Transitioning toward sustainability: The emergence and transformation of business models in France's plastic packaging industry[1]

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Résumé :

Face à l'urgence environnementale de l'industrie plastique, des initiatives politiques, telles que la loi AGEC (2019), visent à promouvoir une économie circulaire afin de réduire ces impacts. Cet article met en lumière la manière dont la transition vers une économie circulaire, à travers des interactions dynamiques entre les niveaux micro (entreprises), méso (filière) et macro (politiques publiques), redéfinit la filière de l'emballage plastique en France. En mobilisant une approche théorique combinant la perspective multi-niveaux et l'approche systémique des business models (BMs), nous analysons comment ces derniers contribuent à la transition et sont façonnés par des dynamiques complexes. Notre étude qualitative, fondée sur des entretiens avec des acteurs de la filière et des intermédiaires de l'innovation, montre que certaines innovations de niche, parfois incompatibles avec le système sociotechnique actuel, créent des opportunités pour de nouveaux BM et transforment ceux des entreprises existantes. Toutefois, certains acteurs résistent au changement, contribuant ainsi à maintenir le statu quo. Cet article met en lumière la coévolution des différents niveaux impliqués dans la transition, ainsi que le rôle clé des innovations de niche dans l'industrie de l'emballage plastique.

Mots-clés : Business model – Innovation – Perspective multi-niveaux – Transition durable

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Transitioning toward sustainability: The emergence and transformation of business models in France's plastic packaging industry

1. INTRODUCTION

In 2022, humanity crossed the fifth of the nine planetary boundaries essential for maintaining a viable ecosystem—this boundary refers to chemical pollution and the introduction of novel entities into the biosphere (Persson et al., 2022). Among these pollutants, plastic has emerged as a major concern given its persistence in the environment and its widespread presence across ecosystems (European Parliament, 2020). To address the impacts of plastic pollution, governments and other groups have implemented measures at the global (United Nations Environment Programme), European (Single-Use Plastics Directive and Packaging and Packaging Waste Regulation [PPWR]) and national (e.g., France's anti-waste AGEC law for a circular economy in 2020, Germany's Packaging Act in 2019) levels. A common thread across these initiatives is the ambition to transition toward a circular economy paradigm. A sustainable transition, such as a shift toward a circular economy (Bertassini et al., 2021), requires more than just technological innovations; it also demands cultural, political, consumer, market, and infrastructure changes (Geels, 2019). It engages various social groups and affects multiple facets of society, including production, consumption, and usage. In this context, innovation plays a crucial role, as it can drive transformations across these various dimensions. According to Geels et al. (2018), following Schumpeter (1934), innovations are novelties that diverge from existing systems in one or more dimensions. This perspective encompasses both incremental and radical innovations.

Such a transition occurs at three levels influencing interactions (Kirchherr et al., 2017; Markard et al., 2012; Smith et al., 2010): micro (company), meso (value chain), and macro (country and public policies). Nevertheless, current research tends to focus only on one of these levels without exploring their interactions. A systemic approach,[2] however, is essential (Kirchherr et al., 2017). On the one hand, it would enhance management and inter-organizational strategies (Korhonnen, 2018); on the other hand, it would facilitate the societal changes required for the transition (Merli et al., 2018). Furthermore, such an approach would provide a framework for better coordinating the efforts of policymakers, practitioners, and researchers in implementing circular economy innovation strategies (Borrello et al., 2020).

Literature on sociotechnical transitions has often served as an analytical framework for studies investigating sustainable transitions from a systemic perspective (Geels, 2019; Köhler et al., 2019; Markard et al., 2012; Smith et al., 2005). However, while studies have explored the role of business models [BMs] in sociotechnical transitions (e.g., Bidmon and Knab, 2018; Bolton and Hannon, 2016; Tongur and Engwall, 2014; Wainstein and Bumpus, 2016), most do not provide a comprehensive framework linking innovation, BMs, and transition dynamics, or they focus on case studies in the energy or mobility sectors (Bidmon and Knab, 2018; Schaltegger et al., 2016). Moreover, scant research has examined how BMs interact and co-evolve in an industry undergoing transition, particularly in the context of the circular economy. Yet, as Schaltegger et al. (2016) emphasize, adopting a co-evolutionary perspective is crucial to understand the dynamic interactions among sustainability pioneers, incumbents, and the broader market transformation. Incorporating BMs into Geels's (2002) multi-level perspective, Bidmon and Knab (2018) explored their different roles in sustainable transitions, thereby expanding the scope of research by considering organizational innovations alongside the technological advancements typically emphasized in transition studies. Bidmon and Knab (2018) emphasized the need for further investigation into the co-evolutionary dynamics and

[2] A systemic approach to the circular economy involves fundamental changes occurring simultaneously at the micro, meso, and macro levels; it aims to highlight the holistic systemic change required for the implementation of the circular economy (Kirchherr et al., 2017).

interrelationships across the three levels of the MLP and called for empirical research to support and refine their conceptual integration.

To address this research gap and building on the work of Bidmon and Knab (2018), we examine the impact of interactions among the three levels—micro, meso, and macro—on the BMs in the plastic packaging sector, in which regulatory pressures and circular economy goals are driving significant changes. Our aim is to contribute to the existing literature by connecting research on BMs with that on sociotechnical transitions. To this end, our study draws on Geels's (2002, 2004, 2019) multi-level perspective to analyze BM dynamics in the plastic packaging sector in France. Our research question is as follows: How does the transition to a circular economy in France's plastic packaging industry affect its BMs?

We address this research question by combining the multi-level perspective (Geels, 2002, 2004, 2019) with the literature on BMs and their innovation in sustainability transitions (Geissdoerfer et al., 2018; Roussignol & Garreau, 2024). The multi-level perspective conceptualizes transitions as the result of dynamic interactions between niches (micro-level innovations), regimes (meso-level rules and practices), and the landscape (macro-level trends and pressures). This framework is particularly relevant for analyzing the non-linear, path-dependent, and multi-actor nature of systemic change. It highlights the role of niches as sources of radical innovation and the conditions under which these innovations can destabilize and eventually transform existing socio-technical regimes (Geels, 2019). While the multi-level perspective provides a robust framework to analyze interactions across levels, it often falls short in capturing the micro-level mechanisms through which individual actors — such as firms — adapt, stabilize, and scale innovations (Elzen and Wieczorek, 2005; Bidmon and Knab, 2018). Transition studies have traditionally focused more on the interactions between different actor groups than on the internal transformation processes within single groups of actors. To address this, we draw on the literature on BMs, which offers a unit of analysis that "allow[s] zooming in on organizations without losing the systemic perspective" (Bidmon & Knab, 2018, p.913). This approach enables us to capture the co-evolution of firms, industries and regulation, while also examining how value creation, delivery, and capture are reconfigured in the context of sustainability transitions (Boons & Lüdeke-Freund, 2013; Geissdoerfer et al., 2018).

The integration of the MLP and BM literature enables a comprehensive analysis of transition dynamics, encompassing both macro evolution and micro-organizational processes that underpin systemic change towards a circular economy. We address our research question through an exploratory qualitative study of the transformations in France's plastic packaging industry, in an effort to highlight key elements of the ongoing transition.

This article is structured as follows: Section 2 presents our theoretical framework that guides the analysis of our empirical data. Section 3 details the study's qualitative research methodology. Sections 4 and 5 present the results and discussion elements, respectively. Section 6 concludes with a summary of the study's key contributions.

2. THEORETICAL FRAMEWORK

2.1. THE MULTI-LEVEL PERSPECTIVE FOR THE TRANSITION TO A CIRCULAR ECONOMY

The literature on sociotechnical transition provides a pertinent analytical framework for examining the transition to a circular economy, as it expands the unit of analysis to sociotechnical systems (Markard et al., 2012). Today's environmental challenges, such as climate change and biodiversity loss, are systemic and complex issues that require profound transformations in several dimensions (technological, economic, social, and cultural) and cannot be resolved by technological innovations alone, especially in the long run (Savaget et al., 2019).

A sociotechnical system represents an interdependent functional whole that links the tangible and intangible elements needed to perform an essential societal function, such as transport, food, or communication (Geels, 2002, 2004; Geels et al. 2018; Geels and Schot, 2007; Rip and

Kemp, 1998). This system comprises multiple dimensions: technology, policies and regulations, industrial structure, cultural meanings, user practices, markets, and maintenance and distribution networks. These dimensions are reproduced and shaped by actors and social groups whose perceptions and actions are influenced by intangible elements, such as rules and institutions, that are encompassed within the concept of a sociotechnical regime (Geels et al. 2018; Genus and Coles, 2008). From Geels's (2002, 2004, 2019) multi-level perspective, various regimes (e.g. technological, political) represent the deep structure of the sociotechnical system (Geels, 2002, 2019; Genus and Coles, 2008; Smith et al., 2010). Thus, a sociotechnical system emerges from a complex network of dynamic interactions between these regimes. Its transition depends on the simultaneous transformation of multiple interconnected elements (Grin et al., 2010; Kemp, 1994; Markard et al., 2012). This process is inherently dynamic and complex, involving changes in both technological and social structures, which in turn drives the emergence of new services, products, organizations, and BMs (Elzen et al., 2004; Geels, 2019).

Geels's (2002, 2004, 2019) perspective contextualizes this sociotechnical transition by analyzing the dynamic interactions among three levels: niche, regime, and landscape. The sociotechnical niche is a "protected space" that can take the form of specific markets, subsidized programs, or research laboratories (Geels et al., 2018; Kemp et al., 1998). In these "incubation rooms," niche players can test and develop so-called "niche" innovations, while reducing various uncertainties (techno-economic, cognitive, or social) and thus enabling innovations to gradually take shape (Geels et al., 2018). Niche innovations refer to technological novelties that differ on one or more dimensions from existing systems (Geels et al., 2018; Kemp et al., 1998). To promote large-scale adoption of these innovations, niche actors must overcome various cognitive, institutional, and economic challenges to reinforce the social legitimacy of the innovation, convince other actors of the dominant system, and facilitate the diffusion of innovation beyond the limits of the niche (Kemp,1994; Smith et al., 2010). Thus, while sociotechnical regimes (and, by extension, sociotechnical systems) are inherently stable, they can be disrupted by niche innovations. As these innovations mature and gain momentum, they have the potential to challenge the dominant existing regime and potentially initiate a sociotechnical transition—specifically, the emergence of a new regime in which they are fully integrated and have replaced or reconfigured components of the system. However, for these innovations to succeed in destabilizing the existing regime, a combination of external pressures and internal tensions must weaken the established system (Geels et al., 2016).

External pressures include those exerted by the landscape, which encompasses elements such as "material environments, shared cultural beliefs, symbols and values" (Geels, 2004, p. 913). These aspects of the macro-environment are not easily influenced by the actions of individuals, such as economic and health crises, climate change, wars, or oil shocks, which can exert pressure within the regime (Geels, 2019; Geels et al., 2017). These tensions can weaken the stability of the existing regime, making it more vulnerable to disruptions caused by niche innovations. Additional internal tensions within the regime, such as performance deficiencies, negative externalities, or conflicts in objectives and values, can also destabilize the regime and create opportunities for niche innovations to emerge (Berkhout et al., 2004). In this study, we focus on the interactions between the niche and sociotechnical system of the plastic packaging industry in France. However, given that the landscape also plays a key role in transitions, we present its influence within the framework of the multi-level perspective developed by Geels (2002, 2004, 2019).

2.2. The BM as an analytical tool for sociotechnical transitions: a systemic approach

In this section, we establish a link between BMs and the multi-level perspective. This perspective allows for a deeper understanding of the critical role of BMs in sociotechnical transitions.

The BM is a strategic tool that describes "how an organization creates, delivers, and captures value" (Osterwalder and Pigneur, 2010, p. 14). Relying on this definition, we distinguish three components of the BM: value creation, which describes both the specific value proposition and the way it is created; value delivery, or the way an offering is distributed to target customers; and value capture, which encompasses cost structure and revenue generation (financial viability).

To account for the growing complexity of socioeconomic and ecological systems, we propose adopting the systemic approach Roussignol and Garreau (2024) proposed, which envisages BM as a dynamic system in which components interact continuously and thus influence its evolution and value creation over time. This perspective redefines value as "the adequacy between the outcomes of the [BM] and its purpose" (Roussignol and Garreau, 2024, p. 7). The systemic approach also motivates us to examine both internal and external interdependencies. Internally, this involves analyzing how a firm's resources and capabilities are mobilized to achieve its strategic objectives. Externally, the focus shifts to interactions with the broader environment and various stakeholders—not only identifying who they are but also understanding how these relationships actively shape and transform the BM over time (Freudenreich et al., 2020; Roussignol and Garreau, 2024). From this perspective, BM is no longer conceived as a firm-centric artefact, but as a structure in constant interaction with a broader ecosystem, including suppliers, customers, partners, institutions, and regulatory frameworks (Fehrer et Wieland, 2021).

In the case of circular business models [CBM], adopting such a systemic approach highlights the need for close coordination among actors across value chains to enable the effective implementation of strategies aimed at closing, slowing, intensifying, dematerialising, or narrowing resource loops, which are essential to achieving a truly CBM (Bocken et al., 2016; Geissdoerfer et al., 2018). From this perspective, value creation is no longer the sole responsibility of a single firm but emerges dynamically through the ongoing resource integration practices of a broad and interconnected set of actors (Fehrer & Wieland, 2021). This systemic understanding reinforces the importance of multi-stakeholder collaboration as key enablers for the effective design and implementation of CBMs.

Achieving the implementation of circular strategies requires innovation within existing BMs to support their evolution toward circular configurations (Geissdoerfer et al., 2020). This innovation may take the form of designing entirely new BMs (Circular start-ups), diversifying into additional BMs, acquiring alternative BMs, or transforming existing ones (Geissdoerfer et al., 2018; Geissdoerfer et al., 2020). These BMs innovations do not occur in isolation but rather emerge from alignment processes operating across different system levels. As such, understanding the evolution and success of CBM innovations requires a multi-level analytical lens that captures the interdependencies shaping BMs.

Indeed, in the shift toward a circular economy, BMs are not only key enablers for the development and commercialization of sustainable niche innovations (Bidmon & Knab, 2018), but also essential vehicles for coordinating change across organizational and inter-organizational boundaries (Lewandowski, 2016; Susur & Engwall, 2023). This dual role of BMs as both innovation carriers and coordination mechanisms justifies our conceptualization of BMs as coordination devices between physical and social technologies (Beinhocker, 2006; Foxon, 2011).

According to Beinhocker (2006) and Foxon (2011), physical and social technologies co-evolve over time. Building on this perspective, BM can be understood as mechanisms that coordinate these two dimensions by structuring human, financial, and material resources by defining specific strategies for the production, distribution, and sale of products and services. Physical technology includes the material elements required to carry out an economic activity, while social technology encompasses the methods of organization and coordination put in place by the actors involved (Nelson, 2008; Nelson and Nelson, 2002).

The systemic approach to BMs, along with their role as tools for coordinating social and physical technology, reveals several points of convergence: an emphasis on value creation that extends beyond purely economic dimensions, the recognition of interactions and interdependencies, and a dynamic perspective of BMs that evolve through continuous interaction with their social and technological environments (Beinhocker, 2006; Nelson, 2008). Building on Beinhocker's (2006) conceptualization of physical and social technologies as co-evolving systems, we conceptualize BMs as a form of coordination between these two dimensions. This framework allows us to integrate BMs into the multi-level perspective to comprehend the French plastics industry's transition to a circular economy.

3. METHODOLOGY

We conducted an exploratory, multiple embedded case study to investigate transformations within the plastic packaging value chain, with a particular focus on those driven by regulatory changes aimed at fostering a circular economy (Yin, 2009). The case study approach enables an in-depth analysis of complex phenomena by interpreting data within the specific context of each case (Yin, 2013). The multiple embedded case study design, in particular, allows for the examination of several organizations within the plastic packaging value chain, while incorporating embedded units of analysis—such as specific processes, roles, or practices within each organization. This approach enables us to explore the interdependencies between actors and processes, while addressing broader questions related to sustainability and circularity in the plastic packaging sector. In addition, the exploratory approach is well suited for analyzing complex social contexts (Guba and Lincoln, 1994), such as the transition in the plastics industry, which involves multiple levels of intervention and diverse actors.

3.1. Case study description: the plastic packaging industry in France

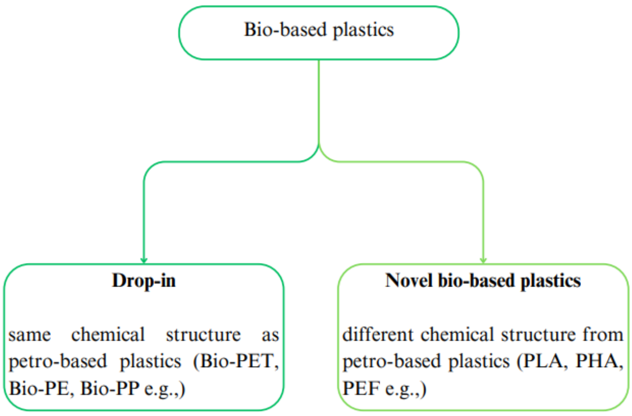
3.1.1. Context of destabilization in the plastic value chain

Political decision-makers have recently taken concrete steps to overcome the negative externalities associated with plastics and to promote a circular economy. Notably, the European and French regulatory frameworks for plastic waste management have undergone significant evolution, guiding the industry toward more sustainable practices. Key initiatives include the 2019 European Directive on Single-Use Plastics (EU Directive 2019/904), complemented at the national level by the AGEC law (Ministry of Ecological Transition, 2020), which enacts this directive into French law. Furthermore, the "Proposal for a Packaging and Packaging Waste Regulation" (EC, 2024), marks a new phase in regulatory action. This regulation's primary objectives focus on reducing, reusing, and recycling plastic packaging to minimize environmental impact.

Eco-organizations play a central role in aligning regulatory targets with the fast-moving consumer goods (FMCG) sector (Ministry of Ecological Transition, 2017). In pursuit of the goal to recycle 100% of plastics by 2030, an eco-organization has initiated a call for projects aimed at accelerating the development of chemical recycling (CITEO, 2023). This innovative process offers a solution for plastics that cannot be recycled through conventional mechanical methods, as is the case with most plastics, with the exception of transparent PET (polyethylene terephthalate) bottles (Polyvia, 2023). Chemical recycling allows for the production of high-quality recycled plastics, on par with virgin plastics, making them suitable for demanding applications such as food packaging. This marks a significant step forward in closing the recycling loop for many plastic packaging types that would otherwise be downcycled or disposed of in landfills. While enzymatic recycling falls under the same category, it stands out from the use of enzymes to break down polymers into their basic components. This innovative process offers the advantage of reduced energy consumption, positioning it as a more sustainable option. Currently, only one company in France is in the industrialization phase of a PET enzymatic recycling project.

Upstream of the value chain, technological advancements are creating a new dynamic with the development of bio-based plastics. These materials, which are partially or entirely derived from biomass, offer alternatives to meet environmental challenges (Spierling et al., 2018). Bio-based plastics have emerged during the last 30 years in response to environmental challenges and the depletion of petrochemical resources. They can be categorized into two main groups, as summarized in Fig. 1.

Figure 1. Plastics classification: drop-in and novel bio-based plastics (adapted from Spierling et al., 2018).



3.1.2. Key players in France's plastic packaging value chain

The production and life cycle of plastic packaging involves several distinct stages, each managed by specialized actors. Petrochemical companies extract and refine petroleum (naphtha) and formulate polymers (IEA, 2018; Plastics Europe, 2024), which are then transformed into plastic materials by plastics manufacturers (or petrochemical companies, in some cases). Fast-moving consumer goods companies (FMCGCs) are significant users of these plastic materials, primarily employing them for food packaging. Consequently, they are directly affected by evolving regulations, especially those related to extended producer responsibility

(EPR) (CITEO, 2024). Once plastic is used by consumers and placed in the recycling bin, its end-of-life process is divided into three key stages: collection, sorting, and recycling. Waste collection is managed by local authorities that delegate responsibility to private companies through tendering processes. These companies subsequently transport waste to sorting and recycling facilities operated by recyclers. The organization of this value chain is further supported by innovation intermediaries that facilitate innovation by establishing connections, coordinating actions, and sharing knowledge, thus driving systemic change (Hansen and Schmitt, 2021; Kivimaa et al., 2019).

The choice of France as a study ground is based on its dynamic regulatory framework, notably the AGEC law, which actively promotes the transition to a circular economy. This legislation reinforces EPR and extends the responsibilities of eco-organizations, creating an environment conducive to the analysis of interactions between niche innovations and industrial dynamics. In addition, the plastic packaging value chain in France is in a state of flux, with regulations still under development, providing an opportunity to assess transition processes in a context in which innovations have not yet been fully integrated or rejected by political decision-makers.

3.2. Data collection and analysis

For data collection, we applied specific selection criteria to each category of actor in the plastic packaging value chain. We first identified the various players in this sector and then adapted the selection criteria to each category. A common criterion for all firms was their presence in France, regardless of their activities in other locations. For petrochemical companies, we selected large units that primarily sell polymers for packaging. We also included companies specializing in bio-based polymers (i.e., innovative plastics manufacturers). For start-ups, we selected those at technology readiness level 7, meaning ready for large-scale production. The selection criterion for ("traditional") plastics manufacturers (and/or plastics converters) was their specialization in plastic packaging processing. The criterion for FMCGCs was that they needed to be multinational corporations, given their significant influence on the sector in terms of the circular economy and their accountability to EPR due to their high volume of packaging placed on the market. Recyclers needed to have a dedicated recycling stream for plastic food packaging. We interviewed a distributor that was not initially included in our list of players, as we had the opportunity to do so. We did not include any other distributors as they did not provide any relevant information and were content to act as intermediaries between petrochemical companies and the FMCGC. Finally, we selected innovation intermediaries by their presence in the industry, scope of their network, and impact on innovation and support for other players.

We conducted 38 semi-structured interviews in total between June 2023 and September 2024, including 26 interviews with companies in the sector and 12 with innovation intermediaries (see the Appendix; Table 1). Each semi-directed interview lasted from 20 to 153 minutes. The aim of this approach was to give interviewees some freedom in their responses, allowing us to gather additional information while maintaining a structure that was sufficiently framed to obtain data relevant to our research question (Saunders et al., 2009). The interview guides, though slightly adapted for each category of stakeholders according to their role in the value chain, fell along four main themes: (1) the company's BM and the innovative elements in its value proposition; (2) the impact of BM innovations on the value chain and, conversely, the influence of value chain innovations on BMs; (3) the effect of regulations on the BM and the value chain; and (4) collaboration and relationships within the value chain. To strengthen the validity of our study, we interviewed respondents from different functions and levels in companies, enabling data triangulation (Gibbert et al. 2008; Yin, 2009). We recorded the interviews with respondents' consent and transcribed and stored them in a secure database. For data analysis, we adopted an abductive approach, alternating between field data and literature (Gioia et al., 2013; Magnani and Gioia, 2023; Peirce, 1901). This method yields a greater richness of data than a strictly deductive or inductive approach, which is particularly relevant in exploratory processes. We coded our primary data with NVivo. First, we performed open coding based on the raw data collected to structure the information and compare it in a second step with the literature (Yin, 2017). Second, we grouped these codes into categories according to Gioia et al. (2013), which led to the emergence of aggregate dimensions. Table 2 (see appendix) presents our data structure, including the set of 1st-order terms, 2nd-order themes, and the resulting aggregate dimensions. Furthermore, we triangulated our primary data by incorporating secondary data related to the circular economy and the plastic packaging sector. These sources include reports from private research organizations (e.g., CITEO, Plastics Europe), public institutions (e.g., OECD), and foundations (e.g., Ellen MacArthur Foundation).

4. RESULTS

In the plastics industry, the evolution of the regulatory context (at the regime level) is creating opportunities for the emergence of niche innovations, such as bio-based plastics (novel and drop-in) and new recycling processes (chemical and enzymatic), with the objective of enhancing the industry's circularity. These transformations are fundamental to the innovation of BMs in the industry, resulting in modifications to existing BMs and the emergence of new ones.

Considering this, the first part of this section focuses on innovations. We highlight the two main categories of niche innovations that coexist—product innovation (bio-based plastics) and process innovation (recycling processes)—and analyze their degree of compatibility with the existing sociotechnical system. The diffusion of these niche innovations is characterized by tensions between them and the existing regime and its multiple dimensions (Geels, 2019). Consequently, the extent to which these innovations become embedded in the system depends on their interactions with the established regime dimensions.

The second part focuses on the BMs innovations in the plastic packaging industry that emerge from this transitional phase in the plastic sector. It highlights two distinct categories: emerging BMs, which are innovative approaches reshaping the industry, and transforming or diversifying BMs, which are evolving from traditional practices to more sustainable solutions.

4.1. Degree of compatibility between niche innovations and the industry's sociotechnical system

The sociotechnical system of the plastic value chain comprises tangible elements of the system reproduced by social groups and sociotechnical regimes (e.g., technological, political, cultural) (Geels, 2018; Genus and Coles, 2008). Though relatively distinct, these regimes are deeply interdependent; the rules and practices of one regime influence and interact with those of others, creating a relatively stable sociotechnical system (Geels, 2002; Genus and Coles, 2008).

Our results show that the industry's sociotechnical system is evolving with the emergence of niche innovations both upstream and downstream of the value chain. These innovations, whether new products or processes, are distinguished by their radicality, or the degree of disruption from the existing regime (Schot and Geels, 2008). Bio-based plastics (novel or drop-in) and advanced recycling processes (chemical or enzymatic) exemplify these dynamics, each exhibiting a variable degree of radicality. The more radical the innovation, the greater is the challenge of incorporating it into the sociotechnical system.

Novel bio-based plastics feature distinct chemical structures that set them apart from petro-based plastics, making them incompatible with the existing recycling infrastructure designed for petro-based materials. Consequently, integrating them into a circular economy necessitates the development of dedicated recycling channels. While some bio-based plastics are compostable, France currently lacks organized systems for the collection and industrial composting of biodegradable materials. Establishing these specific infrastructures is a significant challenge, particularly given that production volumes of novel bio-based plastics are still minimal compared with the overall plastics market, which limits the profitability of the required investments. According to Inter6, "*In theory, almost everything can be recycled, but in practice this depends on the investment resources required for the recycling process. As key players in the value chain, recyclers must be able to make their operations profitable*." The uncertainty surrounding investment in these materials is further compounded by the regulatory context, as public policies currently focus primarily on plastic recycling and the integration of recycled plastics into production processes.

Drop-in plastics, on the other hand, have the advantage of being easily integrated into the existing infrastructure because of their chemical structure, which is similar to that of petro-based plastics. Owing to this chemical similarity, drop-in plastics are recyclable and meet the current regulatory requirements for plastic waste management. However, despite these advantages, their competitiveness is still limited by their high production costs. To overcome this constraint, drop-in plastic producers have called for incentive policies to support the adoption of these materials. As Bio5 noted, "*I believe that this problem of low production capacity can be tackled on a legislative level by introducing tax incentives that support the bio-based plastics industry, while penalizing the oil and chemical industries*." Despite the greater compatibility of drop-in plastics with current infrastructure, both categories of innovative plastics face similar challenges.

In France, entering this market means overcoming several obstacles, including a poorly structured supply chain and high production costs. Compared with petro-based plastics, bio-based plastics are subject to higher raw material costs, particularly for bio-naphtha. As Petro5 explained: "*Today, we are dependent on the two bio-naphtha producers in Europe.... They control the prices..., and we have no bargaining power. However, in the future, if more players enter the market, there will be competition and more competitive prices*." These high costs, reflected in the final price of bio-based plastics, make them economically uncompetitive with

petro-based plastics. In addition, the environmental impact of transporting these materials over long distances creates a paradox. While bio-based plastics are often perceived as having a low carbon footprint, the long transportation distances of these materials raise a paradox. As Plast1 noted: "*Making bio-based bottles from sugarcane residues coming from Brazil.... The carbon footprint is dramatic ... but our clients don't care, because they only communicate on the fact that the bottle is made from bio-based materials, not on the overall environmental impact*."
Downstream in the plastic value chain, process innovations are being developed to complement traditional mechanical recycling by addressing plastic packaging that cannot be recycled through conventional methods. Whether chemical or enzymatic, these innovations are designed to complement rather than compete with mechanical recycling while preserving the industrial status quo. As a result, these processes present a promising solution for meeting the growing demands of regulations such as the PPWR, which aims to achieve 100% recycled packaging. As Recycl3a stated, "*There is no need to establish a different process or system or to modify waste collection. Our solution is compatible with the current system*." The integration of these processes into current operations involves fewer organizational constraints (than novel bio-based plastics) and helps meet the targets for incorporating recycled plastics into food packaging. This makes them a viable option, garnering both institutional support and endorsement from key stakeholders in the industry. As Inter1 noted, "*this technology reassures everyone: members, ministries, environmentalists, and academics. But for the time being, it's just marketing*." Some chemical recycling projects benefit from substantial funding. According to Inter1: "*There are chemical recycling projects that [an eco-organization] finances to the tune of millions, as does the French government*." However, despite their compatibility with the technological and infrastructural dimensions of the sociotechnical regime, recycling processes face significant economic challenges. The efficiency of these technologies can be low, leading to high production costs and making chemically recycled plastics less competitive

than virgin plastics. As Bio5 indicated: "*For PE and PP [polyethylene and polypropylene], pyrolysis has a limited yield, meaning that for every 100 tons of plastic collected, only 50 tons can be recovered*." Moreover, the economic viability of these processes relies on handling large volumes of material, which conflicts with one of the core principles of the circular economy: reducing waste at the source. As Inter6 explained, "*This process is only profitable if very large volumes are used. Clearly, the investments are substantial. To be profitable, you need a large quantity of materials to process*." Despite significant investment and the environmental challenges involved, industry players continue to implement chemical recycling, driven by the goal of incorporating recycled plastics into their packaging. However, these innovations risk merely perpetuating existing systems without fundamentally reducing their dependence on plastic. Table 3 highlights the degree of compatibility of niche innovations with various dimensions of the sociotechnical regime.

A clear distinction emerges between two major types of innovation: upstream bio-based plastics and new downstream recycling processes. Novel bio-based plastics show limited compatibility, leading to greater competition with the existing dominant regime and its dimensions. This creates an uncertain context for their large-scale diffusion, as their tensions are more significant than those of drop-ins, which, despite their lower economic competitiveness, manage to limit tensions with other regimes. Similarly, recycling processes align with the dimensions of the existing regime; however, the economic costs associated with these processes remain considerable. In this context, the potential diffusion of each of these innovations affects the regime in different ways. Their introduction into the regime shapes the BM innovation within the plastic value chain.

Table 3. Compatibility of the three innovations in the sector with sociotechnical schemes (adapted from Geels, 2002; Geels and Schot, 2007).[3]

Regimes	Product innovations		Process innovations[a] (Chemical and enzymatic recycling)
	Novel bio-based plastics	Drop-in	
Technological (dominant technological artefacts)	Not compatible with current processing and recycling technologies.	Compatible with the existing infrastructure.	Compatible with current technologies for petro-based plastics but require prior treatment.
Industrial structure (established companies and supply chains)	Semi-compatible: Difficult to source and to convert into plastic products. Limited production capacity and high production costs.	Compatible: No adjustment required to convert them. Limited production capacity and high production costs.	Compatible because they can be integrated downstream, enabling industry players to incorporate recycled plastics into food packaging.
User practices and markets (consumer behavior, preferences, and existing market structures)	Not compatible: Low adoption due to high costs and incompatibility with current practices.	Semi-compatible: Low adoption due to high costs but greater acceptance due to their compatibility with existing industrial structures.	Semi-compatible: High cost but high potential for recycled packaging.
Policies and regulations (laws reshaping the industry)	Not compatible with the plastics recycling regulations.	Compatible with current regulatory requirements.	Compatible with the requirements for the integration of recycled plastic in food packaging.
Scientific knowledge (research agendas on sustainable polymers)	Compatible with ongoing research into more sustainable plastics. However, circularity for some innovations may be questioned.		Compatible with ongoing research into more sustainable plastics. Advances are expected to improve the efficiency and yield of this process.
Cultural significance (plastic, a symbol of convenience but also of pollution)	Compatible with the demand for more sustainable plastics, due to their bio-based nature.		Compatible with the desire to close the loop but raise questions about their real energy sustainability.
Maintenance and distribution networks (automated production lines for packaging, logistics infrastructure)	Not compatible with certain existing infrastructures, need to adapt for collection and recycling and lack of volume to make processes profitable.	Compatible with existing recycling networks.	Compatible, but require a high volume of processed material to be profitable.

A co-evolution occurs between the diffusion of these innovations and the BMs within the plastic value chain. While some firms in the plastic packaging sector emerge with new BMs to commercialize niche innovations, others, as integral components of the sociotechnical regime, remain locked into rigid structures that hinder their transition.

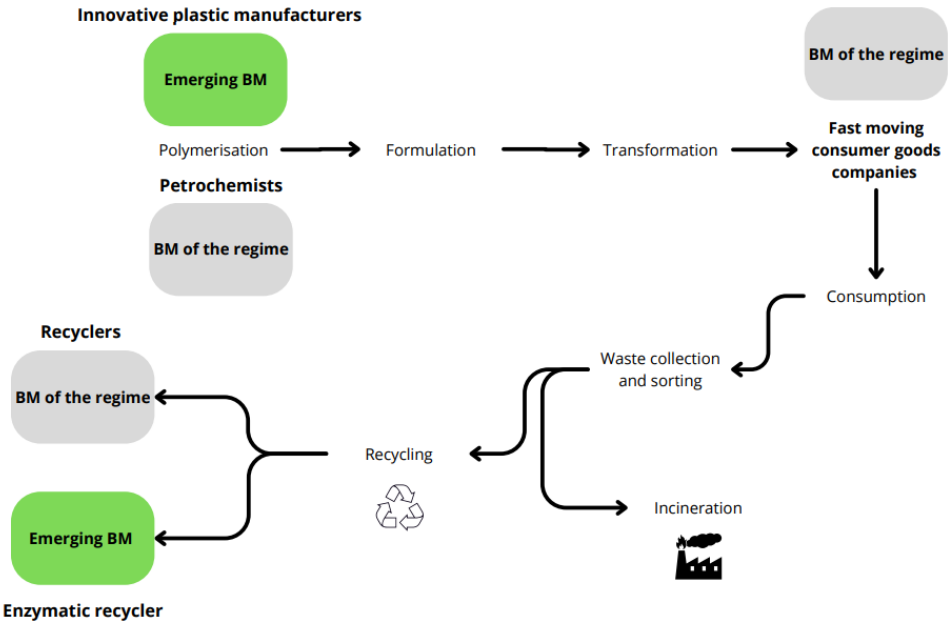
4.2. Impact of the transition on BMs in the plastic packaging industry

In this section, we analyze the implications of the sociotechnical system's instability, the emergence of innovations, and the interactions between the system and niche dynamics on the BMs of the plastics industry. This analysis provided two key findings. First, the industry's

[3] We grouped the new recycling processes (chemical and enzymatic) in the same column because of their similar compatibility with existing regimes, though they differ in their impact on pollution.

instability has fostered the development of entirely new BMs (emerging BMs), particularly those focused on bio-based plastics and enzymatic recycling. Second, companies operating within the regime (i.e., established BMs) primarily concentrate their efforts on transforming their existing BMs or on diversifying into additional BMs to adapt to these changes (see Fig. 2).

Figure 2. Emerging and regime BMs in the French plastic packaging value chain.



4.2.1. Emerging BMs: novel bio-based plastics and enzymatic recycling

Novel bio-based plastics and enzymatic recycling have emerged as innovations for plastics manufacturers and recyclers in poorly structured "niches," with no clear technical specifications, defined expectations, or regulatory framework (Geels and Schot, 2007; Hoogma et al., 2002; Kemp et al., 1998). We identify three key processes for the stabilization of viable niche innovations that are ready to be diffused within the sociotechnical system: (1) articulating visions and expectations of the innovation (Schot and Geels, 2008), (2) aligning learning processes to establish shared expectations and facilitate the emergence of a "dominant design," and (3) expanding actor networks to reinforce legitimacy and secure resources (Hoogma et al., 2002). Together, these processes stabilize innovations and facilitate the emergence of adapted BMs. Niche actors co-construct physical and social technologies, crafting BMs that enable the integration of innovations into the existing sociotechnical system.

First, in order to stabilize niche innovations and enable their diffusion, niche actors articulate expectations and align learning processes to support the development of an innovative value proposition. In the emerging bio-based plastics sector, the convergence of learning processes primarily occurs with two polymers: PLA (polylactic acid) and PHA (polyhydroxyalkanoates). However, the absence of a dominant design maintains a diversified product offering among the French plastics manufacturers (see Table 4). Conversely, enzymatic recyclers concentrate on a process adapted to a specific type of plastic, with research efforts directed to developing end-of-life solutions for alternative plastic types (notably PLA).

These emerging actors strategically target FMCGCs, the principal stakeholders in the industry whose decisions directly influence the selection of materials and technologies. This approach enables them to circumvent potential resistance from more hesitant participants (e.g., plastic converters, which are the direct consumers of innovative plastics manufacturers in the value chain). As Bio1 explained: "*Today, the most pertinent idea is to turn to our real interlocutors, the decision-makers [FMCGCs]*." FMCGCs view these solutions as powerful tools for enhancing their environmental image. Recycl3b, with an innovative enzymatic recycling process, shared this approach: "*The idea is to work with decision-makers, as they are the ones who choose their packaging and influence the practices of converters*." These collaborations help demonstrate the potential of innovations to more hesitant stakeholders while facilitating their gradual adoption within the industry.

In an industry increasingly scrutinized for greenwashing, the environmental credibility of innovations has become a critical criterion. As Bio1 noted: "*We emphasize CSR arguments, particularly regarding sourcing and the social aspects tied to product origins, to address* *growing consumer demand*." These practices not only address market expectations but also strengthen companies' credibility as pioneers in the circular economy. Moreover, substantial investments in R&D are driving process optimization, such as improving efficiency and reducing energy consumption in enzymatic recycling, enabling it to align more effectively with evolving market demands.

Table 4: Innovative value proposition for plastics manufacturers and enzymatic recyclers.

Plastics manufacturers	
Offer	- Association of biopolymers, biocomposites with fillers (recycled), plastics with fillers
Clients	- No fixed customer base or sector - FMCGCs and plastic converters aiming to reduce their carbon footprint by using bio-based plastics, primarily located in France - Companies focused on minimizing their environmental footprint
Basic strategy	- Formulation of low-impact, novel bio-based plastics designed to meet specific performance criteria - Commitment to the circular economy (life-cycle analysis, toxicity rate, and assessment of the circularity of materials)
Enzymatic recyclers	
Offer	Enzymatic recycling: - A physico-chemical treatment that alters polymer properties to facilitate enzyme access. This technology helps meet food contact criteria and can increase recycling efficiency by two–three times. PLA biodegradation technology using an enzyme: - Using enzymes, PLA packaging can be biodegraded in industrial composters at a faster rate, without producing particles
Clients	Enzymatic recycling: - Packaging converters (for PET) PLA biodegradation technology using an enzyme: - FMCGCs operating in PLA-friendly markets (e.g., the European Union).
Basic strategy	- Development of an innovative enzymatic recycling technology for PET - Achieving 100% biodegradation of PLA (using enzymes) without leaving microplastic

Second, consolidating actor networks and creating value are essential strategies for emerging BMs, as they help strengthen legitimacy and facilitate the integration of innovations within the industry. One of the main strategies for emerging BMs is to strengthen their networks by forging partnerships with various actors in the value chain (see Table 5). Recycl3b, for example, works with recyclers to demonstrate the effectiveness of the firm's technology and accelerate its integration into the industry: "*We work with [a recycler] to convince not only recyclers but also legislators. Convincing [a recycler] represents a significant step toward shifting mindsets and* *driving progress within the sector*." These partnerships strengthen the legitimacy of innovations, in terms of both feasibility and performance, while also providing broader support. As Bio1 explained: "*Decision-makers truly need guidance…. The idea is to offer a service, providing support in eco-design and life-cycle analysis*."

These partnerships facilitate engagement with public institutions, offering a dual opportunity: aligning BMs with regulatory requirements while influencing policy evolution to support innovation adoption. Strong public–private partnerships play a crucial role in this transition by facilitating access to funding, expertise, and policy support, thus reducing the financial and operational barriers to adoption (Ferasso et al., 2024). Moreover, such partnerships enhance access to joint projects that bring together a range of industry stakeholders. Bio3, for example, referred to the European Union's support for one of the company's projects: "*As part of [projectbio3], funds were allocated by the European Union to support our various activities. For example, out of a budget of €100,000, [Bio3] will receive 10% for the development part*." These collaborative initiatives, often supported by public funds, bring together universities, technical centers, and companies, encouraging fruitful exchanges between firms. This accelerates the development of innovations, while strengthening their legitimacy in the industry. As a result of these diverse practices, organizational and economic mechanisms are being put in place to integrate niche innovations into the industry, leading to the development of new BMs with innovative value propositions and value creation mechanisms.

Table 5: Value creation of emerging BMs (innovative plastics manufacturers and enzymatic recyclers).

Strategies	- Developing strategic partnerships with key players in the sector to maximize synergies and collaboration opportunities - Supporting their customers in facilitating the integration of innovations into their processes - Engaging with governmental institutions to ensure regulatory compliance and anticipate potential legislative changes
Creating value for the whole value chain	- Reducing dependence on non-renewable resources - Raising awareness of and educating the market on the benefits of bio-based plastics

	- Collaborating with customers to propose eco-designs, reducing the risk of greenwashing
Partners	For bio-based plastics and enzymatic recycling - The French state - Academic institutions - Consortium with major brands - Eco-organizations involved in the launch and implementation of new technologies Only for novel bio-based plastics - Partnering with large-scale converters to produce high volumes Only for enzymatic recycling - Collaborating with FMCGCs to develop novel PLA-based packaging solutions and increase their acceptance among converters and the wider industry. - Partnering with recycling facilities to validate their interest and demonstrate the full biodegradation of PLA through enzymatic processes (in industrial composting conditions).

However, beyond the emergence of entirely new BMs, some existing BMs diversify by adding new models specifically designed for the commercialization of niche innovations while others merely undergo transformation without integrating any such niche innovations.

4.2.2. The BM innovation of regime firms

Among the BM innovations observed, some incumbent companies are diversifying their BMs by incorporating niche innovations into existing regimes. Specifically, incumbent petrochemical companies and recyclers within the regime are integrating niche innovations—such as drop-in plastics and chemical recycling—into their existing operations. While these BMs remain largely aligned with the dominant regime logic, they nonetheless act as important drivers of change by supporting the diffusion and stabilization of emerging technologies within the sociotechnical system (Bidmon & Knab, 2018). These diversified BMs facilitate the stabilization and breakthrough of novel technologies by contributing to the three processes (previously outlined). According to Bidmon et Knab (2018), these BMs can be considered "intermediates between the niche and the socio-technical regime."

One of the key processes supporting the stabilization and breakthrough of niche innovations is the **articulation of visions and expectations.** This dynamic is reflected in our empirical data.

Traditionally, petrochemical companies have focused on producing naphtha-derived polymers. Today, these actors are diversifying their product offerings by incorporating bio-based raw materials, such as bio-naphtha, to produce drop-in plastics (see Table 6). According to Petro2: "*By purchasing bio-naphtha, sourced from non-food materials like paper pulp, animal fats and used oils, we replace petro-based naphtha and use it to manufacture bio-based plastics*." This new value proposition allows the company to enhance the environmental sustainability of its product portfolio while preserving the existing system. This innovation aligns with the demands of FMCGCs, regulatory requirements, and the current infrastructure. Through this diversification, incumbent petrochemical companies contribute to shaping shared expectations around drop-in plastics as a viable and scalable pathway to circularityµ. Petro 5: "*Bio-circular materials can be used for packaging, they cause any problem, because the principle is that you integrate renewable, bio-based products with fossil-based ones*". Their involvement facilitates collective sense-making and lends legitimacy to these innovations within the regime, thus reinforcing their stabilization. The idea that drop-in bio-based plastics represent a viable and easily integrated pathway to circularity is echoed in the discourse of certain key institutional actors. For instance, Inter 13 explains: "*Bio-based PET or PE [drop-in plastics] ? No problem, they recycle very well — we support them. PLA, PHA [new bio-based plastics] … that's more complicated. We follow the law, and right now, except for fruit and vegetable bags, composting is not allowed. We're not against biodegradability as a function, but it has to be recyclable.*" However, costs remain a significant barrier to the widespread adoption of drop-in plastics.

This novel offering is further complemented by chemically recycled plastics, enabling the production of monomers comparable to those of virgin plastics. The approach is developed in collaboration with recyclers that manage the sorting, crushing, and washing of plastics upstream, while petrochemical companies handle the subsequent chemical transformation processes (see Tables 5 and 6). This collaborative configuration illustrates how diversified BMs contribute to building inter-organizational networks by linking technological innovation to other actors of the value chain. Eco-organizations, particularly Inter13 plays a central role in orchestrating this coordination. As noted by a Packaging and plastic recycling engineer (Recycl2(a)): *"[*Inter13] *decides how to allocate the different sorted waste streams and which recycling processes to prioritize—whether chemical recycling, pyrolysis, or others. They conduct studies to assess which options are the most environmentally and operationally effective. Based on these assessments, they issue calls for tenders, and companies compete to take over the streams and propose the most suitable recycling solutions."*

Table 6 : New value proposition of petrochemical companies and recyclers.

Petrochemical companies	
Traditional offering	- Production of polymers from naphtha
Innovative offering	- Bio-based raw materials (from bio-naphtha) - Drop-in plastics - Recycled plastics (chemical recycling via pyrolysis and mechanical recycling) - Mass balance (ensures that a specific proportion of recycled or bio-based materials is integrated into the production process, even if mixed with virgin raw materials)
Clients	- Plastics manufacturers and FMCGs
Recyclers	
Traditional offering	- Sale of mechanically recycled plastics (clear PET for bottle production, rigid PE, PP)
Innovative offering	- Chemical recycling in partnership with petrochemists
Clients	- FMCGCs and plastics manufacturers (in France)

Furthermore, these BMs act as mechanisms for inter-organizational learning, supporting the exchange of technical knowledge and user requirements across the value chain, which helps refine processes and improve performance over time. This dynamic is illustrated by Petro5, who described the iterative process leading to the development of a pilot plant: *"In 2019, we developed the process in the lab. Then, we had to convince partners to move forward. Today, we are in the phase of building the pilot plant with one of them"*

The integration of these advances addresses concerns about their carbon footprint. As Petro1 explained: "*The driver is a reduction in the carbon footprint. The entire industry requires products with a reduced environmental footprint, which drives the use of bio-based raw* *materials*." This new value proposition represents a significant strategic risk: chemical recycling, a technology that requires substantial capital investment. However, unlike emerging BMs, these firms are integrated into a robust network that aligns with this process innovation (see Table 7).

Table 7: New value creation by petrochemical and recycling companies within the regime.

Strategies	**<u>Petrochemical companies and recyclers</u>** Chemical recycling is presented as: - A complementary solution to mechanical recycling, not a replacement - An option for processing plastics that are difficult to recycle mechanically **<u>Petrochemical companies</u>** -Adapt their offerings to meet the current demands of the sector by producing drop-in plastics
Creating value in the value chain	Drop-in and chemical recycling are innovations in symbiosis with the regime: - These innovations follow and adapt to the dominant design of petro-based plastics, their production/end-of-life processes, and their consumption practices. - Chemical recycling reinforces the use of this dominant design, as it requires a large quantity of plastic to be recycled to be economically viable.
Partners	**<u>Petrochemical companies and recyclers for chemical recycling</u>** - Partnerships with eco-organizations that supply waste for chemical recycling and finance the construction of chemical recycling plants - Consortiums with FMCGCs to ensure commitments regarding the demand for chemically recycled plastic to support the industrial phase of production

Unlike other sectors in which technological transitions create a competence dilemma for incumbent firms (Christensen, 2006; Tongur and Engwall, 2014), the transformation of the plastic packaging industry is primarily driven by regulatory and organizational challenges rather than technological obsolescence. Both incumbents and new entrants must align their BMs with evolving regulations and circular economy principles. However, while this transition fosters innovation, it is not always driven by niche innovations; many actors instead focus on incorporating incremental innovations. Moreover, concerns about greenwashing emerge, as some firms may only appear to comply with regulations, without fundamentally altering their value creation and capture mechanisms.

Alongside the emergence of new BMs and the established companies that diversify their BM some regime actors adapt their BMs through incremental innovations that respond to regulatory pressures. FMCGCs are now required to remit eco-taxes to eco-organizations to finance the collection and recycling of the waste they generate. The enhancement of EPR through the AGEC law has prompted a reevaluation of their packaging strategies, in an effort to reduce these eco-taxes by modifying various aspects of their BM. We organize the key changes, as outlined in Table 8, into two columns—before and after the implementation of the AGEC law—for greater clarity.

FMCGCs are developing strategies to improve packaging circularity with the objective of complying with future PPWR standards. They allocate resources to recyclable packaging, incorporate increased quantities of recycled materials, and optimize their designs to minimize extraneous materials while maintaining product integrity. To establish structured recycling channels, they collaborate through inter-professional associations and form strategic partnerships with petrochemical companies to promote chemical recycling. However, these initiatives reinforce the existing paradigm of petro-based plastics without fundamentally challenging it. Critics also argue that the financial involvement of influential FMCGs in eco-organizations could reinforce their dominant practices, potentially sustaining the current, often linear, structure of the value chain without challenging it fundamentally. According to Plast3, "*Today, significant questions are emerging about the role of [an eco-organization], which is being asked to take on more and more responsibilities. It is becoming a key arbiter of choice rules, which are increasingly frustrating manufacturers.... [An eco-organization] listens to some of its members, but it is clear that not all of us are bottled water producers. Not all of us align with [one beverage company] or [another beverage company], and this sentiment is widely shared across the sector*."

Table 8 : Incremental changes in FMCGC BMs.[4]

[4] [a] Here, we focus solely on the transformations related to plastic food packaging.

Consequently, although these firms have transformed their BMs to comply with regulatory requirements, they nevertheless maintain the status quo of the existing system, and as such, industry practices are remaining largely unaltered. Some organizations are investigating

BM component	Before	After
Value proposition	- Practical, economical packaging - Mainly based on petro-based plastics	- Recyclable packaging incorporating recycled materials - Reduction of superfluous materials
Distribution channels	- Volume-driven standard supply chains	- Partnerships with eco-organizations for collection and recycling
Customer relations	- Simple transactional relationship	- Reinforced communication on environmental efforts - Raising consumer awareness of circularity
Key activities	- Standardized packaging production	- Design of recyclable packaging and integration of recycled materials - R&D to replace non-recyclable materials
Key resources	- Petro-based plastics	- Access to recycled plastics - R&D investment in recyclable alternatives - CSR department
Key partnerships	- Few collaborations upstream or downstream of the chain	- Petrochemical companies for chemical recycling - Inter-professions to structure the sector
Overall impact on value chain	- Little cross-sector collaboration	- Active collaboration to structure the industry and promote plastics recycling

alternatives, such as reuse, which could potentially deviate from the disposable model; however, two major challenges persist: the need to educate consumers and the logistical complexities involved in implementing these solutions.

In the plastic packaging sector, incumbents tend to align with the existing regime rather than disrupt it. Some firms integrate niche innovations, such as chemical recycling, into their operations in ways that complement current supply chains and regulatory frameworks. Others opt for incremental changes, improving recyclability or incorporating recycled plastic within established production models. This dynamic illustrates how incumbents navigate the transition by balancing adaptation with continuity, shaping an evolutionary rather than revolutionary shift toward circularity.

5. DISCUSSION

This article responds to the call by Bidmon and Knab (2018) for empirical research on the co-evolution of BMs and multi-level dynamics by analyzing how interactions between niche innovations, regime actors, and regulatory pressures shape BM innovations in the plastic packaging sector. In doing so, it contributes to bridging BM literature and sociotechnical transition studies within the context of circular economy transition.

The progressive destabilization of the dominant regime—particularly under the pressure of new regulatory constraints—creates windows of opportunity for niche innovations to emerge within the system, aiming to address its internal tensions (Geels and Schot, 2007; Geels, 2019). Our findings reveal that these radical innovations, initially developed within niches, do not align equally with the established sociotechnical system. Drop-in plastics and chemical recycling processes follow a logic of symbiosis with regime dimensions: they can be integrated without requiring major transformations of infrastructures, practices, or user behaviors. They thus foster incremental transitions by preserving dominant structural logics (Geels and Schot, 2007). By contrast, novel bio-based plastics compete with several regime dimensions and their large-scale diffusion would require a profound structural readjustment, characteristic of a more radical transition—one that involves the realignment of technologies, institutional rules, and actor behaviours (Elzen and Wieczorek, 2005). These differences in alignment with the sociotechnical system have direct implications for the forms taken by the BMs associated with these innovations. Novel bio-based plastics emerge in BMs that act as "intermediaries" that facilitate their gradual integration by coordinating and articulating emerging innovation logics with established structures (Bidmon and Knab, 2018). Rather than adapting to the current regime, they propose a new business logic by reconfiguring value creation, delivery, and capture (Osterwalder & Pigneur, 2010). They structure their value proposition around low-environmental-impact bio-based materials, targeting -often environmentally committed-customers with whom they co-develop product uses and requirements. Value delivery involves specific channels and strong environmental messaging, while value capture relies on partnerships, engagement with public institutions, and the creation of environmental value beyond profit. This threefold transformation positions these models as "entirely new business models" in the sense of Geissdoerfer et al., (2016, 2018): rather than replicating existing logics, they invent new strategies capable of supporting innovation. Nevertheless, the lack of coordination with other regime actors currently limits the circularity of their BM. This misalignment with the rest of value chain prevents the creation of closed loops, a key condition for a truly circular BM (Bocken et al., 2016; Geissdoerfer et al., 2018). Without an organized system to manage the end-of-life of these plastics—such as collection, sorting, and recycling—these innovations remain outside circular loops, limiting their sustainability potential.

Conversely, if these BMs successfully align with those of the dominant regime—through logistical partnerships, shared standards, or aligned public policies—they could play a key role in the transition to a circular economy. This highlights that circularity is not an intrinsic property of a product or a BM, but rather the result of a coordinated ecosystem where value is co-produced through multiple interactions (Fehrer and Wieland, 2021).

The BMs associated with innovative recycling processes—enzymatic (with emerging BMs) and chemical (with regime BMs)—illustrate a different dynamic. In these cases, the innovation aligns with various dimensions of the regime, and value creation relies on close coordination between upstream and downstream actors in the value chain (FMCGs and recyclers for enzymatic recycling, petrochemicals and recyclers for chemical recycling). This coordination gives the physical technology (the recycling process) a social technology that enables the integration of these innovations within the value chain while ensuring compliance with regulatory requirements. This dynamic illustrates the conception of the BM as a coordination device between social and physical technologies (Beinhocker, 2006; Foxon, 2011). This also resonates with the systemic approach to BM, in which value emerges dynamically through practices of resource integration and stakeholder interaction (Roussignol and Garreau, 2024). In the case of enzymatic recycling, the value created derives not only from the technology itself, but from its ability to integrate into a sociotechnical system capable of supporting, diffusing, and collectively optimizing it.

The potential of a BM to drive a transition does not rely solely on its innovative character (Bidmon and Knab, 2018), but also on its capacity of coordination. In other words, a BM may offer a technologically circular solution, yet remain marginalized within the system if it fails to connect with other BM in the regime—particularly to organize end-of-life processes, establish adequate infrastructures, or reshape collective practices around a shared sustainability logic. We contend that the transition potential of a BM is as much about its coordination dynamics as it is about its novelty, thereby highlighting the need for a systemic perspective when assessing its transformative capacity in the context of a transition to a circular economy.

In this regard, BMs of the regime that have integrated niche innovations may present a transition potential, even if they are not entirely novel. These models largely remain aligned with the dominant regime logic and their diversification contributes to the transformation of the sociotechnical system by supporting the diffusion and stabilization of emerging technologies (Bolton and Hannon, 2016; Schaltegger et al., 2016; Bidmon and Knab, 2018). For instance, the incorporation of drop-in plastics or chemical recycling allows petrochemical firms and recyclers to retain their position within the regime while introducing innovations that appear to contribute to a more circular value chain. These incumbents respond strategically by integrating niche innovations that are in symbiosis with the existing regime, allowing them to absorb potentially disruptive developments (Hockerts and Wüstenhagen, 2010). However**,** such emerging technologies do not contribute to a radical transformation of the current sociotechnical system.

6. CONCLUSION

Drawing on a theoretical approach that combines the multi-level perspective and the systemic approach of BMs, this study demonstrates how BMs are both shaped by complex dynamics and actively contribute to the transition. We highlight how the shift toward a circular economy is reshaping existing BMs while also fostering the emergence of new ones within the plastic packaging value chain in France. These transformations illustrate the ability of incumbent actors to adapt and renew their BMs, whether through incremental innovations or niche innovations (Bidmon and Knab, 2018; Schaltegger et al., 2016; Rovanto and Bask, 2021). BMs play a coordinating role between niche innovations and the sociotechnical system. They serve as stabilizing mechanisms for some innovations, such as enzymatic recycling, which aligns with existing structures, while acting as disruptive agents for others, such as novel bio-based plastics, which demand profound transformations. Our findings demonstrate that the potential for transition of BM depends on its novelty and its integration into an expanded network of actors (value chain, institutions, and clients) to ensure the circularity of its innovation. In that sense, an incumbent BM that diversifies can drive a transition; however, as it remains closely tied to certain dimensions of the existing regime, the true extent of circularity achieved can be questioned. Additionally, a BM that creates value through interaction among stakeholders, rather than relying solely on a techno-centric approach, has a higher chance of engaging the entire value chain and achieving higher levels of circularity, as stakeholders are essential enablers in developing innovative solutions for sustainability (Freudenreich et al., 2020).

This research highlights the paradoxes of public policies supporting the circular economy transition in plastic packaging. While bio-based plastics are seen as sustainable, regulatory incentives remain limited. Conversely, chemical recycling, although promoted, raises sustainability concerns due to the large volumes required. Ultimately, these solutions offer only partial circularity, perpetuating a disposable consumption model and calling for more radical alternatives (Befort, 2021).

This study has two main limitations. First, it focuses on the plastic packaging value chain in France, limiting its broader applicability and overlooking innovations like reuse or non-plastic alternatives. Second, it examines niche and system interactions without considering the role of final consumers or innovation intermediaries. Future research could explore how intermediaries influence technological priorities, overcome institutional barriers, and support a more coherent transition (Kivimaa et al., 2019).

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APPENDIX

Pseudonym	Company	Size	Interviewee's Position	Date	Duration (min)
Petro1	Petrochemical	Large	Scientific director	18.01.2024	41
Petro2	Petrochemical	Large	Marketing manager	25.01.2024	49
Petro3	Petrochemical	Large	Head of scientific affairs and environmental policy	07.03.2024	31
Petro4	Petrochemical	Large	CEO	26.03.2024	45
Petro5	Petrochemical	Large	Key accounts manager	21.03.2024	55
Plast1	Plastics manufacturer	Small	CEO	26.05.2024	62
Plast2	Plastics manufacturer	Mid-sized	Innovation and eco-design project manager	16.10.2023 10.11.2023	41 82
Plast3	Plastics manufacturer	Large	Sustainable development manager	07.02.2024	41
Plast4	Plastics manufacturer	Large	Project manager	11.03.2024	35
Plast5	Plastics manufacturer	Large	HSE coordinator CSR coordinator	21.03.2024	52
Distri1	Distributor	Large	Sales director	4.10.2023	89
FMCG1	FMCG	Large	CSR project manager	02.02.2024	45
FMCG2	FMCG	Large	Packaging innovation manager	03.10.2024	50
FMCG3	FMCG	Large	Senior packaging specialist	22.03.2024	28
Recycl1(a)	Recycler	Large	R&D manager - plastics and composite materials and processes	24.10.2023	49
Recycl1(b)	Recycler	Large	R&D and eco-design manager - plastic recycling streams development	05.01.2024	47
Recycl2(a)	Recycler	Large	Packaging and plastic recycling engineer	10.05.2023	53
Recycl2(b)	Recycler	Large	Marketing manager	15.02.2024	32
Recycl3(a)	Recycler	Start-up	Research engineer	13.02.2024	21
Recycl3(b)	Recycler	Start-up	Innovation director	14.02.2024	50
Bio 1	Innovative plastics manufacturer	Start-up	Environment- CSR manager	08.06.2023	78
Bio 2	Innovative plastics manufacturer	Mid-sized	Market development manager	20.05.2023	47
Bio 3	Innovative plastics manufacturer	Small	Sales - export manager	22.01.2024	58
Bio 4	Innovative plastics manufacturer	Mid-sized	Sales director	17.06.2024	44
Bio 5	Innovative plastics manufacturer	Large	Technical affairs manager	16.10.2024	33
Bio 6	Innovative plastics manufacturer	Mid-sized	Consultant - new product development	10.10.2024	61
Inter1	Innovation intermediary	Eco-organization	Technical director	09.02.2024	65
Inter2	Innovation intermediary	Competitiveness cluster	General director Operations director	29.01.2024	47
Inter3	Innovation intermediary	Association	Founder	18.03.2024	35
Inter4	Innovation intermediary	Professional organization	Project manager	28.03.2024	42
Inter5	Innovation intermediary	Professional organization	CSR manager	20.03.2024	35
Inter6	Innovation intermediary	Technical center	Deputy R&D director	09.10.2023	59
Inter7	Innovation intermediary	Public institution	Environmental engineer – circular economy	01.02.2024	35
Inter8	Innovation intermediary	Private non-profit organization	Materials engineer – plastic recycling	25.01.2024	43
Inter9	Innovation intermediary	Circular economy consultant	Consultant	28.09.2023	20
Inter10	Innovation intermediary	Plastic packaging circularity consultant	Consultant	26.03.2024	43
Inter11	Innovation intermediary	Research laboratory	Extended research production plan manager	02.02.2024	153
Inter12	Innovation intermediary	Family office	Environmental project manager	01.12.2023	29
Inter13	Innovation intermediary	Eco-organization	Director of Materials R&D	20.02.2025	52

Table 1: Company characteristics and profiles of interviewees

First-order terms	Second-order themes	Aggregate dimensions
Regulatory changes influencing practices within the sector and impacting the end-of-life management of plastic packaging	Transformation of formal (regulations) and informal (social pressure, citizen expectations) institutions within the sector	Destabilization of the sector's sociotechnical regime
Criticisms and failures of regulations in France		
Increasing societal pressure on practices within the sector		
Growing consideration of Life Cycle Assessment (LCA) and carbon footprint in the industry's decision-making	Deployment of incremental innovations to strengthen the circularity of plastic packaging	
Increasing integration of recycled plastics to reduce dependence on fossil resources		
R&D investments to develop reuse and circularity solutions		
Plastics that disrupt recycling streams	Niche innovations that disrupt the functioning of the value chain	Niche innovations in symbiosis or competition with the socio-technical regime
The conditional entry of bio-based biodegradable plastics: when usage makes sense		
The challenges of circularity and recycling for bio-based plastics: volume, collection, and regulation		
Economic and technical barriers and a lack of alignment with the industry's recycling priorities		
Bio-based plastics designed to replicate the properties of fossil-based plastics while being recyclable	Drop-in plastics: niche innovations that preserve existing practices while addressing environmental concerns	
A niche market and a weakly incentivizing regulatory framework		
High-cost plastics as a barrier to adoption in low value-added markets		
Environmental incentives and marketing strategies driving the adoption of drop-in plastics		
An innovative technological process driven by petrochemical companies and recyclers to capture new markets	Chemical recycling: niche innovations that preserve the status quo of the value chain	
Chemical recycling: between closed-loop ambitions and environmental costs		
Fragile profitability and a technology still in the industrialization phase		
Enzymatic recycling as a less energy-intensive process compared to other chemical recycling methods		
Multi-stakeholder partnerships to structure the value chain: between circular commitment and preservation of the status quo	Incumbent business models integrating incremental innovations embedded in the existing regime	Business model innovations: new, diversified, and transformed in response to the sociotechnical dynamics of the sector
Integration of recycled plastic driven by economic optimization and regulatory compliance		
Efforts toward circularity: R&D projects on reuse and refill, and creation of internal teams dedicated to CSR and packaging circularity		
Multi-stakeholder partnerships to structure the value chain: between circular commitment and preservation of the status quo		
An innovative technological process driven by petrochemicals and recyclers to capture new markets	Incumbent business models diversifying by integrating niche innovations	
New value proposition of drop-in plastics to reduce the carbon footprint of petrochemical companies		
Strategic partnerships within the value chain to secure R&D investments		
Anchoring innovation by supporting and engaging key decision-makers within the value chain	New business models emerging within the packaging value chain	
Building environmental credibility		
Strengthening networks through strategic partnerships		
Lack of coordination towards a dominant design		

Table 2 : Data structure