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Axes of contestation in sustainability transitions

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ABSTRACT

Research in sustainability transitions increasingly acknowledges that the structural characteristics of socio-technical systems differ. However, little attention has been paid to the specific transition dynamics that can result from this structural variation. In response, this paper develops a framework for studying transition dynamics that takes the structural characteristics of socio-technical systems and their influence on agency into account. We introduce the concept *contestation axis* to highlight alternative potential interfaces between functional solutions in a socio-technical system. We argue that considerable agency and frictions between actors can play out at other axes than between established regimes and emerging niches. Our conceptual framework is applied to a case study in the waste sector. We explore how the growing influence of the circular economy triggers misalignment between multiple socio-technical configurations in the Danish waste sector. In the case, we zoom in on three actual frictions that have manifested along different contestation axes.

1. Introduction

Infrastructure sectors can be conceptualized as 'socio-technical systems', consisting of complex configurations of actors, institutions and technologies that have co-evolved over long periods of time (Geels and Schot, 2007). Socio-technical systems in infrastructure sectors are often built around a highly institutionalized core configuration of user practices, technological designs, regulations and professional standards and identities (Jensen et al., 2016) that reflect the high degree of materiality inherent in established infrastructure systems, such as the energy- and water grids, or road- and rail infrastructure. As such, infrastructure sectors are by definition characterized by a high degree of path dependence, few technological opportunities and high entry barriers (Castellacci, 2008). In transition studies, these sectoral path dependencies are attributed to the existence of socio-technical 'regimes'(Kemp et al., 1998), referring to the dominant institutional rationality of a socio-technical system (Fuenfschilling and Truffer, 2014).

In influential transition frameworks, such as the 'multi-level perspective' (MLP) (Geels, 2002), transitions are often understood as a process of gradual regime-substitution, heavily inspired by insights from the energy sector. A core argument has been that the prevailing regime, understood as the institutionalized 'grammar' of a socio-technical system, is challenged by actors operating in protected 'niches', which eventually cumulate and upscale to replace the core rationalities of the incumbent regime (Geels, 2002; Geels and Raven, 2006). Studies have explored different substitution pathways (Geels et al., 2016), but nevertheless focused on the

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niche-regime nexus. This has had a fundamental impact on studies investigating agency in sustainability transitions, leading to an extensive focus on 'power struggles' between incumbent regime actors, resisting change, and niche actors promoting it (Geels and Schot, 2007; Geels, 2014a).

Recent contributions, however, have challenged the depiction of this conventional transition trajectory, arguing that it might be a result of the energy sector, which is not necessarily applicable across different sectors (Van Welie et al., 2018; Runhaar et al., 2020; Miörner et al., 2021). This has informed more nuanced perspectives that move beyond the traditional niche-regime dichotomy. Building on these insights, recent research highlights the importance of taking sector characteristics into account when studying transition patterns and governance in different socio-technical systems (Alkemade, 2019; Andersen et al., 2020; Miörner et al., 2021). But yet, few studies emphasize these structural characteristics and their influence on agency when studying transition dynamics.

In this paper, we target this gap in the literature and develop a framework for studying transition dynamics that takes the structural characteristics of socio-technical systems into account. We introduce the concept of the *contestation axis* to highlight other potential interfaces between functional solutions in a socio-technical system. We argue that specific dynamics result from the various constellations of emerging and established socio-technical configurations that can be found across different sectors, which means that considerable agency can play out at other axes than between established regimes and emerging niches. We aim to complement the emerging configurational approach to transition patterns and dynamics, which emphasizes the alignment and institutionalization of actors, institutions and technologies (see Fuenfschilling and Truffer, 2014, Fuenfschilling, 2019, Heiberg et al., 2022, Miörner et al., 2022), with a perspective on transition dynamics and agency reflecting these recent conceptual contributions.

Our conceptual framework is applied to a case study in the waste sector. Against the backdrop of growing concerns over climate change and resource extraction, the multitude of challenges associated with inefficient waste management are increasingly illuminated. Challenges experienced in the waste sector differ between regions in the world, but globally the World Bank (Kaza et al., 2018) estimates that five percent of greenhouse gasses emitted in 2016 were generated from solid waste management. They moreover expect annual global waste generation to increase by 70% by 2050. Beyond generating greenhouse gasses, inept waste management has profound health repercussions in some communities, it is a source of environmental pollution and causes the loss of valuable and at times finite resources (European Environment Agency, 2014).

Consequently, there is growing awareness of the need to radically transform waste management (Morone et al., 2016; Ellen MacArthur Foundation and Material Economics, 2019; UNEP, 2022). In the EU, this need is embedded in the larger vision of achieving a circular economy, which describes "a regenerative system in which resource input and waste, emissions, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops" (Geissdoerfer et al., 2017 p. 766). The paper explores how the growing influence of the circular economy triggers misalignment between multiple socio-technical configurations in Denmark. The case study illuminates how agentic processes are materialized at multiple axes of contestation and shows that the relationship between different socio-technical configurations is altered in the process. We zoom in on three actual frictions that have materialized along three different contestation axes in the Danish waste sector.

2. Conceptual framework

Transitions literature conceptualizes sector transformation as structural changes in socio-technical systems. Scholars increasingly emphasize a variegated perspective when it comes the dynamics underpinning structural changes in sectors (Raven and Verbong, 2007; Konrad et al., 2008; Van Welie et al., 2018; Miörner et al., 2021) and we argue that this variegated perspective also has implications for the way we can approach and understand transition dynamics and agency.

Socio-technical systems are made up of socio-technical configurations, which are actors, institutions and technologies that are aligned to fulfill societal functions, such as energy- and food provision, or waste management (Kemp et al., 1998; Markard et al., 2012; Geels, 2002). Recent frameworks emphasize a continuum between emerging and established socio-technical configurations, as opposed to a stricter niche-regime dichotomy (Van Welie et al., 2018). This has in turn allowed scholars to emphasize variation in the structural patterns of sectors (Miörner et al., 2021). The structural composition varies from ones dominated by a single configuration that permeates virtually all territorial subsystems of a sector (i.e. a global regime of centralized water-based infrastructure) (Fuenfschilling and Binz, 2018), to ones made up of several configurations that are aligned (or not) in the provision of societal functions (Van Welie et al., 2018; Miörner et al., 2021; Bergek et al., 2021). To exemplify the latter, Van Welie et al. (2018) describe the urban mobility sector, which consists of a combination of socio-technical configurations related to personal motorized individual transport (cars and motorcycles), road- and rail-based public transport, and various forms of human-powered mobility modes (bicycles, pedestrian mobility). Each of these have developed a degree of institutionalization in terms of the particular configuration of technologies, infrastructures, regulations and user practices, that makes it possible to characterize them as complementary, or sometimes competing, socio-technical configurations established in the urban mobility sector.

From this follows that transition dynamics, including the agency targeted at transforming the sector in a more sustainable direction, ought to look very different between different sectors. In some sectors, the most plausible transition trajectory is indeed a gradual regime-substitution through which a sector regime is completely replaced by one or several niche alternatives (Geels, 2002; Geels and Raven, 2006), leading to contestation between niche actors and regime incumbents. In other types of sectors, however, transitions may involve a changed relative importance of different configurations that are in and of themselves already highly institutionalized alternatives in the sector (e.g. shifting towards an increased importance of bicycling in urban mobility systems). It may also be the case that niche actors target one among a set of established, highly institutionalized and well-aligned configurations, in order to facilitate sustainable shifts in production and/or consumption without substantially challenging the underlying rationales of the sector.

In other words, sector characteristics are likely to shape transition trajectories and in turn the 'axes' at which actors engage in

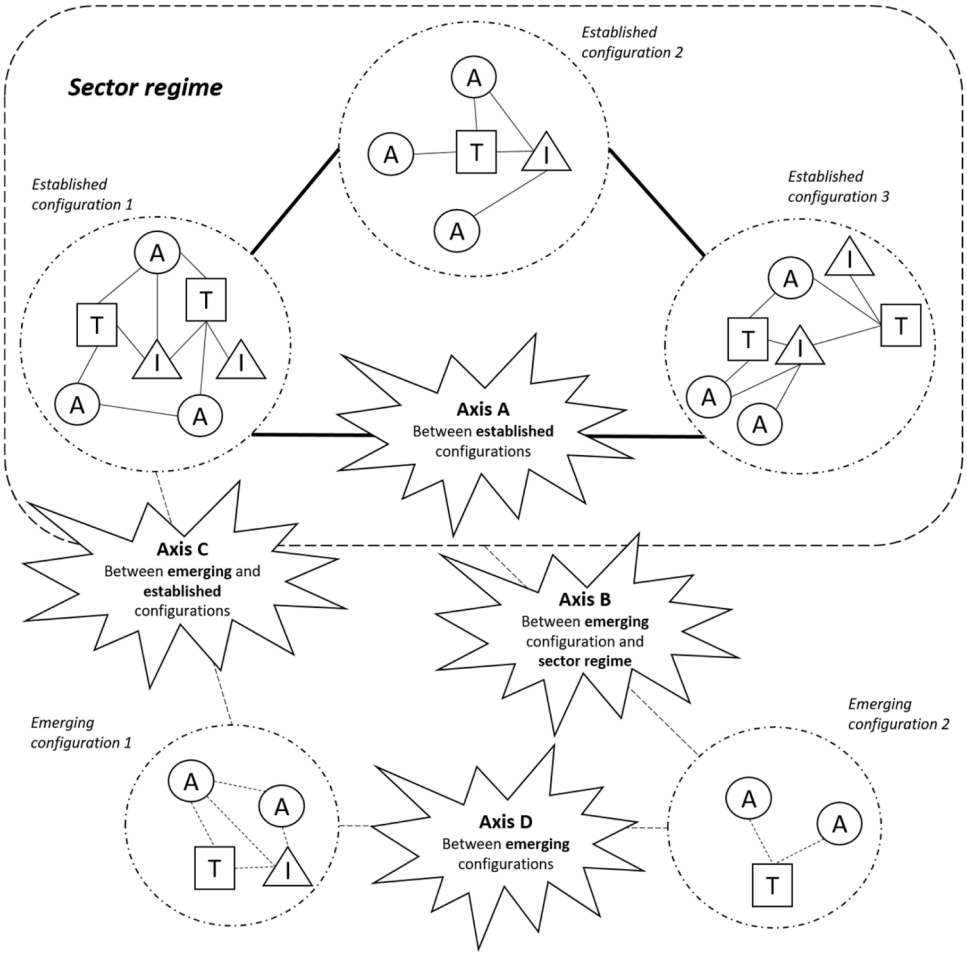

Fig. 1. Contestation axes (own elaboration). Actors (circles), Technologies (quadrants) and Institutions (triangles) form emerging and established configurations representing different ways of providing societal functions such as water, energy and transport.

agency to shape institutional change. In some sectors prominently featured in transition studies, such as the energy sector, it may indeed be the case that agency is focused around one main axis of contestation at the interface of emerging niche- and established sector regime-configurations. In other sectors, however, it is possible to hypothesize a number of additional contestation axes. We begin to conceptually explore this in the next section.

2.1. Exploring contestation axes in socio-technical systems

In the discussion so far, we have emphasized the need to distinguish between different emerging and established configurations in the socio-technical system underpinning infrastructure sectors. We have argued that sectors can exhibit different structural patterns with regards to the combination of emerging and established configurations, and we have acknowledged that sustainable transitions can materialize in other ways than through a full sectoral regime substitution. Taken together, this variegated perspective allows for the identification of a number of contestation axes of relevance to the study of sustainability transitions. We define the concept of contestation axis as: *the interface between two or more socio-technical configurations where actors engage in agency dynamics to shape institutions.* Conceptually, we identify four ideal-type contestation axes (see Fig. 1).

First, established configurations may be misaligned with each other, and incumbent actors may engage in framing struggles in order to change the relative importance of different established configurations within the sector regime (**Axis A: established vs established**). This can happen without fundamentally challenging the combination of configurations that exist to provide a societal function, as well as the underlying rationalities of the sector at large. It is likely that this leads to substantial contestation between proponents and opponents of different established configurations.

Second, contestation may take place between the emerging configuration(s) and the established sector regime reflecting the conventional focus of transition studies (**Axis B: emerging vs sector regime**). Actors positioned in the emerging configuration may challenge the underlying rationale of the sector. This is likely to lead to contestation between actors positioned in the emerging

configuration(s) and the established sector. Incumbents are expected to resist new institutional structures set up to enable a transition (Geels, 2014b; Hess, 2016), but we may also see incumbents engage in niche-regime interactions (Berggren et al., 2015).

Third, actors positioned in emerging configurations may promote alternative technologies, user practices and organizational forms that target one (or several) established regime configurations, but not fundamentally challenge the set-up of the sector at large (**Axis C: emerging vs established**). This could be seen as a form of 'piggybacking' on the existing alignment between configurations in a sector, by developing and legitimizing an alternative that replaces an established configuration, without altering its relation to other configurations in the system. Incumbents positioned in the established configurations may be resisting change and work to preserve their interests in status quo, but studies have shown that incumbents may also be mobilized to participate in change processes (Steen and Weaver, 2017; Hellsmark and Hansen, 2020), if they see a way to keep fundamental sector rationales intact.

Finally, contestation may take place between different emerging configurations that compete to become the dominant alternative to the established configuration(s) in the sector (**Axis D: emerging vs emerging**). Actors positioned in emerging configurations may engage in framing struggles related to the definition of underlying issues that should be targeted, the direction of change processes or competition between different ways to provide new services, or existing services in new ways, in the sector (Lin and Sovacool, 2020; Rosenbloom et al., 2016). Here, actors may differ in terms of their underlying incentives and interests, ranging from strategic business interests among new or established firms, to normative ideas about sustainable development among political actors and interest organizations.

So far, we have outlined four ideal-type contestation axes on which we expect actors to be able to engage in agency that shape institutional change in the sector. However, the actual frictions that manifest along these contestation axes will have to be determined empirically. We anticipate that the existence and importance of actual frictions will vary between different sectors depending on their structural pattern. To further advance the analysis of agency dynamics playing out between various socio-technical configurations, the subsequent section elaborates on the relationship between sector characteristics and agency.

2.2. Sector characteristics and agency

Taking sector characteristics into account has implications for how to approach the questions of agency and actor roles in sustainability transitions (Fuenfschilling and Truffer, 2014; Battilana et al., 2009). Agency is embedded within the institutional context of the socio-technical system and its structural characteristics may not only heavily shape the forms, types and modes of agency deployed by actors, but also constitute an important factor enabling actors to act upon their perceived interests and objectives (Fuenfschilling, 2019; Miörner, 2022; Battilana et al., 2009; DiMaggio, 1988; Garud et al., 2002; Simoens et al., 2022). Following previous studies in the transitions literature (Fuenfschilling, 2019; Binz et al., 2016; Duygan et al., 2019; Löhr et al., 2022), we operationalize our interest in agency by focusing on the 'institutional work' of actors (Lawrence and Suddaby, 2006; Lawrence et al., 2011). The focus on institutional work reflects a practice perspective on agency, allowing us to zoom in on the concrete actions and activities that actors engage in to shape institutional change processes (Jarzabkowski and Paul Spee, 2009; Fuenfschilling, 2019). Some types of institutional work have been associated with the creation of new institutions (e.g. advocacy, defining, constructing normative networks, changing normative associations and educating), while other types of institutional work have been associated with either the maintenance of institutions (e.g. deterring, embedding and routinizing) or the disruption of institutions (e.g. disconnecting sections) (Lawrence and Suddaby, 2006). Please see Appendix table 1 for a full list of the institutional work types identified in Lawrence and Suddaby's (2006) original description.

When exploring agency in transitions, it is adamant to take into account both the structural position of actors, as well as the 'field conditions' enabling and/or conditioning their agency (Fuenfschilling, 2019). The structural position of actors in a socio-technical system is here understood as an actor's attachment or association with one or several socio-technical configurations and is thus defined by the alignment between different configurations in the socio-technical system. The transitions literature has so far ascribed the structural position of actors to being either 'incumbent', i.e. centrally positioned in an established configuration, or as 'niche', i.e. positioned in an emerging configuration, which is institutionalizing in parallel to the dominant one. As the discussion in the previous sections suggests, different sector characteristics may give rise to structural relationships between actors extending beyond this basic niche-regime dichotomy. For example, the literature has clearly demonstrated that incumbent actors may play an important role in the development and upscaling of emerging niche configurations (Hoogma et al., 2002; Elzen et al., 2012; Späth et al., 2016). They possess political power and other important resources that can be mobilized by niche actors in various forms of strategic collaborations (Elzen et al., 2012; Bergek et al., 2013; Steen and Weaver, 2017; Van Mossel et al., 2018; Yang et al., 2020; Hellsmark and Hansen, 2020). Whether or not incumbent actors can serve as 'change vehicles' (Lesch, 2022) will however depend on their structural position, i.e. the alignment between different emerging and established configurations in the socio-technical system.

The structural composition of the socio-technical system gives rise to a certain set of 'field conditions' that influence the scope for, and forms of, institutional work that is feasible for actors. Here we find inspiration in the work of Duygan et al. (2019), who review the literature on institutional entrepreneurship and institutional work, with specific attention to the attributes that condition the ability of actors to carry out different forms of institutional work. They outline three constituent elements of institutional work: resources, discourses and social networks.

Resources are the foundation for the ability to carry out most forms of institutional work. Resources refer here to both physical-material resources such as infrastructures and materials, financial resources in the form of access to economic resources, intellectual resources including knowledge and expertise, as well as politico-judicial resources in the form of formal authority over specific decision processes. While plentiful resources are the basis of much institutional work, they are however often a necessary rather than sufficient condition. Consequently, many forms of institutional work require coupling of resources with powerful discourses and/or

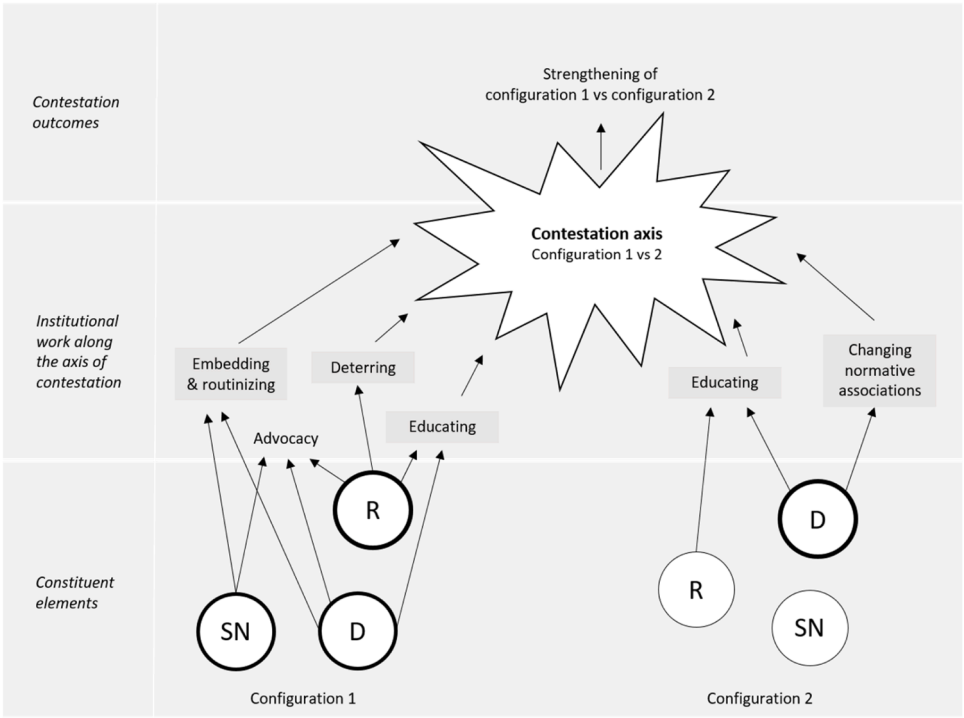

Fig. 2. Stylised illustration of the relationship between field conditions, institutional work along the axis of contestation and contestation outcomes (own elaboration). Circle outline thickness indicates strength of discourses (D), social networks (SN) and resources (R), which enable or constrain institutional work and in turn affect the contestation outcome.

network relations. *Discourses* are here understood as coherent storylines that provide clear narratives in relation to a specific topic, by defining current problems, their sources, and visions about ways of addressing them that open up for more promising futures. Finally, *social networks* reflect the distributed character of agency, highlighting that alliances and other forms of relations between actors are important for coordinating institutional work, but also for providing access to complementary resources. Duygan et al. (2019) suggest that the different forms of institutional work require different combinations of the three constituent elements. Building on the original descriptions of forms of institutional work by Lawrence and Suddaby (2006), they propose that while some forms of institutional work only require access to one of the constituent elements (e.g. discourses for 'Valorising and demonizing' or resources for 'Deterring'), most types of institutional work require access to two or three of them. Fig. 2 illustrates our understanding of the relationship between constituent elements, institutional work and contestation outcomes.

Building on this understanding, we approach our empirical case with a focus on identifying contestation axes, the structural position of actors involved in these, the types of institutional work actors carry out and the constituent elements that either enable or constrain actors' ability to carry out institutional work and influence the contestation outcome.

3. Case selection and methods

The Danish waste sector is chosen as a case study to illustrate and test the applicability of our conceptual framework. It is a socio-technical system with numerous parallel configurations, currently experiencing major transformation pressure as a result of changing policy and legislation connected to the advancement of circular economy visions. The growing influence of circular economy visions has triggered a misalignment between socio-technical configurations in the sector accompanied by intensifying actor struggles over directionality for the transition in the sector, which illuminates transition dynamics beyond the classic niche-regime axis.

To set the scene for our analysis, we begin our empirical case study with a general introduction to the historical emergence and institutionalization of key socio-technical configurations in the Danish waste sector. We subsequently zoom in on two waste streams to explore three different frictions that have manifested along three different contestation axes:

1 We consider the treatment of food waste from households to unpack a friction between two established socio-technical configurations ('incineration' and 'recycling').
2 We consider the treatment of plastic packaging waste to unpack two different frictions between emerging and established configurations: 'chemical recycling' is emerging and specifically targets the established 'incineration' configuration, while the emergence of 'reuse' more fundamentally challenge the established configurations.

Table 1
Total waste generation in Denmark in million tons across treatment types in percent in 1985, 2000 and 2019 (Environmental Protection Agency, 1991; Environmental Protection Agency, 2001; Environmental Protection Agency, 2020).

	1985	2000	2019
Recycling (%)	21	65	47
Backfilling (%)	n/a	n/a	24
Incineration (%)	22	24	25
Landfill (%)	57	11	3
Total waste generation (million tons)	9,3	13,0	12,7

*From 2018, the amount of waste used for backfilling is reported separately from the amount of waste reported as recycled. Backfilling includes recovery operations where waste is used for e.g. reclamation in excavated areas or road construction (Environmental Protection Agency, 2020).

In our empirical case study, we have relied on triangulation of multiple qualitative data sources. Our background to the Danish waste sector is based on extensive desktop research (see also Madsen, 2022). The empirical case study draws on a total of 29 semi-structured interviews, conducted between August 2019 and September 2021, and participant observations from 17 sector events taking place between November 2017 and June 2021. The interviews targeted diverse stakeholders from the sector including waste management companies, interest organizations, NGOs, civil servants and researchers The interviewees were first identified based on desktop research and later also based on recommendations from those interviewed (snowball method) (May, 2011). Five interviews were conducted face-to-face, while the remaining were conducted over the phone or by videoconferencing software.

Of the interviews, 13 focused specifically on identifying socio-technical configurations in the Danish waste sector, actors, and their position. The remaining 16 interviews explored the identified contestation axes. We first asked interviewees to describe how plastic packaging and food waste from households had been managed in the Danish context prompting them to consider complementarity and competition between alternatives, how this changed over time and possible reasons for these changes. We also asked interviewees to identify actors advocating for or opposing particular socio-technical configurations and what these actors did (their concrete actions and activities) to push their particular agenda. Here we asked interviewees to explicitly consider collaboration partners, sources of support and major obstacles. In the interviews, we aimed to identify the institutional work that took place at the three frictions, but we also used this material to qualify the field conditions of actors (resources, discourses and social network) to gain a better understanding of their ability to carry out different forms of institutional work. The interviews lasted 75 min on average, were recorded and transcribed verbatim (see anonymised list of interviews in Appendix Table 2).

The interviews were further complemented by a structured newspaper analysis. We collected[1] and analysed relevant articles from 7 national newspapers and 4 online media outlets, the latter covering topics related to waste specifically or technology and cleantech more generally. The collection of newspaper articles, which consisted of 176 articles, was used as an additional source of material to both map institutional work carried out by actors as well as gain more insights on the resources, discourses and social networks of actors. We also made use of this material to further probe in many of the interviews. Appendix Table 3 includes the full reference of quoted newspaper articles.

The empirical material was analyzed through thematic coding (Crang, 2005). We first coded our material to identify the ideal-type contestation axes along which empirical frictions were materializing. We subsequently coded the material to situate each friction in the broader policy change connected to the advancement of circular economy visions, focusing particularly on events that triggered misalignment between actors. We used our empirical material to identify the structural position of actors and then coded the material according to constituent elements of actors (discourses, resources and social networks) as well as the institutional work carried out by actors involved in each of the frictions. Based on the coding we developed aggregate descriptions for each friction. In Appendix Tables 4–6 we have included additional quotes from our empirical material to illustrate the basis of our aggregate description.

4. Analysis

4.1. Introduction to the Danish waste sector

Up until the 1970s, landfilling was the only established socio-technical configuration in the Danish waste sector. The landfilling configuration was shaped by a public health rationality particularly focused on improving the wellbeing of the growing urban population, since poor waste management had been an attributing factor to the outbreak of cholera in Copenhagen during the mid-19th

[1] Search string for contestation axis 1 (recycling vs. incineration): (“madaffald” OR “biogas”) AND (“forbrænding”), timeframe covered: 2012-2018. Search string for contestation axis 2 (reuse vs. established configurations): (“genbrug” OR “behandling”) AND (“plastikemballage”), timeframe covered: 2016-2021. Search string for contestation axis 3 (chemical recycling vs. incineration): (“kemisk genanvendelse” OR “pyrolyse” OR “forbrænding”) AND (“plastemballage”), timeframe covered: 2016-2021. All three searches were limited to articles from: Jyllands-Posten, Børsen, Berlingske, Dagbladet Information, Politiken, Weekendavisen, Kristeligt Dagblad, Ingeniøren, WasteTech, CleantechWatch, Altinget, then manually filtered to only include articles about the management of food waste from households for contestation axis 1 and management of plastic packaging for contestation axes 2 and 3, database: Infomedia.

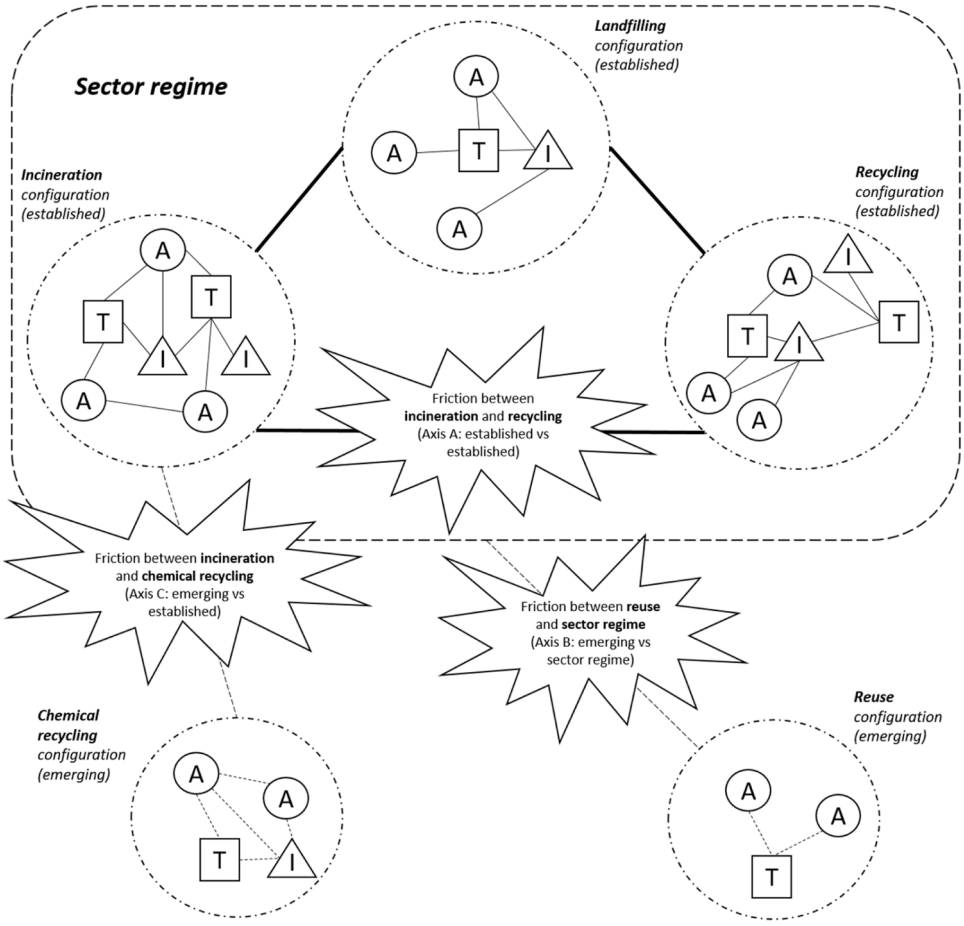

Fig. 3. Frictions identified along different contestation axes in Danish waste management.

century (Pagh, 2006). From the 1960s, socioeconomic changes and growing environmental awareness put increasing pressure on the landfilling regime. Intensifying urbanization and an economic boom was followed by prosperity and higher levels of both consumption and disposal (Rasmussen and Brunbech, 2009). As a result of the increasing level of per capita waste generation, landfilling capacity was exhausted (Environmental Protection Agency, 1978b). Moreover, landfilling came under pressure as understanding about pollution developed. Landfill leachate came to be understood as a cause of ground water pollution, which further emphasized the need for a shift in Danish waste management (Velzé and Fischer, 2019)

In response, incineration, the combustion of waste in combined heat and power plants, and recycling, the physical breakdown of discarded products to reprocess into new products, increased (see Table 1). Recycling focused largely on homogenous waste fractions such as industrial waste, while more heterogeneous waste fractions, like household waste were mainly incinerated (Madsen, 2022). The shift towards greater shares of incineration and recycling was initially motivated by the exhausted landfilling capacity and environmental concerns described above, but came to also be motivated by additional rationalities. Expanding the incineration capacity played a crucial role in powering district heating networks and reducing dependence on oil imports. Increasing recycling levels reduced the import of virgin raw materials. This was motivated by high raw material prices, but also by the wish to reduce resource consumption, which was a growing concern (Environmental Protection Agency, 1978a; Environmental Protection Agency, 1982; Fischer, 2012). Incineration and recycling eventually became established as two clearly delineated socio-technical configurations. While the end-processing of waste for recycling was done by private actors, the Danish sector was otherwise dominated by municipal ownership and strong municipal autonomy (Madsen, 2022).

A stable alignment between landfilling, incineration and recycling came to characterize the sector. It was supported by a coherent regulatory framework that specified the relationship between the socio-technical configurations. Waste treatment was politically hierarchized; recycling should take precedence over incineration, and incineration over landfilling (Environmental Protection Agency, 1985). This hierarchy was supported by differentiated waste taxes which were introduced in 1987 as well as a ban on landfilling of combustible waste, which was implemented in 1997 (Papineschi et al., 2019). Danish waste management came to be characterised by rapid reduction in landfilling capacity enabled by increased recycling and the development of one of the highest shares of waste incineration in the EU (Eurostat, 2018; OECD, 2019).

Around 2010, the main rationality of waste management began to shift again, particularly in EU policy, which had come to play an

Table 2
Overview of main actors, discourses, social networks, resources, institutional work and outcomes across the three identified frictions in the Danish waste sector.

	Friction manifested on axis A: established VS established*Household food waste*		Friction manifested on axis B: Emerging VS. sector regime*Plastic packaging waste*		Friction manifested on axis C: Emerging VS Established*Plastic packaging waste*	
	Established configuration *(recycling)*	***Established configuration*** *(incineration)*	***Emerging configuration*** *(reuse)*	***Sector regime***	***Emerging configuration*** *(chemical recycling)*	***Established configuration*** *(incineration)*
Main actors	Biogas producers (traditionally farmers, but recently also natural gas companies)	Municipal waste companies	NGOs Reuse start-ups	Recycling industry Municipal waste companies	Chemical recycling companies Petrochemical companies	Municipal waste companies
Discourses	Recycling food waste through the production of biogas and fertilizer is superior to incineration in multiple ways. It enables nutrients to recirculate back to agriculture. It enables the production of a storable and high quality energy (can be used for motor fuel production). Finally, contributes to a more sustainable livestock agriculture by reducing greenhouse gas emissions and water pollution from manure.	The suggested benefits of food waste recycling have not been sufficiently documented and cannot motivate why all municipalities should make large investments in source separation of food waste. Instead, incineration of food waste is effective and also produces electricity and heat.	The production of packaging waste must be reduced. Reuse is expected to reduce the consumption of resources used for the production and disposal of packaging and limit pollution. Increasing plastic recycling will not address the challenge alone.	Reuse is acknowledged as a way forward for select purposes, but not generally considered a feasible solution. Instead, the recycling configuration highlights the advantages of current plastic packaging (reduced food waste and reduced CO_2 emissions from transport) and promote recycling as a way to both retain these advantages and address the challenges associated with plastic packaging waste. The incineration configuration insists on the continue need for incineration.	Chemical recycling enables the recycling of plastic packaging, which is currently incinerated and cannot be mechanically recycled. Chemical recycling is arguably favorable to incineration because it allows for material circulation and emits less CO_2. The chemically recycled material can be used in high quality products e.g. food packaging, which is very difficult to achieve with mechanical recycling.	Denmark should not be exporting plastic packaging waste as high quality treatment is difficult to ensure abroad. Instead, we ought to use our incineration infrastructure, which is world-class. The prospect of treating plastic waste with chemical recycling is also interesting and potentially an alternative.
Resources Physical-material Financial Intellectual Politico-judicial	*Physical-material:* biogas plants, growing capacity from 2008, after 2012 integration with extensive natural gas infrastructure. *Financial:* dependent on government support, but improved with natural gas companies entering the market. *Intellectual:* long-term experience with biogas technology, policy process expertise, developing know-how on ensuring high quality of household food waste. *Politico-judicial:* no formal decision-making power over	*Physical-material:* large-scale plants and infrastructure. *Financial:* steady, financed through municipal waste management fee and production of heat and electricity. *Intellectual:* long-term experience with incineration technology, policy process expertise. *Politico-judicial:* municipalities enjoy considerable autonomy over waste management, have a right to allocate household waste.	*Physical-material:* small-scale, experimental return systems. *Financial:* limited, dependent on fundraising. *Intellectual:* Expertise focused on policy processes and public communication, limited technical know-how. *Politico-judicial:* no formal decision-making power over waste management.	*Physical-material:* large-scale plants and infrastructure *Financial:* ample, and increasing for recycling actors as that agenda increases in importance. *Intellectual:* expertise in policy process and public communication, strong technical know-how. *Politico-judicial:* public authorities have formal decision-making power over waste management.	*Physical-material:* expanding, pilot plants have been built, larger, commercial plants have been announced. *Financial:* growing esp. from partnerships and investors. *Intellectual:* technical know-how, but still an experimental phase. *Politico-judicial:* no formal decision-making power over waste management.	*Physical-material:* large-scale plants and infrastructure. *Financial:* steady, financed through municipal waste management fee and production of heat and electricity. *Intellectual:* technical know-how and policy experience in current system, but limited knowledge of chemical recycling. *Politico-judicial:* municipalities enjoyed considerable autonomy over waste management, have independent powers of taxation, financially invested in waste infrastructure (mainly incineration).

(*continued on next page*)

Table 2 (*continued*)

	Friction manifested on axis A: established VS established*Household food waste*		Friction manifested on axis B: Emerging VS. sector regime*Plastic packaging waste*		Friction manifested on axis C: Emerging VS Established*Plastic packaging waste*	
	waste management.					
Social networks	National public authorities Recycling industry NGOs	Incineration technology companies and consultancies	Social movement among concerned citizens	Retailers (mainly recycling) Brand owners (mainly recycling) Food producers (mainly recycling) Packaging producers (mainly recycling) Public authorities (mainly recycling)	Recycling industry Universities Investors (private individuals and companies)	Public authorities
Institutional work	*Advocacy:* meeting with politicians, parties, civil servants; publishing opinion papers *Educating:* presenting and sharing experiences at conferences *Disconnecting sanctions:* change in state subsidies *Constructing normative network:* Biogas Taskforce *Changing normative associations:* developing and sharing knowledge about the safety/ risk of using household food waste as fertilizer	*Advocacy:* meeting with politicians, parties, civil servants; publishing opinion papers *Maintain normative network:* appointing board members *Deterring:* non-compliance with national targets; working around the national targets	*Advocacy:* meeting with politicians, parties, civil servants; political proposals and opinion papers *Educating:* hosting webinars; commissioning and publishing reports	*Advocacy:* meeting with politicians, parties, civil servants; political proposals and opinion papers *Educating:* public outreach campaigns, hosting conferences (mainly recycling) *Constructing normative networks:* Forum for Circular Plastic Packaging; Rethink Plastic Consortium (mainly recycling) *Embedding and routinizing:* quantitative recycling and incineration targets in public policy and statistics.	*Advocacy:* meeting with public authorities and politicians, opinion papers. *Educating:* presentations at sector and industry conferences, guided plant tours, publishing LCA analyses *Defining:* obtaining third party certification of production	N/A
Outcomes	Waste management practices and legislation has changed in favor of recycling rather than incinerating household food waste.		Reuse actors struggle to shape institutions related to the use and management of plastic packaging.		Chemical recycling is gaining strength and legitimacy, while incineration is under political pressure to reduce capacity.	

increasingly important role in the Danish context. The rationality for waste management was broadened to explicitly encompass economic concerns. It was argued that not only environmental protection, but also wealth generation and competitiveness depended on improved resource productivity (Domenech and Bahn-Walkowiak, 2019; Kern et al., 2020). This shift was manifested in the vision of a circular economy, which was reflected in EU policy (European Commission, 2014; European Commission, 2015) and EU waste legislation. When implemented in the Danish context, the new policy and legislation created misalignments between configurations in the Danish waste sector and in turn triggered actors to engage in agency processes in attempts to shape the institutional change that followed.

In the following section we elaborate on three frictions that materialize across different axes of contestation identified in the Danish waste sector (illustrated in Fig. 3). These frictions are (at least partly) a result of the growing influence of circular economy visions in the Danish waste sector. With these, we begin to illuminate how specific transition dynamics result from different constellations of emerging and established socio-technical configurations. For every friction, we structure the analysis according to Fig. 2, outlining constituent elements, institutional work along the contestation axis and contestation outcomes (see overview in Table 2).

4.2. Contestation axes in the Danish waste sector

4.2.1. Contestation over food waste

We focus on food waste from households to illustrate a friction materializing along the contestation axis between the two established socio-technical configurations: recycling and incineration. Food waste from Danish households has traditionally been incinerated in plants owned by municipal waste companies; a strategy endorsed by national authorities (e.g. Environmental Protection Agency, 2003). However, the view of national authorities changed when EU waste legislation specified recycling targets for household waste in an attempt to encourage greater material circularity. The legislation implied more recycling and less incineration and landfilling. This change was clear for the first time in 2013, when the national waste management plan, *Denmark without waste,* was

published (Environmental Protection Agency, 2014) and stipulated that 50% of household waste should be recycled by 2022. Municipalities remained free to decide how to achieve this goal, but it was stated in the waste management plan that national government wanted municipalities to use household food waste for the production of biogas and fertilizer.[2] Our empirical material also suggests that there was an underlying expectation that municipalities were to source separate food waste from households in order to reach the recycling goal.

4.2.1.1. Friction between recycling and incineration. This changing policy landscape triggered competition between the two established configurations (Axis C: established vs established, cf. Fig. 3). Actors in the incineration configuration, mainly municipal waste companies, were reluctant to set up source separation for household waste, and actors in the recycling configuration, mainly biogas producers, competed for access to household food waste in order to expand their production of biogas and fertilizer.[3]

Constituent element 1: discourses. Actors promoting the recycling configuration argued that using household food waste for the production of biogas and fertilizer brings a host of advantages across multiple sectors compared to incinerating that same material. First, they highlighted that it enables a recirculation of nutrients back to agricultural land, most noticeably phosphor. Second, biogas was emphasized as an important component in energy and transport transitions as it can be stored and used to produce electricity, heat and motor fuel. Third, it was highlighted that when food waste is mixed with manure in the production of biogas it arguably reduces greenhouse gas emissions and water pollution, particularly nitrate leaching from agricultural production.

Actors promoting incineration highlighted an efficient and world-class Danish incineration sector and emphasized its production of both heat and electricity. They moreover argued that the suggested advantages of recycling food waste had not been adequately documented. Since source separation of food waste is expensive, municipal waste companies argued that they needed more evidence to motivate the investment.

> We [municipal waste companies] want more recycling if there is documentation that it makes sense to do. We just haven't seen that documentation yet (Newspaper article 5).

Constituent element 2: social networks. Following the introduction of the circular economy agenda at EU-level, Danish national authorities such as the Ministry of Environment and the Danish Energy Agency began to support recycling. Biogas producers also mobilized NGOs as allies as well as other parts of the recycling industry e.g. private companies that process food waste into biomass that can be used for biogas production. Our empirical material suggests, that actors from the incineration configuration mainly allied with companies that either service or produce incineration technology, but were otherwise increasingly isolated as other actors pledged alliance to the recycling agenda.

Constituent element 3: resources. The recycling configuration had considerable physical-material resources including biogas plants of various sizes and facilities to pre-process the food waste. From 2012 onward, upgraded biogas was also distributed in the natural gas network, which further extended the infrastructure. The configuration is dependent on government support, but when natural gas companies began investing in biogas around 2012, the financial resources improved. Biogas had been produced in Denmark for more than four decades and therefore a strong technological know-how had developed, but with the inclusion of more household food waste in biogas production, the actors in the configuration had to develop new expertise in sorting and pre-possessing the waste fraction.

The incineration configuration was endowed with considerable resources including a well-developed infrastructure, stable financing arrangements through waste management fees, and experience with policy processes in the waste sector. But perhaps most important for this contestation is that municipalities, who own the municipal waste companies and by extension the incineration plants, had considerable formal authority over waste management. Municipalities had the right to allocate all waste produced from households within their jurisdiction to the treatment facility of their choice. Moreover, municipalities faced no legal consequences if they did not meet nationally set waste targets.

Institutional work. Actors in the recycling configuration mobilized considerable resources and a broad spectrum of allies enabling them to carry out various types of institutional work. Drawing on financial and intellectual resources biogas producers and their industry associations actively engaged in *advocacy* and *educating* work. They continuously lobbied and communicated their storyline to political parties, civil servants and the public. This storyline was legitimized by NGOs and national authorities, which allied with the recycling configuration. The support from national authorities was also important for the recycling regime to succeed with *disconnecting sanctions* from previous practices. State subsidies were changed in the 2012 Energy Agreement (Danish Energy Agency, 2012) to support the expansion of biogas production. Their broad spectrum of allies also enabled the *construction of normative networks,* notably the Biogas Taskforce, which brought together sector stakeholders to evaluate and support the expansion of Danish biogas production. By initiating research projects and stakeholder dialog, recycling actors and their allies have worked on *changing normative associations* regarding the safety of using digestate produced from household food waste as fertilizer.

Actors in the incineration configuration also engaged in *advocacy* work, actively defending incineration and questioning the advantages of recycling household food waste. They used resources to finance LCA analyses comparing incineration and recycling of food waste from households and drew on these results in their advocacy work highlighting the disadvantages of recycling. Despite

[2] Biogas production from food waste counts as recycling provided that the digestate is recycled as a fertilizer (Interreg Europe, 2021).

[3] To increase the biogas yields of manure-based plants, co-digestion with organic waste like food waste is necessary. Waste from food processing industries has been a key source, however, as biogas production increased, the demand for organic waste from food processing industries exceeded supply, which in turn increased the interest in accessing food waste from households to co-digest in manure-based plants (Raven and Gregersen, 2007).

mobilizing fewer allies, actors in the incineration configuration worked to continuously *maintain normative networks* that are willing to lobby on behalf of them. The appointment of board members in municipal waste companies comes across as an important practice to achieve this. Actors in the incineration configuration were also able to mobilize significant resources and their politico-judicial resources were particularly important for enabling actors to carry out institutional work to maintain the incineration configuration. Since municipalities were not legally required to meet national recycling targets, we see that a few municipalities simply did not comply, by not investing in source separation of household waste drawing on the argument that the advantages of recycling were not sufficiently documented (*variant of deterring)*. Our empirical material also suggests that some actors in the incineration configuration found ways to achieve the national set recycling target but still maintain the incineration of household waste by e.g. focusing on the recycling of household wood, which is a heavy waste fraction that also has a large effect on the overall recycling percentage (*variant of deterring*).

Contestation outcomes. We have seen a change in the relative strength between the established configurations, since the contestation axis erupted over the management of household waste. This change is reflected in waste management practices and legislation. In 2014, 16 municipalities collected source separated household waste for biogas production (Environmental Protection Agency, 2014) By 2019, this number had increased to 52 municipalities. In the same time period, the amount of collected household food waste more than tripled. Finally, new national waste legislation stipulates that municipalities are required to collect household food waste from July 2021 (Ministry of Environment, 2021).

4.2.2. Contestation over plastic packaging waste

We focus on plastic packaging waste to explore two additional contestation axes. The first is between an emerging configuration (reuse) and the set of established configurations representing the sector regime, the second is between an emerging configuration (chemical recycling) and an established configuration (incineration). Plastic waste is an EU circular economy priority because it is a significant source of pollution and because material recirculation is low, leading to continued dependence on fossil fuel extraction for new production (European Commission, 2015; European Commission, 2018). It is estimated that packaging accounts for approximately two thirds of the plastic waste generated in the EU and improving the circularity of this waste stream is therefore emphasized. To encourage a transition towards more circular plastic packaging, the EU amended the directive governing plastic packaging in 2018. The amended directive introduced new recycling targets for plastic packaging (50% is to be recycled in 2025 and 55% in 2030) and a stricter method of measuring recycling levels (Directive 2018/852). Complying with the amended directive on packaging waste requires major change in Denmark where it was estimated that in 2018 approximately 82% of the plastic packaging was incinerated and about 15% mechanically recycled.[4]

4.2.1.2. Friction between reuse and the sector regime. The increasing focus on circularity of plastic packaging is triggering a contestation between the emerging reuse configuration and the sector regime (Axis B: emerging vs sector regime, cf. Fig. 3). NGOs and start-ups promote reuse as a solution to the challenges associated with plastics packaging, while established sector regime actors either focus on increasing mechanical recycling of plastic packaging (mainly the recycling industry and their allies) or insist on the continued need for incineration (mainly municipal waste companies).

Constituent element 1: discourses. The actors promoting reuse argue that the challenges associated with plastic packaging require a reduction of packaging waste, which can be achieved by replacing single-use packaging with refillable containers that can be used multiple times. The reuse configuration confronts the established configurations because it rejects the idea that changes to the relative importance of existing established configurations (e.g. less incineration and more recycling) will be sufficient to address the challenges associated with plastic packaging waste. Actors in the reuse configuration do not envision a complete regime substitution, but a reduced relative importance of the current established configurations as the lifetime of packaging increases.

Actors in the sector regime have heterogeneous views on reuse and future alternatives. Actors from the incineration configuration are quite supportive of the reuse agenda, but they insist that there will always be a waste residue in Denmark or abroad, which cannot be reused or recycled and incineration will therefore also be needed in the future. They highlight incineration as critical infrastructure due to its important role as a source of heating. Actors from the recycling regime acknowledge reuse as a way forward for select purposes, e.g. takeaway, but reuse of plastic packaging is not broadly considered a feasible solution. For example, they argue that reuse in grocery retail will increase food waste. Instead, actors in the recycling configuration promote improved recycling as a way to address the challenges of plastic packaging while also retaining its advantages (reduced food waste and reduced CO_2 emissions from transport).

Constituent element 2: social networks. Compared to the established configurations, actors promoting reuse struggle to mobilize allies. There are social movements among some concerned consumers, who try to limit single-use packaging, and we see one-off projects where regime actors engage in various types of institutional work with NGOs and start-ups to promote reuse.

> *We, the green NGOs, are standing in one corner calling for more reuse. Everyone else is aware of us, but most of the time the conversation is focused on recycling or incineration* (Interview 21).

Meanwhile, retailers, brand owners, food and packaging producers ally with actors from the recycling configuration, while actors

[4] In 2018, 31 percent of Danish packaging waste from households was collected for recycling and 67 percent was collected for incineration (Environmental Protection Agency, 2020) However, it is estimated that approximately half of the collected plastic packaging waste is rejected in subsequent sorting processes and therefore incinerated (Danish Government, 2018).

from the incineration configuration are more isolated, reflecting the general de-legitimatization of this technology (as also described in the friction over household food waste).

Constituent element 3: resources. The skewed mobilization of allies is also reflected in the resources that actors are able to mobilize. Compared to the established configurations, actors promoting reuse possess fewer resources. Extensive investments have been made in plants and infrastructure that support the established configurations, such as facilities to collect, sort, recycle and incinerate plastic packaging waste, while the reuse configuration rely on small scale return systems. Likewise, reuse actors possess more modest financial resources, and unlike actors from the established configurations, struggle to form ties with more affluent allies. Reuse actors also highlight a lack of intellectual resources. NGOs and start-ups do not have the technical know-how to assess and critique the performance of established technologies in a more substantial way. Finally, the formal decision-making power over waste management lies with public authorities and currently public policy supports the established configurations, however placing increased emphasis on the need to recycle more and incinerate less).

Institutional work. Given modest resources and allies, the institutional work carried out by actors in the reuse configuration is limited to *advocacy* and *educating*. NGOs and to some extent reuse start-up companies, mobilize their storyline and intellectual resources, particularly knowledge of the policy process and public communication skills, to advocate for reuse and warn against the shortcomings of a system focused too heavily on recycling and incineration. The actors lobby for quantitative reuse targets to be implemented in public policy and for public investments to be made in reuse infrastructure. Also drawing mostly on their intellectual resources, NGOs host webinars and publish reports on reuse to share skills, knowledge and experiences.

The configurations in the sector regime carry out more diverse institutional work compared to actors in the reuse configuration. Both configurations draw on greater and varied resources, and the recycling configuration on a broad range of allies, too, which enable this. Actors from the incineration and recycling configurations both engage in *advocacy*, although they work towards different goals. Municipal waste companies mobilize resources to defend incineration as a critical infrastructure, and emphasize its important role as a source of heat. This is done in media, but also in meetings and communication with politicians. Industry associations representing the recycling industry as well as packaging and food producers lobby for better conditions for recycling. Intellectual resources help enable continuous communication with politicians and civil servants, while financial resources play a key role in allowing actors from the recycling configuration to promote and defend recycling and the need for packaging in media and through public outreach campaigns (educating). Through their expansive network of allies, actors from the recycling configurations are also able to play a crucial role in *constructing normative networks.* Key examples include Forum for Circular Plastic Packaging and Rethink Plastic Consortium that both bring together actors from across the plastic packaging value chain to develop plastic packaging design principles. The design principles focus extensively on recycling and thus contribute to providing normative sanctions in the system. The alignment between the established configurations (both recycling and incineration) and public authorities finally plays a crucial role in enabling *embedding and routinizing* work to take place. In Denmark, packaging reuse is not counted in public statistics and quantitative policy targets are limited to recycling and incineration, which maintains and reproduces these practices.

Contestation outcomes. Our empirical material suggests that reuse actors are struggling to shape institutions related to the use and management of plastic packaging. Reuse actors are currently lobbying for a reuse target to be included in the Danish implementation of the extended producer responsibility on packaging, which needs to be in place by 2025. However, the reuse actors interviewed for our study considered this unlikely to happen.

4.2.1.3. Friction between chemical recycling and incineration. The challenges of achieving more circular plastic packaging is also illuminating a friction between the emerging chemical recycling configuration and the established incineration configuration (Axis C: emerging vs established, cf. Fig. 3). Start-ups and petrochemical companies promote chemical recycling of plastic packaging as an alternative to incineration, which is done by municipal waste companies.

Constituent element 1: discourses. In Denmark, actors promoting chemical recycling argue it will offer material recirculation of plastic waste that cannot be mechanically recycled and is therefore currently incinerated. As such, chemical recycling is presented as a solution to the problems associated with plastic waste. Actors highlight a CO_2 benefit from treating plastic packaging waste with chemical recycling rather than incinerating it. Moreover, it is emphasized that chemically recycled material can be used in high quality products and therefore does not 'downcycle' the material as is often the case with mechanical recycling.

Actors in the incineration configuration have not articulated a very clear storyline with regards to chemical recycling of plastic packaging waste. On a more general level, representatives from municipal waste companies argue that export of plastic waste should be avoided, since it is very difficult to document and secure high quality mechanical recycling abroad. Since little mechanical recycling of plastic packaging takes place in Denmark, actors from the incineration configuration highlight that the national treatment options for plastic waste should be used, which is incineration and potentially chemical recycling.

Constituent element 2: social networks. The chemical recycling configuration has been successful in mobilizing allies. Actors from the Danish recycling configuration collaborate with chemical recycling actors to carry out institutional work on behalf of chemical recycling, while collaborations with universities contribute to advancing the technology. Investors are a key source of financial resources as described in the quote below:

> *There are now big investments in chemical recycling all over Europe strongly supported by large petrochemical companies and huge consumer goods companies* (Interview 27).

Actors from the incineration configuration collaborate with Danish public authorities on generating more knowledge of chemical recycling, but we are not otherwise seeing signs of the incineration configuration mobilizing allies on this issue.

Constituent element 3: resources. Chemical recycling actors are actively mobilizing resources to further legitimatize and develop. As a result of partnerships and investments, the financial resources among chemical recycling actors are growing and the physical-material resources are in turn expanding. A number of chemical recycling pilot plants have been built in Denmark, and the construction of commercial plants have been announced. Technological developments are still in an experimental phase, which means that intellectual resources are developing in the emerging configuration. Experience with policy processes reside mainly with chemical recycling actors that are more established in other industries e.g. petrochemical companies.

Although the incineration configuration is endowed with considerable resources e.g. incineration infrastructure, stable financing through waste management fees, long standing experience with the policy process, technical know-how of the current system and some formal authority over waste treatment, we do not see incineration actors mobilizing these resources against the chemical recycling configuration.

Institutional work. Actors in the chemical recycling configuration mobilize their discourse as well as growing resources and allies to carry out various types of institutional work. Actors and allies of the emerging configuration use their financial and intellectual resources and persuasive storyline to lobby for chemical recycling in opinion papers and meetings with public authorities and politicians (*advocacy*). Chemical recycling companies draw on their intellectual resources to disseminate knowledge about the configuration through presentations at sector and industry conferences and in guided tours of their plants (*educating*). Chemical recycling actors also use financial resources to develop life-cycle analyses of chemical recycling and alternative treatment options. These results are used in advocacy work to highlight advantages of chemical recycling and provide evidence for educating work. We also see chemical recycling companies mobilize mainly financial resources to obtain third party certifications (*defining*), which can be seen as attempts to formally validate their treatment processes.

Our empirical material suggests that actors in the incineration configuration are not doing institutional work related to chemical recycling of plastic packaging waste, which mirrors their relatively weak discourse and modest mobilization of resources and allies. We do see incineration actors drawing on their resources and relationship with public authorities to build a better understanding of chemical recycling. It is our impression that the growing political opposition to plastic incineration is forcing municipal waste companies to consider other methods of treatment, and they are currently in a process of making up their mind about chemical recycling.

Contestation outcomes. We see multiple signs that the chemical recycling configuration is gaining strength. A 2020 political agreement to decrease the national incineration capacity by 30% supports the chemical recycling configuration, while weakening the incineration configuration (Danish Government, 2020). Chemical recycling is moreover legitimized and described as necessary in roadmaps developed to guide national research and innovation partnerships (Aalborg University et al., 2021).

5. Discussion and conclusion

This paper has contributed with a framework taking into account the structural characteristics of socio-technical systems in the analysis of sustainability transitions. The concept of the contestation axis was introduced to highlight interfaces between different configurations in a socio-technical system and show how agency dynamics can play out, and frictions materialize, along other axes than the (for transition studies) typical niche-regime axis.

Taken together, the contribution of this paper has been to complement the emerging configurational approach in transition studies with a perspective on transition dynamics and agency that reflects how sectors differ in terms of their structural composition and potential transition trajectories (Alkemade, 2019; Andersen et al., 2020; Miörner et al., 2021; Van Welie et al., 2018) . While there are many frameworks for analyzing niche-regime interaction, how to analyze agency in sectors characterized by a less pronounced niche-regime dichotomy and a more complex configurational set-up has remained under-addressed in the literature. We demonstrate that agency and frictions between actors positioned in different socio-technical configurations cannot be fully understood if limiting the analysis to the niche-regime axis in the system, but requires an analysis acknowledging different socio-technical configurations, the actors' position in these emerging or established configurations, and their alignment, into account. Based on the empirical analysis, we highlight three issues that merit further discussion.

First, our analysis points to the importance of avoiding negligence of intra-regime dynamics. The introduction of circular economy policy by the EU caused a friction in the Danish waste sector between the two established configurations of recycling and incineration. In this process, actors in the recycling configuration have engaged in a wide portfolio of forms of institutional work, drawing on persuasive storylines, plentiful resources, and powerful allies from the private, public, and non-governmental sectors. As a response, actors from the incineration configuration have engaged in efforts to maintain institutions, drawing also on their rich resources. However, given a more defensive storyline and less powerful allies, these efforts have only been partially successful, leading to a change in the relative strength between the established configurations.

We argue that such changes in the regime matter significantly for transition processes. While frictions between established configurations do not directly involve emerging configurations, they may have indirect influence on them. To exemplify, institutional work by recycling actors to de-legitimatize incineration in light of circular economy visions may indirectly support the emerging configuration of chemical recycling. This underlines the value of taking a whole-sector perspective in the analysis of transitions, which considers interrelations between multiple configurations.

Second, our empirical case study highlights the need to appreciate variation among emerging socio-technical configurations and suggests that this variation, at least in part, is shaped by the character of relations between an emerging configuration and other socio-technical configurations in the system. When zooming in on the two emerging configurations aimed at managing plastic packaging waste in the Danish setting, reuse and chemical recycling, we show how the emerging configurations position themselves differently in relation to the established configurations. Reuse more fundamentally challenges the set of established configurations in the sector,

while chemical recycling only seeks to replace the incineration configuration. We see this difference reflected in the resources, discourses and social networks of actors and in turn the type of institutional work actors are able to carry out on behalf of their respective configuration.

The actors promoting reuse are in a more confrontational relationship with established configurations and struggle to mobilize resources and social networks. Consequently, they are more limited in their institutional work. They advocate for reuse and attempt to increase awareness and knowledge about the emerging configuration, but are unable to influence normative sanctions and practices in the system, which are maintained through the institutional work carried out by actors from the established configurations. In contrast, the actors promoting chemical recycling are in a largely uncontentious relationship with established configurations. In fact, we do not see any established configurations trying to mobilize against chemical recycling. Thus, chemical recycling actors have successfully mobilized allies and resources, which are put to use when carrying out institutional work on behalf of the configuration. As a result, chemical recycling actors are not as limited as reuse actors in the forms of institutional work they carry out, but they are also able to carry out the different forms of institutional work in more sophisticated ways, e.g. *educating* based on commissioned LCA analyses rather than self-written reports.

Third, we argue that these findings have implications for policy. In particular, they suggest the need for acknowledging the heterogeneity among emerging configurations. Niches (in classic transitions terms) are not necessarily homogenous, but may consist of multiple emerging configurations with very different preconditions for initiating institutional work. In turn, these configurations are likely to require vastly different policy support to further institutionalize. In our empirical analysis, this is clearly illustrated by the chemical recycling actors, which have access to the resources and networks of powerful allies such as the petrochemical industry. This creates a vastly different context for policy compared to the reuse configuration, where resources and networks are significantly more scarce.

The present paper draws on a single case study to illuminate how agency play out between different socio-technical configurations. The structural pattern of sectors and the actual frictions between configurations that can be observed empirically are the result of both contextual and relational processes. We expect frictions to manifest along similar contestation axes in contexts with similar structural set-ups, but more research is needed in other contexts with similar or different configurations to test this assumption. To explore whether the same contestation axes are relevant in other national or regional contexts, future research could utilize semi-quantitative methods such as Socio-Technical Configuration Analysis (STCA) (Heiberg et al., 2022) in order to identify relevant configurations and contestation axes in a larger set of geographical contexts. How agency play out along these axes could then be further investigated with in-depth case studies, potentially allowing for the development of ideal-typical patterns of agency along the four axes identified in our study. This holds potential in terms of informing existing frameworks for analyzing transition pathways (Geels and Schot, 2007; Geels et al., 2016) with a more sector-sensitive perspective.

Furthermore, studies into other sectors than the waste sector is a relevant direction for future research. We expect that the general framework is applicable to other sectors, such as water, mobility and energy, and future studies should be concerned with exploring how the particular configurational set-up in these sectors shape the propensity and opportunity for agency when it comes to contributing to transitions. For example, socio-technical systems exhibiting a range of different contestation axes should be expected to be more dynamic, i.e. have a higher transformative capacity, than sectors with only one 'active' contestation axis.

Finally, future studies would need to explore frictions along the axis of contestation between two or more niches (Axis D: emerging vs emerging, cf. Fig. 1), which did not stand out in our empirical case. With the exception of a few studies (e.g. Lin and Sovacool, 2020), the relationship between niches is a largely unexplored topic in transitions research. We also of course encourage research into the identification of additional ideal-type contestation axes not covered in the present framework.

Declaration of Competing Interest

None.

Data availability

The authors do not have permission to share data.

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Appendices

Table A1–A6

Table A1
Forms of institutional work and their definition as described in Lawrence and Suddaby (2006).

Creating institutions

Advocacy: The mobilization of political and regulatory support through direct and deliberate techniques of social suasion

- **Defining**: The construction of rule systems that confer status or identity, define boundaries of membership or create status hierarchies within a field
- **Vesting**: The creation of rule structures that confer property rights
- **Constructing identities**: Defining the relationship between an actor and the field in which that actor operates
- **Changing normative associations**: *Re*-making the connections between sets of practices and the moral and cultural foundations for those practices
- **Constructing normative networks**: Constructing of interorganizational connections through which practices become normatively sanctioned and which form the relevant peer group with respect to compliance, monitoring and evaluation
- **Mimicry**: Associating new practices with existing sets of taken-for-granted practices, technologies and rules in order to ease adoption
- **Theorizing**: The development and specification of abstract categories and the elaboration of chains of cause and effect
- **Educating**: The educating of actors in skills and knowledge necessary to support the new institution

Maintaining institutions

Enabling work: The creation of rules that facilitate, supplement and support institutions, such as the creation of authorizing agents or diverting resources

- **Policing:** Ensuring compliance through enforcement, auditing and monitoring
- **Deterring**: Establishing coercive barriers to institutional change
- **Valourizing and demonizing**: Providing for public consumption positive and negative examples that illustrates the normative foundations of an institution
- **Mythologizing**: Preserving the normative underpinnings of an institution by creating and sustaining myths regarding its history
- **Embedding and routinizing**: Actively infusing the normative foundations of an institution into the participants' day to day routines and organizational practices

Disrupting institutions

Disconnecting sanctions: Working through state apparatus to disconnect rewards and sanctions from some set of practices, technologies or rules

- **Disassociating moral foundations**: Disassociating the practice, rule or technology from its moral foundation as appropriate within a specific cultural context
- **Undermining assumptions and beliefs:** Decreasing the perceived risks of innovation and differentiation by undermining core assumptions and beliefs

This list of institutional work developed by Lawrence and Suddaby (2006) is developed bottom-up, based on a literature review of multiple empirical case studies. Consequently, on the one hand, not all types of institutional work will necessarily be relevant in each case; on the other hand, other forms of institutional work not included in the list by Lawrence and Suddaby (2006) may also be identified. In our case we have added one type of institutional work, which we refer to as 'maintain normative networks'. This describes a practice where actors are able to recruit new members to a pre-existing normative network, which in turn maintains and strengthens that network.

Table A2
Overview of interviews.

No.	Interviewee	Date
1	Industry association representative	Aug 2019
2	Municipal association representative	Aug 2019
3	Former MP	Oct 2019
4	NGO representative, waste sector expert	Oct 2019
5	Former MP	Oct 2019
6	NGO representative, waste sector expert	Oct 2019
7	Former civil servant, Ministry of Environment	Jan 2021
8	Municipal association representative	Feb 2021
9	Municipal waste sector representative	Sep 2021
10	Consultant, waste sector expert	Sep 2021
11	Former Mayor of Copenhagen	Sep 2021
12	Industry association representative	Sep 2021
13	Consultant, waste sector expert	Sep 2021
14	Municipal waste sector representative	Nov 2021
15	Industry association representative	Nov 2021
16	Professor in chemical engineering	Nov 2021
17	Biogas expert	Dec 2021
18	Biomass association representative	Dec 2021
19	Biogas association representative	Dec 2021
20	Waste sector expert	Dec 2021
21	NGO representative	Jan 2022
22	Industry association representative	Jan 2022
23	Waste sector expert	Feb 2022
24	Chemical recycling start-up	Feb 2022
25	Chemical recycling start-up	Feb 2022
26	Municipal association representative	Mar 2022
27	Chemical recycling start-up	Mar 2022
28	NGO representative	Mar 2022
29	NGO representative	Mar 2022

Table A3
Full references for newspaper articles quoted in main text or Tables A4–A6.

Newspaper article no.	Reference
1	Ege, C. (2012) Debat: Gylle mindsker udslip af klimagasser, *Politiken*, January 6, p. 5.
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Table A4
Exemplary empirical material for discourses, resources, social networks and institutional work from interviews and newspaper analysis relating to the friction over food waste between recycling and incineration (Axis A: established vs established).

	Established configuration (recycling)	Established configuration (incineration)
Discourses	• "District heating is basically hot water and we can make that in many ways, but with biogas we can get a much higher energy quality that's difficult to make in other ways (e.g. fuel), which can then be used where a transition is more difficult (e.g. transport sector)" (Interview 19). • "In Denmark, biogas is also very much about making agricultural production more circular and sustainable" (Interview 19). • "The establishment of biogas production in Denmark is closely linked to the country's large livestock production. It became clear in the late 1970s, early 1980s that spreading	• "The alternative to biogas, the current waste incineration infrastructure, also generates energy. Although phosphor from the waste cannot be used as fertilizer after incineration [… we, the municipal waste companies] are not convinced that biogas is so much better than waste incineration, which is suggested in the current taxes and subsidies" (Newspaper article 6). • "Organic waste [in biogas plants] can potentially in the future be used to make green fuel for e.g. trucks, but when we only produce electricity today, one could in reality just as well send the waste to incineration at Amager. Then you

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Table A4 (*continued*)

	Established configuration (recycling)	Established configuration (incineration)
	raw manure was bad for water quality and in response it was decided that farmers should store their manure and only spread it at certain time during the year. It was not a long jump to go from storing the manure to making biogas out of it" (Interview 20). • "Biogas production enables us to recycle phosphor, which is a limited resource and a necessary plant nutrition. If we use organic waste [food waste] in biogas production, we get a fertilizer where the phosphor can be used again. However, if we burn the organic waste and deposit the ash in cement, then plants cannot use the phosphor again. Then we get big problems with supplying food to the growing global population" (Newspaper article 1). • "Biogas production works much better and more cost-effectively when manure is mixed with more energy intensive organic residual fractions. A very obvious residual fraction is the wet household waste from Danish households. The first advantage of not incinerating the organic waste is that we support the biogas sector. We increase our degree of national self-sufficiency of energy […] The second advantage is that we increase the national recirculation of nutrients in agriculture. When the organic household waste is first used for production of biogas and then composted it becomes a very nutrient product that can replace part of the fertilizer we otherwise import" (Newspaper article 2). • "If in the future, more municipalities can supply organic waste to the biogas sector and it will result in more plants. In that way you will be able to treat more of the raw manure that today is spread on fields emitting methane to the atmosphere" (Newspaper article 3). • "Biogas can stabilize the future wind dominated energy system. At the same time, it can supplement heavy and collective transport systems where electricity will not be sufficient on its own" (Newspaper article 4).	would have, in addition to electricity, also gotten some district heating out the waste" (Newspaper article 7). • "The Danish Waste Association finds that there are not environmental-, resource-, energy- or economic reasons to generally source separate organic waste. A source separation of organic waste can make sense locally depending on the existing infrastructure and energy supply or in situations where investments have to made in new infrastructure […] The Danish Waste Association has tried to find information about other system conditions that can motivate why it is preferable to source separate organic waste. Topics that may be relevant include for instance that the waste could replace energy crops in the manure based biogas plants, that biogas can be upgraded to natural gas quality and thereby work as a flexible fuel in the future energy system and or be used as a fuel in the transport sector or that the source separation of organic waste will have a positive spillover effect on citizens general sorting efforts. However, these conditions have not been assessed from an environmental and socioeconomic perspective compared to continued incineration of the organic waste" (Newspaper article 4). • "One challenge is that the agricultural sector is not as such lacking the nutrients and carbon that the waste sector can add to the agricultural soil. Waste can potentially contribute with so little that it is meaningless in the big picture especially if adding waste based nutrients can effect demand for the agricultural products" (Newspaper article 4).
Resources	*Physical-material* • "Biogas production goes back to the 1970s in Denmark and today there is more than 100 plants across the country" (Interview 17). • "The Danish natural gas infrastructure was built in the 1980s, and today that is part of the biogas infrastructure because it was decided that biogas could be distributed though the natural gas network" (Interview 19). *Financial* • "The biogas sector is now supported by large natural gas companies that focus increasingly on biogas since natural gas eventually is to be phased out. They are able to loan money easier than what farmers could esp. after the financial crisis" (Interview 19). *Intellectual* • "While there is a long tradition for biogas production in Denmark, one of the key challenges when including more household food waste has been developing experience with sorting the household waste and making sure contamination was low. The farmers don't want pieces of plastics spread on their fields, and for a long time dairy farmers were cautious about using fertilizer made from co-digestion between manure and household food waste" (Interview 17).	*Physical-material* • "Since the 1980s, we have seen Danish municipalities make very large investments in incinerations plants, and Denmark has one of the highest shares of household waste incineration in Europe (Interview 7). • The Danish incineration sector has been very well organized and has treated a big proportion of the waste that was otherwise an environmental problem" (Interview 14). • "Collectively, municipalities have invested about DKK 20 billion in incineration plants, and local politicians are now afraid that the economy of these plants will be undermined. When a greater part of waste is recycled and the organic waste in the future is sent to biogas plants there will be less waste to incinerate and therefore less heat to sell in the district heating infrastructure" (Interview 9). *Financial* • "Municipalities set a waste management fee, which enables them to finance the waste treatment. That is really a beautiful thing about the Danish model – there is actually money to do things" (Interview 14). *Intellectual* • "Although there are disagreements about the size of the Danish incineration capacity, there is no doubt that Danish incineration plants especially the newer ones are world-class. Over a long time period we have perfected the

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Table A4 (*continued*)

	Established configuration (recycling)	Established configuration (incineration)
		building and running of these plants. So much so that we have forgotten or outright disregarded other options" (Interview 10). • "For more than 20 years, the municipal waste sector has managed to dodge major change, sometimes they have been lucky, but they have also been good at working the political system" (Interview 23). *Politico-judicial* • "In the 1980s, Danish municipalities were given full responsibility for waste management. Unless it was explicitly stated in the law that someone else had responsibility, it was the responsibility of municipalities. They could allocate waste produced within their jurisdiction and charge fees for its treatment" (Interview 15).
Social networks	• "In 2012, it was decided that biogas could be distributed in the natural gas network, which made natural gas companies begin to invest in biogas" (Interview 17). • "DAKOFA has been very active in continuing to talk about the importance of biogas in the Danish context and the environmental minister, Ida Auken, has been an absolute driving force for the biogas sector" (Interview 19). • "There is no doubt that NGOs have been skeptical of incineration for many years. The Danish NGOs have broadly supported the biogas agenda, although some have focused a bit more on the composting perspective of treating the organic waste rather than the energy perspective" (Interview 20). • "When household food waste is source separated it needs treatment before biogas can be produced from the collected material. This is a business opportunity for private companies and one reason why they support biogas production compared to incineration" (Interview 17).	• "The integration between incineration and the energy sector, through companies such as Vølund as well as Bruun & Sørensen, is certainly part of the reason why incineration became so important in Denmark" (Interview 10). • "The large Danish incineration sector is also a result of expertise provided by the consultancy firm Ramboll and Vølund, the machine supplier" (Interview 9).
Institutional work	• Advocacy: "Since our organization was founded we have been concerned with getting access to organic waste from households. Our job is to go around and make ourselves visible. We have had regular contact with civil servants and politicians for many years" (Interview 19).	• Deterring: "In 2014, the Minister of Environment begged the municipalities to collect organic waste, but far from everyone did so. Instead, some municipalities focused on increasing the collection of wood from household for recycling. This is a heavy waste fraction so in many cases you could reach the 50% without collecting organic waste from households" (Interview 15)

Table A5
Exemplary empirical material for discourses, resources and social networks from interviews and newspaper analysis relating to the friction over plastic packaging between reuse and the sector regime (Axis B: emerging vs sector regime).

	Emerging configuration (reuse)	Sector regime
Discourses	• "If we can get our resources to circulate in reuse systems, then we don't have to continually spend energy on reprocessing those resources and extracting new resources to fulfill the same function" (Interview 21). • "In Denmark over the past years, there has been a lot of focus on the treatment of plastic waste. There is a growing acknowledgement that we produce a lot of waste and that we need to find out what to do with it. In all of this we take for granted that the waste is there. After years of an extensive focus on recycling, it's our opinion that we need to turn off the tap and significantly reduce the production of plastic […] the dominating focus on recycling is a challenge for the reuse agenda, recycling is considered so legitimate that reuse is not even considered by many" (Interview 28).	• "In most situations, packaging will quickly be discarded as waste, so therefore we really need to find some good ways to recycle that discarded material" (Interview 20). • "Plastic waste significantly reduces food waste […] and reduces the CO2 emission from the transport of food. If we just removed plastic or reduced our use significantly, the big losers would be our environment and climate. Also when it comes to packaging" (Newspaper article 10). • "It is our [the plastic industry] understanding that a big part if the solution is to see plastic as a resource that should be collected and recycled after use" (Newspaper article 11). • "Recycled plastic can save 50–70% of the CO2-emissions that come from the production of new plastic […]

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	Emerging configuration (reuse)	Sector regime
	• "The problem with plastic is that we use too much of it especially plastic packaging, which after a short lifetime ends as waste. If we want to address the issue of plastic pollution, then we need to invest in a circular plastic economy that is designed to prevent plastic from becoming waste" (Newspaper article 8). • "It is our opinion [4 Danish NGOs] that Denmark should formulate a target to reduce the use of plastic packaging and takeaway packaging by 50% in 2025, and 80% in 2030. To achieve these targets, we must think of entirely new business models where subscription services, sharing systems and deposit systems play a much bigger role" (Newspaper article 9).	Everything suggests that the use of plastic will increase in the future. Therefore, it is of great importance that we reduce the CO2 emissions from the production and use of plastics. But we should not forget that plastic is a unique material, that is necessary when we need to secure the durability of food. Plastic has contributed to the great reduction in food waste we have seen in recent years" (Newspaper article 13). • "In most cases, plastic packaging has an important and practical purpose […] which is also why, from a climate perspective, it does not always make sense to not select packaging just because it is made from plastic […] Instead, we should focus on how we in Denmark can improve our recycling of plastic packaging, because it is here the big climate gain is to be made" (Newspaper article 14). • "We have been doing our very best to tell the population and politicians that incineration is part of the backbone of public services – its critical infrastructure. We can reuse and recycle more and still keep our incineration sector as it is today. If there is not enough waste in Denmark, we import from other countries. In many places landfilling is still common, and treating that waste in Danish incineration plants would be better for the environment" (Interview 8).
Resources	Physical-material • "Today we see many different, small systems being tested, which is great, but we really need the state to facilitate the creation and upscaling of a more standardized return system" (Interview 21). *Financial* • "Establishing reuse systems is relatively costly and I think that is one of the biggest challenges for these systems to take off. An initial investment needs to be made in the system before you can start running a business. We are hoping this is something politicians are looking to support" (Interview 22). • "In our organization, I am the only person working on this agenda [circular economy], and that goes for most of the other NGOs in Denmark, too, on this issue. We have limited funding and must be very tough then we prioritize what we focus on" (Interview 21). *Intellectual* • "They [NGOs] don't have the kind of technical knowledge necessary to critique these industrial processes. That goes for chemical recycling, but also incineration and other recycling processes. It takes years to understand how these things really work" (Interview 20). • "We have strategically decided not to go into too many discussions about recycling. There is of course a need to do that, and I hope another organization will do that, but it requires so much technical knowledge to understand these processes, and in this respect we are just always falling behind the industry" (Interview 29). *Politico-judicial* • "It is clear, that if we had a government who actually focused on increasing reuse, everything would be a lot easier. It is an uphill battle, when those who actually have the power to decide, do not want to make that change" (Interview 29).	Physical-material • "The current system of Danish waste management, where we mainly recycle and incinerate, has been built over decades. A lot of money has been invested in plants that sort waste, recycle or incinerate it. But there is also the system of collection. Just consider the investment in waste bins at every household. It may seem like a small thing, but this is the infrastructure that supports our current system" (Interview 20). • "The great interest in recycled and recyclable plastic packaging for food products makes Danish plastic producers reorganize their production and invest massively to meet demand […] in 2018, Færch bought the Dutch 4Pet Group […] Sky Light invested 55 million on a new production line" (Newspaper article 12) *Financial* • "Funding from the Environmental Technology Development and Demonstration Program (MUDP) primarily goes to recycling projects, not reuse" (Interview 23). According to the Ministry of Environment (2022), of the DKK43 million that were granted to projects relating to plastic and circular economy (plastic in general, not only packaging) in 2021, 96% was granted to recycling projects, 4% to a reuse project. • "The recycling idea has really been taken up and it is allowed to dominate both in terms of technology, development and funding. It been like that for a while and it is becoming even more so now" (Interview 29). • In 2020, Færch, a Danish based plastic food packaging producer focusing on the use of recycled PET, was bought by A. P. Møller Holding that sets out to make long-term investments in the company (Newspaper article 25). *Intellectual* • "Forum for Circular Plastic Packaging was about bringing actors and stakeholders together. Plastic was an exploding topic on the political agenda and it became clear that no actor could solve this challenge alone, so we wanted to pool knowledge from different actors and start sharing and

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Table A5 (*continued*)

	Emerging configuration (reuse)	Sector regime
		discussing ways forward with people from different places in the value chain" (Interview 7). Politico-judicial • "Current public policies only include quantitative targets for recycling and incineration. That is what is being counted and therefore what everyone works towards […] It is telling that we do not even have a statistics that counts reuse packaging" (Interview 29)
Social networks	• "It is a mystery to me that the reuse agenda is not being picked up politically […] I don't see any political party taking ownership over this agenda" (Interview 29). • "We certainly don't see them [industry] as allies on this issue [reuse] although they officially support reduction and reuse we don't see them walking the talk. They surely have an interest in recycling, too, as it enables them to keep on producing" (Interview 28). • Examples of citizens that supporting the reuse agenda: newspaper article 15, 16, 17, 18	• "At the moment, all attention is directed towards recycling, no packaging producers are interested in reuse" (Interview 23). • "The ministries and politicians have focused their energy on the existing system of waste management. Focus has been on reducing incineration and increasing recycling" (Interview 22).
Institutional work	• Educating and advocacy: "We host webinars about how municipalities can support the increase of reuse, about reuse packaging for instance sharing experiences about using reuse packaging at larger events like festivals. Our key aims are to creating awareness, engage citizens and take part in political work. We are represented in a host of political work groups and boards, and we meet with political parties on a running basis" (Interview 21).	• Constructive normative networks: "The design principles developed in Forum for Circular Plastic Packaging have been very well-received. It is my understanding that the industry now has more of a common language and understanding of what good plastics is" (Interview 12)

Table A6
Exemplary empirical material for discourses, resources and social networks from interviews and newspaper analysis relating to the friction over plastic packaging between chemical recycling and incineration (Axis C: emerging vs established).

	Emerging configuration (chemical recycling)	Established configuration (incineration)
Discourses	• "Chemical recycling can be a very valuable addition to the recycling tool box. The result is that less plastic waste is incinerated and more is recycled. There is a clear CO_2 benefit from that. And not only a CO_2 benefit, but also a circular economy benefit as hydrocarbons are being kept in the loop rather than disappearing as they do in an incineration plant […] Then of course there is the issue of upcycling. A lot recycling technologies have a finite number of times that a polymer can be recycled before it loses its properties. So chemical recycling has the advantage of putting it back to building blocks so that we can build up virgin-like plastics" (Interview 27). • "From a realistic point of view, we know that there is going to be a huge demand for plastic products from many years to come and we think that it is evident that we need better recycling" (Interview 27). • "After a chemical recycling process, the end product can be used in new production making the plastic circular. That will result in environmental advantages compared to today, where the same plastic is incinerated […] Chemical recycling will help reduce large amounts of plastic waste globally, and the method will be a natural supplement to traditional recycling" (Newspaper article 19). • "We [chemical recycling company] do not want to compete with mechanical recycling. There is room enough for both of us on the market, and we can take some of the products that they struggle to recycle. The advantage is also that we	• "Plastic that is used in Denmark should be treated in Denmark […] We must avoid exporting our waste problems and instead focus on achieving a higher quality and better economy in recycling […] It is absurd, that a big part of the plastic sorted by citizens in households is sent far away with the intention to be recycled, but then ends up with a significantly worse environmental treatment than it would have received in Denmark […] In Denmark, we have some of the most modern and well-functioning waste-to-energy plant with state-of-the-art cleaning technology and therefore minimal emissions of pollutants. Alternatively, the non-recyclable plastic can be chemically recycled" (Newspaper article 24). • "Of course, we are all [municipal waste companies] looking at this possibility to chemically recycle plastic packaging waste, we are positively curious […] but the thing we are nervous about is that it requires too much energy. How energy intensive is it to carry out the pyrolysis and the subsequent steps such cracking? Maybe even compared to incineration with carbon capture? That's not what we're doing today but the type of perspective we're looking into" (Interview 26). • "The incineration plant operators do not seem to be concerned about the reduced level of plastics in the waste they burn [which would follow from more chemical recycling]. They keep telling me that the plants are very

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	Emerging configuration (chemical recycling)	Established configuration (incineration)
	can upcycle the materials to new products – we don't downcycle like you almost always end up doing with mechanical recycling" (Newspaper article 20). • "Today, it is almost impossible to produce that kind of products [food grade packaging] from mechanically recycled material. But it is possible to produce them from chemically recycled material using a mass-balance approach. That would result in products with the exact same properties as those made from fossil raw materials. This is the unique advantage of chemical recycling" (Newspaper article 21).	robust. The biggest challenge is to actually get the plastic out of the residual waste fraction" (Interview 26). • "Resistance to chemical recycling is not coming from incineration. At least we have not felt that directly […] They [incineration plants] want a low calorific value or a balanced calorific value, which has been difficult to achieve since China stopped import of low quality plastic waste. This meant that they [incinerators] were forced to receive more plastics, which made their business very bad. There was a time in Europe when large incinerators were all in red, they were losing money" (Interview 27).
Resources	*Physical-material*	*Physical-material*
	• "Things are really happening now. The plants are no longer just being built in an odd garage somewhere, but are larger scale and professional. We are really seeing the building of an industry" (Interview 25). • "While the use of thermochemical processes like pyrolysis for recycling of e.g. plastic waste is something BASF and others have worked on for years, the technology has not yet found foothold in an industrial scale […] there are only a handful of commercial pyrolysis plants in Europe today" (Newspaper article 21)	• "Since the 1980s, we have seen Danish municipalities make very large investments in incinerations plants, and Denmark has one of the highest shares of household waste incineration in Europe" (Interview 7). • "The Danish incineration sector has been very well organized and has treated a big proportion of the waste that was otherwise an environmental problem" (Interview 9). • "Recycling of plastic is very much on the political agenda today, but it is clear that if you have an incineration tradition like we've had in Denmark where you burn plastic and make heat out of it, then it takes a lot for this to change because in some ways it works well. It is a conservative sector that is difficult to change" (Interview 24).
	Financial	*Financial*
	• "It is in the last couple of years that money has started to massively flow into this industry [chemical recycling]" (Interview 25). Examples: In 2019, BASF invest DKK 150 million in Quantafuel and their plant in Skive, Denmark (Newspaper article 22); In 2020, Kirkbi holding and investment company invest DKK 170 million in Quantafuel (Newspaper article 23).	• "Municipalities set a waste management fee, which enables them to finance the waste treatment. That is really a beautiful thing about the Danish model – there is actually money to do things" (Interview 9).
	Intellectual	*Intellectual*
	• "Our theoretical data suggests that we can make around 80% oil from the plastics feed into the plant […] but it is too early to conclude anything about our yields based on data from the plants as we are still trying to run the plant commercially" (Interview 27). • "It would be great if you could get it all [the recycled material] back to the plastic industry. That's what we want, but we'll have to see. I don't know how we'll get there […] that is where the big players come in, the petrochemical players. They are used to refining oil that's what they've been doing for many years. We need to bring that knowledge into the industry now" (Interview 25). • "We can't just say that we're doing this and that for the environment, we have to provide evidence. That's why we're working a lot to develop LCA analyses" (Interview 24).	• "At this point it is not really clear what they [chemical recycling companies] received. The whole thing is a bit of a black-box. We have also asked the Danish Technical University (DTU) to look into mass-balance, carbon balance, energy balance of this. There are some numbers, but not a great deal of research on this, and we're not that much wiser after the work done by DTU" (Interview 26). • "We can get some insight into pyrolysis process, but we can't get any insight into the subsequent treatment and what they do at the refinery" (Interview 26).
	Politico-judicial	*Politico-judicial*
	• "We do not have the resources to actively participate [in negotiations around mass balance approaches] at the EU level, it's extremely resource intensive […] but we are working with our partner to leverage and to give as much good information as possible to inform those regulations" (Interview 27).	• "In the 1980s, Danish municipalities were given full responsibility for waste management. Unless it was explicitly stated in the law that someone else had responsibility, it was the responsibility of municipalities. They could allocate waste produced within their jurisdiction and charge fees for its treatment" (Interview 15).
Social networks	• "One thing that has changed in the last couple of years is that a lot of big consumer brands have really announced targets for how much recycled material they want to have. Chemical recycling is very attractive to them because this is	• "We [municipal waste companies] are co-financing a project with the Environmental Protection Agency looking into various aspects of chemical recycling" (Interview 26).

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Table A6 (*continued*)

	Emerging configuration (chemical recycling)	Established configuration (incineration)
	a brand of recycling that can deliver to food contact and medicine" (Interview 27). • "We are seeing very big companies investing and engaging in this industry on the promise of what we may be able to do even though no real operational results have been achieved" (Interview 25). Examples: In 2019, Quantafuel partnered with BASF (Newspaper article 22). • "We are experiencing a trend where national regulation is helping us, rather than being a hindrance. For instance, the decision to reduce the national incineration capacity. Before, incineration was the best way to get rid of plastic. But this new regulation means that a lot of actors are experiencing big problems with what to do with their plastic waste. And currently this problem can only be solved by one industry – ours" (Interview 25). • "The petrochemical industry is fighting to get access to the waste-to-oil material to improve their footprint. That's why we are seeing them getting involved in this" (Interview 24).	
Institutional work	• Defining: "Getting our processes and products certified is absolutely key for us. We need the certifications to prove both to our customers and to environmental agencies that we are actually recycling the material. This is something we spent a lot of time and money on getting (Interview 27).	• N/A

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