring options towards socio-technical system change. This article draws on the innovation policy literature to investigate whether and how the TIP approach is applied in bioeconomy policies addressing societal challenges and to discuss the match of policy instruments with their policy goals

in accordance with the characteristics of the three innovation policy approaches.

Empirically we focussed our attention on bioeconomy policy mixes in four Nordic countries (Denmark, Finland, Norway, and Sweden) between 2006 and 2019. Compared to existing empirical studies analysing individual policy instruments from the perspectives of TIP, this article takes a broader perspective towards analysing the policy mixes underpinning the development of the bioeconomy. Our approach differs from traditional policy mix studies (e.g. Rogge and Reichardt 2016) in terms of scope of the policy mix examined. We did not have the objective to evaluate specific policy instruments or sector-specific policy mixes, but rather to explore the existence and the expressions of TIP in bioeconomy policy, which is a broad and emerging policy field, encompassing multiple sectors, technologies, and policy domains. To conduct such a study, we chose to accomplish interviews with selected key policy experts in each case country.

Our analysis found that the bioeconomy strategies in all four countries included different elements of transformative policies but that none of the four countries addressed all four transformative change failures (see Table 4). The paper has also documented that despite the emphasis of some TIP elements in the Nordic bioeconomy strategies, the translation and implementation of these strategies into policy instruments do not possess the same TIP profile. Our analysis showed that the TIP rationale expressed in the strategies was not firmly anchored in actual policy instruments. In some cases (especially in Sweden, Norway, and Denmark) we observed how bioeconomy policy strategies and instruments resembled more fragmented efforts, or was a niche detached from the remaining policy apparatus. Overall, the policy instruments underpinning the respective bioeconomy strategies were found to express primarily traditional *innovation for growth* and *systems of innovation* approaches. From this we draw the conclusion that addressing the transformative failures only partially will not be enough. For instance, addressing *policy coordination* failures without setting a clear long-term *direction* for what is to be achieved may lead to weak and ineffective coordination. The same goes for *demand creation* and *reflexivity* needing to be articulated and developed in accordance with the chosen policy direction. Previous studies have indicated that policymakers experience difficulties in developing TIP instruments (Diercks et al. 2019; Grillitsch et al. 2019). Still, as shown in our analysis a transition (to the bioeconomy in our case) that contributes to sustainable development will require a redirection of both strategic policy goals and policy instruments towards TIP.

In this sense, in all countries, the TIP agenda expressed in the policy strategies clearly coexisted with traditional innovation policy approaches when it comes to instruments. For example, all four countries' bioeconomy strategies prescribe a prominent role to R&D support (a market failure instrument) or networks (innovation system failure). Still, despite the shortcomings so far in relation to the full implementation of TIP instruments, we find that policymakers in the Nordics are exploring and introducing new rationales in policy development processes.

These inconsistencies between the rationales underpinning (transformative) strategic goals, and the instruments to achieve policy objectives, may be explained by the development of the bioeconomy policies by *layering* or *drift*.

Table 4. Summary of results illustrating the coexistence of innovation policy approaches in the Nordic countries' bioeconomy strategies and instruments.

	Denmark	Finland	Norway	Sweden
<i>Policy strategies</i>	<ul style="list-style-type: none"> - Strong attention to R&D support (MF1 and MF2) and focus on sustainably produced biomass to avoid overexploitation of commons (MF4) - Emphasis on capabilities' failure (SF4), network failures (SF3), and hard institutional failure (SF2) - Weak focus on directionality (TF1) - Considerable attention to horizontal and vertical coordination (TF3) - Limited attention to demand articulation (TF2) 	<ul style="list-style-type: none"> - Strong attention to sustainable economic growth and well-being backed by long-term targets and visions (TF1) - Strong attention on policy coordination across systemic levels, horizontal and vertical (TF3) - Attention on policy learning (TF4) - Strong focus on addressing attractive operating environments for firms, stimulating capacities, cross-sectoral cooperation as well as well-functioning markets (SF2, SF3, and SF4) 	<ul style="list-style-type: none"> - Emphasis on the role of new knowledge and technologies (MF1, MF2, and SF4) - Attention to networks (SF3), clusters (SF3), and demonstration plants (MF2 and MF4) - Pointing to the need for more circular and sustainable production principles (TF1) - Focus on creating new connections, value chains, and markets across established bio-based sectors (SF3 and TF3) - Broad involvement across ministries and sectors (SF3 and TF3) - High degree of policy coordination (TF3), and a reflexive policy process (TF4) 	<ul style="list-style-type: none"> - Strategy development process carried out in a traditional bureaucratic manner - Some attention to monetisation of economic value of ecosystem services (MF4), but market failures are not a dominating rationale for intervention - Emphasis on infrastructural failures (SF1) and addressing networks connecting actors (firms, universities, research institutes, and public-sector organisations) across sectors (SF3) - Considerable focus on stimulating demand (TF2) and ensuring policy coordination (TF3) and reflexivity (TF4); attention to environmental and social effects of the bioeconomy transition (TF1)
<i>Policy instruments</i>	<ul style="list-style-type: none"> - Strong focus on traditional technology-push instruments and to overcome the 'valley of death' (MF1 and MF2) - Subsidy schemes incentivise the use of biomass in energy recovery (MF3) - Instruments address network failures and the development of strong innovation networks (SF3) - Some attention on coordination across ministries and public-private sectors and on EU level (TF3) - Limited focus on demand articulation and directionality (TF1 and TF2) 	<ul style="list-style-type: none"> - Instruments emphasise network failures (industrial ecosystems), strengthening capacities, and risk financing (SF2 and SF3) - Strong attention on public procurement for the bio- and circular economy (TF2) - Strong attention on stimulating demand from piloting, demonstration, and experimentation (TF4) - Strong attention on creating intersectoral cooperation platforms (e.g. bioeconomy panel) (TF3) 	<ul style="list-style-type: none"> - Strong attention to traditional science-based and technology-push instruments (MF1 and MF2). - Several generic and sector-specific research programmes targeting the bioeconomy (MF1, MF2, and SF4). - Public support to the creation of networks and new arenas, in particular across blue (fisheries and fish farming) and green (forestry and agriculture) bio-sectors, but also other types of connections, e.g. an attempt to connect digitalisation and agriculture (SF3) - Apart from a broad and inclusive policy process (TF3) no particular transformative instruments implemented so far; neither focus on the (un)sustainability of existing value chains 	<ul style="list-style-type: none"> - Strong focus on traditional technology-push instruments (R&D) (MF2) - Some instruments address network failures (SF3), in particular at the regional level - Limited attention to demand-side instruments (TF2) - Unarticulated responsibility for policy learning (TF4), and—thus far—low degree of coordination across instruments (TF3)

Source: Originally elaborated.

Note: The codes attributed to the descriptions follow those used in the operationalisation of the analytical framework (see Table 3).

Nonetheless, in relation to policy processes we found an emerging development towards new types of institutional arrangements underpinning an agenda for transformative change. Examples of such new initiatives are the ‘follow or explain’ policy process in Denmark, the broad and intersectoral Bioeconomy Panels in Finland and Denmark, the establishment of ‘strategic innovation programs’ and ‘strategic collaboration programs’ in Sweden, and the inter-ministerial and open strategy development process in Norway. We also found that the Finnish strategy from 2009 placed strong emphasis on the involvement of stakeholders and active contributions from citizens in the policy process and implementation. These initiatives express attempts to integrate and coordinate different perspectives and interests of users and producers. Nevertheless, we argue that the observed instances of TIP in the countries’ bioeconomy strategies, such as efforts to address directionality, demand, policy coordination, and reflexivity failures, become weakened by not sufficiently acknowledging and addressing the conflicts created by the negative environmental impacts from the natural industries in these countries. These observations also sit within a broader debate about the complexity of addressing societal challenges due to the high risk of conflicts and tensions arising from simultaneously addressing multiple goals—e.g. socio-economic goals, environmental protection, food security, and clean energy (Nilsson et al. 2018; Weitz et al. 2017). To better acknowledge and address such conflicts, the TIP approach needs to be more broadly and deeply anchored in the system beyond the traditional research and innovation policy domains. As part of this challenge, it will be important that policymakers experiment with and explore new ways of balancing traditional and emerging transformative policy approaches.

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Notes

1. We note that Schot and Steinmueller use the terminology of framings and/or generations to indicate the historical unfolding of innovation policy orientations. In our paper, we use the term approaches to distinguish between the key characteristics of Schot and Steinmueller’s three innovation policy framings.
2. Since 2008 Denmark has had a direct subsidy scheme for electricity and heat production from biomass as well as on biogas. The Energy

Agreement from March 2012 introduced a direct subsidy scheme for biogas and biomass used in heat and electricity production. The Energy Agreement from 2018 continued the exemption for energy taxes and CO₂ allowances for biogas and biomass.

3. The NBP was supported by a cross-ministerial secretariat led by the Ministry of Environment and Food and representing four other ministries and several government agencies with the intention to improve horizontal coordination.
4. Until 2018 Business Finland was named Tekes, the Finnish Funding Agency for Innovation. Business Finland is a key funding agency for the bioeconomy with its innovation funding, networking, and internationalisation services in the bioeconomy area.
5. Examples of these type of programmes are ‘the Smart and Green Growth’ programme and ‘the renewable energy Groove programme’.
6. The members of the NBP included representatives from public bodies, business and employee organisations, research and education institutions, and non-governmental organisations. The panel was set up for a period of four years from 2016 to 2019. A new Bioeconomy Advisory Panel chaired by the Minister of Economic Affairs was set up in connection with the update of the national bioeconomy strategy in 2020.
7. The main source for the indicators is the annual national accounts, produced by Statistics Finland.
8. The KEINO Centre is funded by the Ministry of Economic Affairs and Employment.
9. In addition, Kern and Howlett talk about possibilities of conversion and replacement were ‘[c]onversion involves the reverse situation whereby new instrument mixes evolve while holding old goals constant’ and ‘replacement describes a process in which a conscious effort is made to fundamentally restructure both goals and instruments in a coherent and consistent manner by sweeping aside old elements and designing a new mix de novo’ (Kern Howlett 2009: 395).

References

- Altinget. (2019) ‘Derfor har vi brug for en national bioøkonomistrategi. By the Danish Agriculture & Food Council, The Danish society for Nature Conservation, Novozymes and the partnership for Sustainable Biorefining’. <<https://www.altinget.dk/miljoe/artikel/aktoerer-derfor-har-vi-brug-for-en-national-bioekonomistrategi>> accessed 15 Sept 2021.
- Antikainen, R., Dalhammar, C., Hildén, M., et al. (2017) *Renewal of Forest Based Manufacturing Towards a Sustainable Circular Bioeconomy*. Helsinki: Finnish Environment Institute.
- Bakker, S. and Trip, J. J. (2013) ‘Policy Options to Support the Adoption of Electric Vehicles in the Urban Environment’, *Transportation Research Part D: Transport and Environment*, 25: 18–23.
- Birch, K. (2016) ‘Emergent Imaginaries and Fragmented Policy Frameworks in the Canadian Bio-economy’, *Sustainability*, 8: 1007.
- (2019) *Neoliberal Bio-Economies? the Co-Construction of Markets and Natures*. Cham: Palgrave Macmillan.
- Bruvoll, A., Ibenholt, K., and Skjelvik, J. M. (2015) *Rammebetingelser for Bioøkonomi i Norge*. (201507). Oslo: Vista Analyse.
- Bugge, M., Hansen, T., and Klitkou, A. (2016) ‘What Is the Bioeconomy? A Review of the Literature’. *Sustainability*, 8: 691.
- Business Finland. (2018) *Innovation Ecosystems in A Sustainable Bioeconomy. A Finnish Case Study for OECD*. Helsinki: Business Finland and Gaia Consulting.
- Cavicchi, B. (2016) ‘Sustainability that Backfires: The Case of Biogas in Emilia Romagna’, *Environmental Innovation and Societal Transitions*, 21: 13–27.
- Chaminade, C. and Edquist, C. (2010) ‘Rationales for Public Policy Intervention in the Innovation Process: A Systems of Innovation Approach’. In: S. Kuhlman, P. Shapira, and R. Smits (eds) *Innovation Policy – Theory and Practice. An International Handbook*, pp. 95–119. London, UK: Edward Elgar Publishers.

- Coenen, L., Grillitsch, M., Hansen, T., et al. (2017) 'Policy for System Innovation-the Case of Strategic Innovation Programs in Sweden', *Papers in Innovation Studies*, 2017.
- Danish Government. (2013a) *Denmark at work: growth plan for energy and climate*.
- . (2013b) *Denmark at work: Growth plan for food*.
- . (2013c) *Denmark without waste: Recycle more – incinerate less*.
- . (2013d) *Growth plan for water, bio and environmental solutions*.
- Davies, A. and Evans, D. (2019) 'Urban Food Sharing: Emerging Geographies of Production, Consumption and Exchange', *Geoforum*, 99: 154–9.
- Davies, S., Griestop, L., Vironen, H., et al. (2016). 'Promoting Stakeholder Engagement and Public Awareness for a Participative Governance of the European Bioeconomy: Case Studies of National Bioeconomy Strategies in Finland and Germany'. BioSTEP Report.
- Diercks, G., Larsen, H., and Steward, F. (2019) 'Transformative Innovation Policy: Addressing Variety in an Emerging Policy Paradigm', *Research Policy*, 48: 880–94.
- Dubois, O. and Gomez San, J. M. (2016) *How Sustainability Is Addressed in Official Bioeconomy Strategies at International, National and Regional Levels. An Overview*. Rome: Food and Agriculture Organization of the United Nations.
- EUBA. (2018) *The Crucial Role of the Bioeconomy in Achieving the UN Sustainable Development Goals*. Brussels: European Bioeconomy Alliance.
- European Commission. (2004) *Towards a European Knowledge-based Bioeconomy: Workshop Conclusions on the Use of Plant Biotechnology for the Production of Industrial Biobased Products*. Brussels: European Commission.
- . (2012) *Innovating for Sustainable Growth: A Bioeconomy for Europe. Communication*. Brussels: European Commission.
- . (2018) 'A sustainable Bioeconomy for Europe: Strengthening the connection between economy, society and the environment. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions COM/2018/673 final.' Brussels.
- Fagerberg, J. (2018) 'Mobilizing Innovation for Sustainability Transitions: A Comment on Transformative Innovation Policy', *Research Policy*, 47: 1568–76.
- Falcone, P. M., Lopolito, A., and Sica, E. (2017) 'Policy Mixes Towards Sustainability Transition in the Italian Biofuel Sector: Dealing with Alternative Crisis Scenarios', *Energy Research & Social Science*, 33: 105–14.
- Flanagan, K., Uyarra, E., and Laranja, M. (2011) 'Reconceptualising the 'policy mix' for Innovation', *Research Policy*, 40: 702–13.
- Forskningsrådet, Innovasjon Norge og SIVA (2019) *Bioøkonomi-felles handlingsplan for forskning og innovasjon*. Norges forskningsråd, Lysaker.
- FORMAS. (2012) *Swedish Research and Innovation Strategy for a Bio-based Economy*. Stockholm: FORMAS.
- Fritsche, U., Brunori, G., Chiaramonti, D., et al. (2020) 'Future Transitions for the Bioeconomy Towards Sustainable Development and a Climate-Neutral Economy - Knowledge Synthesis Final Report'. Publications Office of the European Union, Luxembourg, ISBN 978-92-76-21518-9 (online).
- Fund, C., El-Chichakli, B., and Patermann, C. (2018) 'Bioeconomy Policy (Part III) Update Report of National Strategies around the World.' A report from the German Bioeconomy Council.
- Giljum, S., Bruckner, M., Gözet, B., et al. (2016) *Land under Pressure. Global Impacts of the EU Bioeconomy*. Brussels: Friends of the Earth Europe.
- Giuliani, E. (2018) 'Regulating Global Capitalism amid Rampant Corporate wrongdoing-Reply to "Three frames for innovation policy"', *Research Policy*, 47: 1577–82.
- Gregg, J. S., Bolwig, S., Hansen, T., et al. (2017) 'Value Chain Structures that Define European Cellulosic Ethanol Production', *Sustainability*, 9: 118.
- Grillitsch, M., Hansen, T., Coenen, L., et al. (2019) 'Innovation Policy for System-wide Transformation: The Case of Strategic Innovation Programmes (Sips) in Sweden', *Research Policy*, 48: 1048–61.
- Grillitsch, M., Hansen, T., and Madsen, S. (2020) 'How Novel Is Transformative Innovation Policy?' *Papers in Innovation Studies*, 2020.
- Grin, J., Rotmans, J., and Schot, J. (2010) *Transitions to Sustainable Development; New Directions in the Study of Long Term Transformative Change*. New York, NY: Routledge.
- Hansen, T., Klitkou, A., Borup, M., et al. (2017) 'Path Creation in Nordic Energy and Road Transport Systems – the Role of Technological Characteristics', *Renewable and Sustainable Energy Reviews*, 70: 551–62.
- Howlett, M. and Rayner, J. (2013) 'Patching vs Packaging in Policy Formulation: Assessing Policy Portfolio Design, Politics Gov', 1: 170–82.
- Hsieh, H.-F. and Shannon, S. E. (2005) 'Three Approaches to Qualitative Content Analysis', *Qualitative Health Research*, 15: 1277–88.
- Huttunen, S., Kivimaa, P., and Virkamäki, V. (2014) 'The Need for Policy Coherence to Trigger a Transition to Biogas Production', *Environmental Innovation and Societal Transitions*, 12: 14–30.
- Janssen, M. J. (2019) 'What Bangs for Your Buck? Assessing the Design and Impact of Dutch Transformative Policy', *Technological Forecasting and Social Change*, 138: 78–94.
- Johansen, U., Bull-Berg, H., Vik, L. H., et al. (2019) 'The Norwegian Seafood Industry - Importance for the National Economy', *Marine Policy*, 110: 103561.
- Jolly, S., Grillitsch, M., and Hansen, T. (2020) 'Agency and Actors in Regional Industrial Path Development. A Framework and Longitudinal Analysis', *Geoforum*, 111: 176–88.
- Kallerud, E., Amanatidou, E., Upham, P., et al. (2013) 'Dimensions of Research and Innovation Policies to Address Grand and Global Challenges'. Working Paper 13/2013. Oslo: NIFU.
- Kern, F. and Howlett, M. (2009) 'Implementing Transition Management as Policy Reforms: A Case Study of the Dutch Energy Sector', *Policy Science*, 42: 391–408.
- Kern, F., Kivimaa, P., and Martiskainen, M. (2017) 'Policy Packaging or Policy Patching? The Development of Complex Energy Efficiency Policy Mixes', *Energy Research & Social Science*, 23: 11–25.
- Kettunen, M., Vihervaara, P., Kinnunen, S., et al. (2012) *Socio-economic Importance of Ecosystem Services in the Nordic Countries Synthesis in the Context of the Economics of Ecosystems and Biodiversity*. Copenhagen: Nordic Council of Ministers.
- Kitchen, L. and Marsden, T. (2011) 'Constructing Sustainable Communities: A Theoretical Exploration of the Bio-economy and Eco-economy Paradigms', *Local Environment. The International Journal of Justice and Sustainability*, 16: 753–69.
- Kivimaa, P. and Kern, F. (2016) 'Creative Destruction or Mere Niche Support? Innovation Policy Mixes for Sustainability Transitions', *Research Policy*, 45: 205–17.
- Klitkou, A., Fevolden, A. M., and Capasso, M. (2019) *From Waste to Value: Valorisation Pathways for Organic Waste Streams in Circular Bioeconomies*. London: Routledge.
- Kuhlmann, S. and Rip, A. (2014) *The Challenge of Addressing Grand Challenges - A Think Piece on How Innovation Can Be Driven Towards the "Grand Challenges" as Defined under the Prospective European Union Framework Programme Horizon 2020*. Twente: University of Twente.
- Levidow, L., Birch, K., and Papaioannou, T. (2012a) 'Divergent Paradigms of European Agro-Food Innovation: The Knowledge-Based Bio-Economy (KBBE) as an R&D Agenda', *Science, Technology & Human Values*, 38: 94–125.
- , — and — (2012b) 'EU Agri-innovation Policy: Two Contending Visions of the Bio-economy', *Critical Policy Studies*, 6: 40–65.

- Markard, J., Raven, R., and Truffer, B. (2012) 'Sustainability Transitions: An Emerging Field of Research and Its Prospects', *Research Policy*, 41: 955–67.
- McCormick, K. and Kautto, N. (2013) 'The Bioeconomy in Europe: An Overview', *Sustainability*, 5: 2589–608.
- Meadowcroft, J. (2011) 'Engaging with the Politics of Sustainability Transitions', *Environmental Innovation and Societal Transitions*, 1: 70–5.
- Ministry of Employment and the Economy. (2014) *Sustainable Growth from Bioeconomy. The Finnish Bioeconomy Strategy*. Helsinki: Ministry of Employment and the Economy.
- Ministry of Environment and Food. (2018) *Handlingsplan for nye bæredygtige proteiner - opfølgning på anbefalinger fra Det Nationale Bioøkonomipanel*. Copenhagen: Ministry of Environment and Food.
- Ministry of the Environment and Ministry of Industry, Business and Financial Affairs. (2018) *Strategy for Circular Economy*. Copenhagen: Ministry of Environment.
- Ministry of Trade Industry and Fisheries. (2016) *Familial Resources-Undreamt of Possibilities. The Government's Bioeconomy Strategy*. Oslo: Ministry of Trade, Industry and Fisheries.
- Morone, P. (2016) 'The Times They are A-changing: Making the Transition Towards a Sustainable Economy', *Biofuels, Bioproducts and Biorefining*, 10: 369–77.
- Mukhtarov, F., Gerlak, A., and Pierce, R. (2016) 'Away from Fossil-fuels and toward a Bioeconomy: Knowledge Versatility for Public Policy?' *Environment and Planning C: Politics and Space*, 35: 1010–28.
- Mustalahti, I. (2018) 'The Responsive Bioeconomy: The Need for Inclusion of Citizens and Environmental Capability in the Forest Based Bioeconomy', *Journal of Cleaner Production*, 172: 3781–90.
- Näyhä, A. and Pesonen, H.-L. (2012) 'Diffusion of Forest Biorefineries in Scandinavia and North America', *Technological Forecasting and Social Change*, 79: 1111–20.
- Nilsson, M., Chisholm, E., Griggs, D., et al. (2018) 'Mapping Interactions between the Sustainable Development Goals: Lessons Learned and Ways Forward', *Sustainability Science*, 13: 1489–503.
- OECD. (2009) *The Bioeconomy to 2030: Designing a Policy Agenda*. Paris: OECD.
- . (2018) *Meeting Policy Challenges for a Sustainable Bioeconomy*. Paris: OECD.
- Patermann, C. and Aguilar, A. (2018) 'The Origins of the Bioeconomy in the European Union', *New Biotechnology*, 40: 20–4.
- Ponte, S. (2009) 'From Fishery to Fork: Food Safety and Sustainability in the 'Virtual' Knowledge-Based Bio-Economy (KBBE)', *Science as Culture*, 18: 483–95.
- Ponte, S. and Birch, K. (2014) 'Guest Editorial. The Imaginaries and Governance of 'biofueled futures'', *Environment & Planning A*, 46: 271–9.
- Prestvik, A. S., Kvakkestad, V., and Skutevik, Ø. (2013) *Agriculture and the Environment in the Nordic Countries Policies for Sustainability and Green Growth*. Copenhagen: Nordic Council of Ministers.
- Prime Minister's Office. (2017) *Finland, a Land of Solutions Mid-term Review. Government Action Plan 2017-2019*. Helsinki: Prime Minister's Office.
- Pülzl, H., Kleinschmit, D., and Arts, B. (2014) 'Bioeconomy – an Emerging Meta-discourse Affecting Forest Discourses?' *Scandinavian Journal of Forest Research*, 29: 386–93.
- Reichardt, K., Negro, S. O., Rogge, K. S., et al. (2016) 'Analyzing Interdependencies between Policy Mixes and Technological Innovation Systems: The Case of Offshore Wind in Germany', *Technological Forecasting and Social Change*, 106: 11–21.
- Richardson, B. (2012) 'From a Fossil-fuel to a Biobased Economy: The Politics of Industrial Biotechnology', *Environment and Planning. C, Government & Policy*, 30: 282–96.
- Rogge, K. S., Kern, F., and Howlett, M. (2017) 'Conceptual and Empirical Advances in Analysing Policy Mixes for Energy Transitions', *Energy Research & Social Science*, 33: 1–10.
- Rogge, K. S. and Reichardt, K. (2016) 'Policy Mixes for Sustainability Transitions: An Extended Concept and Framework for Analysis', *Research Policy*, 45: 1620–35.
- The Royal Swedish Academy of Agriculture and Forestry. (2015) *Forests and Forestry in Sweden*. Stockholm: The Royal Swedish Academy of Agriculture and Forestry.
- RUFF. (2004) *Sunde, sikre og velsmagende fødevarer gennem bioteknologi - en bioteknologisk forskningsstrategi for fødevarerområdet*. Copenhagen: Det rådgivende Udvalg for Fødevarerforskning, Direktoratet for FødevarerErhverv.
- . (2006a) *Viden vi skal leve af - fremtidens fødevarerforskning*. Copenhagen: Det rådgivende Udvalg for Fødevarerforskning, Direktoratet for FødevarerErhverv.
- . (2006b) *Værditilvækst og bedre miljø - en bioteknologisk forskningsstrategi for nonfood og foder*. (8791791715). Copenhagen: Det rådgivende Udvalg for Fødevarerforskning, Direktoratet for FødevarerErhverv.
- Schmid, O., Padel, S., and Levidow, L. (2012) 'The Bio-Economy Concept and Knowledge Base in a Public Goods and Farmer Perspective', *Bio-based and Applied Economics*, 1: 47–63.
- Schot, J. and Steinmueller, W. E. (2018) 'Three Frames for Innovation Policy: R&D, Systems of Innovation and Transformative Change', *Research Policy*, 47: 1554–67.
- Schou, S. J. (2020) *Analyse til Realdania Landbrugsforum*. Copenhagen: University of Copenhagen.
- Scordato, L., Bugge, M., and Fevolden, A. (2017) 'Directionality across Diversity: Governing Contending Policy Rationales in the Transition Towards the Bioeconomy', *Sustainability*, 9: 206.
- Smith, K. (2000) 'Innovation as a Systemic Phenomenon: Rethinking the Role of Policy', *Enterprise and Innovation Management Studies*, 1: 73–102.
- Smith, K. and Wicken, O. (1990) *Evaluering av nasjonal handlingsplan for informasjonsteknologi 1987-1990. Rapport til Næringsdepartementet juni 1990*. Oslo: Næringsdepartementet.
- Sovacool, B. K. and Axsen, J. (2018) 'Functional, Symbolic and Societal Frames for Automobility: Implications for Sustainability Transitions', *Transportation Research Part a-Policy and Practice*, 118: 730–46.
- Stegmann, P., Londo, M. and Junginger, M. (2020) 'The circular bioeconomy: Its elements and role in European bioeconomy clusters', *Resources, Conservation & Recycling X*, 6.
- Straffas, L., Gustavsson, M., and McCormick, K. (2013) 'Strategies and Policies for the Bioeconomy and Bio-Based Economy: An Analysis of Official National Approaches', *Sustainability*, 5: 2751.
- Stirling, A. (2014) 'Transforming Power: Social Science and the Politics of Energy Choices', *Energy Research and Social Sciences*, 1: 83–95.
- Styrelsen for Forskning og Uddannelse. (2017) *Forsk 2025*. (9788793468603). Copenhagen: Ministry of Education and Research.
- The Finnish Innovation Fund. (2009) *A Natural Resource Strategy for Finland: Using Natural Resources Intelligently*. Helsinki: The Finnish Innovation Fund (Sitra).
- The Swedish Government. (2014) *En svensk strategi för biologisk mångfald och ekosystemtjänster*. Stockholm.
- Töller, A. E., Vogelpohl, T., Beer, K., et al. (2021) 'Is Bioeconomy Policy A Policy Field? A Conceptual Framework and Findings on the European Union and Germany', *Journal of Environmental Policy & Planning*, 23: 152–64.
- Van Der Vooren, A. and Brouillat, E. (2015) 'Evaluating CO2 Reduction Policy Mixes in the Automotive Sector', *Environmental Innovation and Societal Transitions*, 14: 60–83.

- Vinnova. (2017) *Årsredovisning 2016*. Stockholm: Vinnova.
- Weber, M. and Rohracher, H. (2012) '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: 1037–47.
- Weitz, N., Strambo, C., Kemp-Benedict, E., et al. (2017) 'Closing the Governance Gaps in the Water-energy-food Nexus: Insights from Integrative Governance', *Global Environmental Change*, 45: 165–73.
- Woolthuis, K., Lankhuizen, M., and Gilsing, V. (2005) 'A System Failure Framework for Innovation Policy Design', *Technovation*, 25: 609–19.
- Yin, R. K. (2014) *Case Study Research Design and Methods*, 5th edn. Thousand Oaks, CA: SAGE Publication Inc.

Appendix 1. List of policy documents reviewed.

	Denmark	Finland	Norway	Sweden
	<p>Directorate for the food industry (2006): <i>Growth and a better environment: A biotechnology research strategy for non-food and feed</i></p> <p>Danish government (2013): <i>Denmark at work: Growth plan for energy and climate</i></p> <p>Danish government (2013): <i>Denmark at work: Growth plan for food</i></p> <p>Danish government (2013): <i>Denmark without waste: Recycle more – incinerate less</i></p> <p>Danish government (2013): <i>Growth plan for water, bio and environmental solutions</i></p> <p>Council for food research, Directorate for the food industry, <i>Healthy, safe and tasty food with biotechnology – a biotechnology research strategy for the food sector</i></p> <p>The National Bioeconomy Panel (2014): <i>Denmark as a growth center for a sustainable bioeconomy</i></p> <p>Ministry for the Environment and Food, and the Ministry of Industry (2018): <i>Strategy for a circular economy</i></p>	<p>The Finnish Innovation Fund (Sitra) (2009): <i>A Natural Resource Strategy for Finland: Using natural resources intelligently</i></p> <p>Ministry of Employment and the Economy, Ministry of Agriculture and Food, Ministry of the Environment (2014): <i>The Finnish bioeconomy strategy: Sustainable growth from bioeconomy</i></p> <p>Finnish government, Prime Minister's office (2015): <i>Finland, a land of solutions. Strategic Programme of Prime Minister Juha Sipilä's Government</i></p> <p>Finnish government, Prime minister's office (2017), <i>Finland, a land of solutions, midterm review. Government Action Plan 2017–2019</i></p> <p>Ministry of Economic Affairs and Employment (2017): <i>Government report on the National Energy and Climate Strategy for 2030</i></p>	<p>Ministry of Trade, Industry and Fisheries, Report to the Storting, 10 (2015–16): <i>A competitive seafood industry</i></p> <p>Ministry of Trade, Industry and Fisheries, Report to the Storting, (2016–17): <i>Greener, smarter and more innovative</i></p> <p>Ministry of Agriculture and Food, Report to the Storting, 33 (2016–17): <i>Growing values. A competitive forest and wood industry</i></p> <p>Ministry of Trade, Industry and Fisheries, Ministry of Agriculture and Food, Ministry of Climate and the environment, Ministry of Education and Research, Ministry of Transport and Communications, Ministry of Foreign Affairs, Ministry of Petroleum and Energy, Ministry of Local Government and Modernisation (2016): <i>Familiar resources – undreamt of possibilities. The Government's Bioeconomy Strategy</i></p> <p>Ministry of Industry and Fisheries and Ministry of Petroleum and Energy (2017): <i>New growth, proud history. The Government's Ocean Strategy</i></p>	<p>Sweden's research council for sustainable development—FORMAS (2012): <i>Swedish Research and Innovation Strategy for a Bio-based Economy</i></p> <p>The Swedish Government (2014): <i>A Swedish strategy for biodiversity and ecosystem services</i></p> <p>Vinnova (2017): Annual report</p>

Appendix 2. List of interviewed organisations.

	Organisation	Type
(1) Denmark	Ministry of Environment and Food of Denmark (D1)	National policy
(2) Denmark	The Danish Environmental Protection Agency (D2)	National policy
(3) Denmark	Innovation Fund Denmark (D3)	Research and innovation funder
(4) Denmark	The Technical University of Denmark and member of the National Bioeconomy Panel (D4)	University
(5) Denmark	Confederation of Danish Industry (D5)	Industry association
(6) Denmark	Ministry of Education and Research (D6)	National policy
(7) Finland	Tekes (F1)	Research and innovation funder
(8) Finland	VTT (F2)	Research institute
(9) Finland	Ministry of Agriculture and Forestry (F3)	National policy
(10) Finland	Ministry of the Environment (F4)	National policy
(11) Finland	Ministry of the Economy and Employment (former director of the Bioeconomy Program) (F5)	National policy
(12) Norway	Research Council of Norway (N1)	Research and innovation funder
(13) Norway	Innovation Norway (N2)	Innovation funder
(14) Norway	Ministry of Trade, Industry and Fisheries (N3)	National policy
(15) Norway	Ministry of Food and Agriculture (N4)	National policy
(16) Norway	Ministry of the Climate and the Environment (N5)	National policy
(17) Norway	Ministry of Local Government and Modernisation (N6)	National policy
(18) Sweden	Sweden's research council for sustainable development—FORMAS (S1)	Research and innovation funder
(19) Sweden	Sweden's Innovation Agency—Vinnova (S2)	Research and innovation funder
(20) Swede	Swedish Energy Agency (S3)	Research and innovation funder
(21) Sweden	Swedish forest industry—Skogsindustrierna (S4)	Industry association

Appendix 3 Interview protocol

Policy strategies

- What do you understand as constituting the bioeconomy?
- Is the policy mix steered towards achieving the goals set in the policy strategy?
- How can a transition to the bioeconomy be achieved?
- What are the most important barriers for achieving a transition to a bioeconomy?
- Which bio-based sectors are of central importance?
- To what extent does the national industry structure have an impact on the policy priorities for the bioeconomy?
- What does the division of work between the ministries and actors involved in developing the bioeconomy look like?
- How was the strategy development process administered and organised?
- How has the coordination across involved actors worked?

- Coordination between the traditional R&D actors?
- Involvement of other/new type of actors, such as NGOs, interest organisations, network actors, and citizens?
- Is the process largely directed by ministries or other public authorities?
- Which actors are central to the implementation of the bioeconomy strategy?

- Have there been/are there any conflicts in developing the bioeconomy strategy? (Clash of rationales from different ministries?)

Policy instruments for the bioeconomy

- What types of policy instruments are most important to achieve the goals of the bioeconomy strategy?

Appendix 4. Exemplary quotes and citations from the document analysis and from the interviews.

Innovation policy approach	Failures	Exemplary quotes
Innovation for growth	Information asymmetries	<p>'The authorities have too a role in providing appropriate regulation and correct for various forms of market failure. Globally, there is a market failure that the price of climate and environmentally harmful emissions linked to production and transportation are not fully included in the calculation' (Ministry of Trade Industry and Fisheries 2016: 39/NO)</p> <p>'Knowledge building and investments in research and innovation is therefore an important prerequisite for developing a modern bioeconomy.' (Ministry of Trade Industry and Fisheries 2016: 5/NO)</p> <p>'To promote efficient utilization and profitable processing, efforts will be directed towards strengthening the focus on bioeconomy-related research and development in the Research Council of Norway' (Ministry of Trade Industry and Fisheries 2016: 10/NO)</p> <p>'there is a lot of [technology] push in Sweden but not so much [demand] pull' (Interview/Sweden)</p>
	Knowledge spill-over	'[t]hey are extremely linear and they, in the sectoral agencies like [agency name], [university name], [agency name], [agency name], their view on this transition is very traditional going from basic... we need basic research' (Interviews/SE)
	Externalisation of costs	<p>'correct pricing on production and consumption that has a negative climate impact is seen to be the most effective instrument to stimulate development and adoption of renewable biobased products' (Ministry of Trade Industry and Fisheries 2016: 40/NO)</p> <p>'Market-based mechanisms and international steering policies designed to integrate all of the costs related to natural resource use in prices should also be promoted' (The Finnish Innovation Fund 2009: 10/FI)</p>
	Over-exploitation of commons	'With the increasing scarcity of resources in the world, it will become more attractive to develop and use water, bio and environmental solutions that can help ease the pressure on scarce resources' (Danish Government 2013d: 7/DK)
	Infrastructural failures	'Achieving a biobased economy also requires, in addition to research and development, demonstration and innovation incentive measures. Governance and investment in demonstrations is also required.' (FORMAS 2012: 23/SE)
Systems of innovation	Hard/soft institutional failures	<p>'Review regulation on nature preservation, environment and energy in order to reduce inappropriate barriers to Danish business development within bio-based solutions.' (Danish Government 2013d: 10/DK)</p> <p>'For Finland to be a favourable and attractive operating environment for firms able to use natural resources successfully and sustainably, our innovation system, physical infrastructure, economic policies, legislation and administration must provide the necessary conditions' (The Finnish Innovation Fund 2009: 7/FI). 'Added value and well-being are primarily generated through efficient, vigorous, adaptable and innovative private enterprise.' (The Finnish Innovation Fund 2009: 6/. FI)</p> <p>'Finland should be proactive and take part in specifying the contents of the new standards, as standardisation will create the framework for the new markets for bioeconomy products and technologies' (Finnish Government 2014: 23/FI)</p>
	Interaction or network failures	The bioeconomy 'necessitate[s] widespread collaboration between companies, sectors, universities, colleges, research institutes and public sector organisations' (FORMAS 2012: 23/SE)
	Capabilities failures	'The bioeconomy is a multidisciplinary entity where competitive solutions cannot be produced without consolidating several sectors and types of competence.' (Finnish Government 2014: 28/FI)
	Directionality failure	<p>'The strategy's long-term vision and goals define the direction for the overall step-by-step process' (Natural resource strategy, Finland).</p> <p>'New models are needed for business, policy-making and everyday socio-economic behaviour' (The Finnish Innovation Fund 2009: 2/FI).</p> <p>'It is vital for the implementation of the Bioeconomy Strategy that existing and new policy actions will be targeted to support the growth of a sustainable bioeconomy' (Finnish Government 2014: 18/FI)</p> <p>'The objective of the Finnish Bioeconomy Strategy is to generate new economic growth and new jobs from an increase in the bioeconomy business and from high added value products and services while securing the operating conditions for the nature's ecosystems' (Finnish Government 2014: 19/FI).</p>
Transformative change		

(continued)

Appendix 4. (Continued)

Innovation policy approach	Failures	Exemplary quotes
	Demand articulation failure	<p>'The collective environmental effects of the systems, both positive and negative, must form the starting point for sustainable production and use.' (FORMAS 2012: 28/SE)</p> <p>Market creation as one of the four priority areas for policy; public procurement suggested to reduce market risk (Ministry of Trade Industry and Fisheries 2016: 9/NO)</p> <p>'To be able to achieve a recycling-adapted society based on biological raw materials requires changing attitudes towards consumption and changing the consumption patterns of both producers and consumers.' (FORMAS 2012: 27/SE)</p> <p>'Resource efficiency thinking should be integrated into public sector purchasing policies' (Finnish Innovation Fund: 6/FI)</p> <p>'Stakeholders and citizens should be widely encouraged to take part in this work' (The Finnish Innovation Fund 2009: 7/FI).</p> <p>'References will be needed to trigger demand: new bioeconomy solutions must be experimented with, piloted and demonstrated in order to commercialise innovations, ensure the functioning of the solutions and reap concrete benefits. A precondition for this will be adequate and flexible funding, even for bold experiments' (Finnish Government 2014: 25/FI)</p>
	Policy coordination failure	<p>'Another important factor will be to use public funds in a more holistic and coordinated way, across sectors and links in the value chain' (Ministry of Trade Industry and Fisheries 2016: 9/NO)</p> <p>'Collaboration agreements are in place between Formas and VINNOVA and between Formas and the Swedish Energy Agency. These agreements can form the basis for more developed forms of collaboration between the agencies in this area.' (FORMAS 2012: 33/SE)</p> <p>'The government will work to ensure that regulation in the EU and Denmark provides market pull for Danish resource efficient solutions' (Danish Government 2013d: 10/DK)</p> <p>'To achieve change, the public sector, businesses and civil society must work together towards a shared vision.' (The Finnish Innovation Fund 2009: 4/FI)</p> <p>'Strategy implementation will be supported by a bioeconomy panel to be set up. The panel will consist of actors in the bioeconomy sector, and it will engage in dialogue with other programmes aiming for a low-carbon and resource-efficient society' (Finnish Government 2014: 30/FI)</p>
	Reflexivity failure	<p>'Increased use of one ecosystem service often has consequences for other ecosystem services and conflicts of objectives can arise. This must always be taken into consideration when managing an ecosystem and drawing on different ecosystem services.' (FORMAS 2012: 18/SE)</p> <p>'The implementation of the strategy will enable the decoupling of economic growth from negative environmental impacts. The burden imposed on the environment will diminish. These key issues must be considered when assessing whether the strategy's goals have been reached' (Finnish Innovation Fund 2009: 4 /FI)</p> <p>'Since the operating environment features many uncertainties, it is important to plan progress flexibly, and with repeated evaluations of the situation. The strategy is characterised by the need to recognise barriers, conduct experiments, and learn continuously' (The Finnish Innovation Fund 2009: 5 /FI)</p> <p>'Measure: Adjusting the operating models of finance providers for research and innovation to enable experimentation' (Finnish Government 2014: 26/FI)</p>