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Accelerating the Protein Transition

Transition Pathways for Plant Proteins in Hauts-de-France and the East Netherlands

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Abstract

The growing demand for proteins for human consumption worldwide makes significant contributions to environmental and health problems. This challenge drives innovation efforts globally to devise and promote plant-based alternatives to meat products. The Technological Innovation System (TIS) is a well-established approach to analyse the development and diffusion of sustainable technologies. Innovation studies also emphasise the role of the regional context to explain how certain firms develop a competitive advantage in a globalised economy, and why innovations diffuse unevenly across regions. In this research, the innovation systems for plant proteins in two European regions with proclaimed ambitions to support the protein transition, namely the East Netherlands and the Hauts-de-France. To that effect, the TIS was complemented with regional context elements from the Regional Innovation System (RIS) theory was used. Findings identify key barriers for each innovation system, based on their development stage. In East Netherlands, innovation is undermined by the lack of common objectives and vision to develop plant proteins across the value chain, and by a lack of resources to increase production capabilities. In Hauts-de-France, the entrepreneurial activities and development of knowledge need to be stimulated, in particular in food technology. Common issues pertain to the fragmented value chain, specific knowledge gaps on novel sources of protein, and understanding how to better engage with consumers. Based on these findings, recommendations are drawn to overcome systemic barriers in East Netherlands and identify areas of collaboration with the Hauts-de-France to further accelerate the protein transition.

Keywords: plant protein, technological innovation system, regional innovation system.

Executive Summary

Balancing the protein mix in European diets has great potential to reduce the pressure of current food systems on the environment, human health and animal welfare. Plant proteins have a lesser impact on natural resources, and counteract the negative health impacts from the overconsumption of animal proteins. This protein transition is a global challenge that require broad socio-technological innovation. Furthermore, innovation studies suggest that the regional context also has a great influence on the trajectory and success of innovation. Therefore, this research explores the innovation systems for plant proteins in two European regions, namely East Netherland and Hauts-de-France, to assess their respective performance and contribution to the global protein transition. The Technological Innovation System (TIS) approach was utilised and complemented with regional context structures, drawing for the Regional Innovation System (RIS) theory. A structural-functional assessment of the innovation systems was conducted by means of 27 semi-structured interviews with key stakeholders between February and June 2019. Findings reveal that both regions present distinct territory-specific strengths leading to a focus on different parts of the value chain; i.e. primary processing and production of protein ingredients in Hauts-de-France and production of consumer products in East Netherlands. Systemic weaknesses were also identified. The limited availability of diverse protein sources in sufficient quality and quantity, too few accessible food grade pilot facilities for entrepreneurs, along with scant in-depth consumer insights and poor institutional engagement to inform citizens are common issues across the two cases. In East Netherlands, the lack of clear and shared vision among actors to achieve sustainable production of plant proteins were also stressed. A less-developed entrepreneurship and weaker academic coordination were specific to the Hauts-de-France. Collaboration potential was identified between the two regions to overcome these problems, as those hinder the global diffusion of plant proteins. In lights of these findings, recommendations are provided to the Province of Gelderland to overcome systemic weaknesses within their region, and joint forces with the Hauts-de-France to further accelerate the protein transition.

Recommendations

As it reviews its circular economy policy, the province of Gelderland can outline clearer and commonly agreed objectives to support the development of plant proteins, in coherence with national and European goals.

First, it is an opportunity to reaffirm its ambitions to design truly circular food production systems. In the case of plant proteins, this necessitates collaborating within and outside the region to stimulate circular production of agricultural resources, utilisation of residue and co-

product streams, evaluation of the environmental performance of extraction and food production processes, among others.

By tapping into the agronomic and biotechnology expertise existing in the Food Valley ecosystem, as well as building on pilot projects with Agrifirm to stimulate local soy production, it can support initiatives for improving the quality and yields of pulses and other protein-rich crops in Netherlands and in Europe.

To overcome the resource bottleneck and encourage production scale-up, structural changes in the innovation system are required. This research identified the lack of a shared food grade technical pilot platform that can be used by the industry, collaboratively or independently, to facilitate passage to the industrialisation phase. The current project of setting up a field lab in the region could respond to this concern, providing it is planned as an independent structure that is financially accessible to small entrepreneurs, for instance through subsidies.

Another important aspect relates to the stimulation of the market and engagement with consumers. Despite a growing interest from consumers, behaviours are changing slowly and the consumption of animal proteins is not reducing significantly. Using public procurement, education campaigns, collaboration such as with local chefs and influencers, there is an opportunity to develop the market size for producers while raising awareness for consumers.

Finally, as The Protein Cluster grows in size, its role and services provided to its members is evolving and becomes more complex. The primary aim to establish the TPC was to leverage the applied knowledge, the experience and resources of entrepreneurs to stimulate further innovation and business growth. This is extremely beneficial and should remain as part of their core activities. As the adoption of plant protein is on the cusp of accelerating, the need to increase production capacity and improve the quality of products intensify. To that end, TPC should consider increasing transversal collaborations by strengthening outward linkages with knowledge institutes, universities, local incubators and large companies, with a focus on identified knowledge gaps (chiefly processes, protein functionality, diversification of protein sources, and in-depth consumer insights).

Although it is a competitive and strategic market, coordination can be sought with the Hauts-de-France on non-competitive issues to avoid doubling efforts. The next European funding programs for the period 2021-2027 provide the perfect opportunity to set up collaborative initiatives in areas such as:

- the mutualisation of expertise to develop crop breeding programs.

- combining complementary expertise on protein extraction and product formulation to improve transformation processes and protein functionality, organoleptic qualities and nutritional values.
- Develop fact-based independent communication tools to complement existing efforts from the industry and civil society.

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Abbreviations

B2B	Business to Business
BBI	Bio Based Industries
BPI	French public investment bank (Banque Publique d'Investissement)
CTCPA	Technical centre for the conservation of agriculture products (Centre Technique de la Conservation des Produits Agricoles)
IPR	Intellectual Property Rights
EU	European Union
GMO	Genetically Modified Organism
HDFID	Hauts-de-France Innovation Development
INRA	National Institute for Agronomic Research (Institut National de Recherche Agronomique)
IS	Innovation System
ISA Lille	Agriculture University of Lille (Institut Supérieur d'Agriculture de Lille)
Kg	Kilogramme
NIS	National Innovation System
NSL	Nutrition, Health and Longevity cluster (Nutrition Santé Longévité)
NWO	Dutch Research Council (Nederlandse Organisatie voor Wetenschappelijk Onderzoek)
PCC	Protein Competence Centre
PIA	Future Investment Program (Programme d'Investissement d'Avenir)
PNNS	National Program for Nutrition and Health (Programme National Nutrition Santé)
R&D	Research and Development
Rev3	3rd industrial revolution (Economic strategy of the Hauts-de-France)
RIS	Regional Innovation System
SBIR	Small Business Innovation Research
SFI	Sustainable Food Initiative
SIS	Sectoral Innovation System
SME	Small and Medium-sized Enterprises
TIFN	Top Institute Food & Nutrition
TIS	Technological Innovation System
TPC	The Protein Cluster
TU	Technical University
UTC	Technological University of Compiègne (Université Technologique de Compiègne)
WUR	Wageningen University and Research

1. Introduction

With a global population expected to reach 9.5 billion by 2050 (FAO, 2007), increasing demand for foodstuff is anticipated (Bastein, Roelofs, Rietveld, & Hoogendoorn, 2013; FAO, 2007; Godfray et al., 2010). To keep apace, it is estimated that agricultural and food production should increase by two third by 2050 (Toop et al., 2017). Modern agriculture has already alarming negative impacts on the environment, disrupting the global nitrogen and phosphorous natural cycles and contributing to biodiversity loss, soil degradation, water pollution and climate change; generally operating beyond the carrying capacity of the Earth (Boer & Aiking, 2011; FAO, 2007; Rockström et al., 2009). The inefficiencies of the food system cost two trillion dollars per year globally when social and environmental costs are internalized (Jurgilevich et al., 2016). Trends relating to population and affluence will compound those challenges posed by and to unsustainable modes of production and consumption. The reliance of western diets on animal proteins, in particular, is seen as particularly detrimental and inefficient (Boer & Aiking, 2011; Godfray et al., 2010; Helms, 2006; ING, 2017). Ruminants are a major emitter of greenhouse gases, and the production of 1kg of meat requires 5-7kg of crops (FAO, 2007; Godfray et al., 2010; Voudouris et al., 2017). Additionally, in the period where the world population doubled from 3 to 6 billion, the consumption of meat increased fivefold (Boer & Aiking, 2011). Innovative production and consumption systems are therefore needed to sustain and increase food production, while preserving the natural resources upon which it relies, ultimately decoupling growth from environmental impacts (Bastein et al., 2013; FAO, 2007; Godfray et al., 2010). With demand projected to double by 2050, the supply of sustainable and nutritious proteins is, in this context, critical (Henchion et al., 2017; Westhoek et al., 2011).

Consequently, many authors argue that a different protein mix with a greater emphasis on plant sources can support more sustainable food systems (Boer & Aiking, 2011; Godfray et al., 2010; Helms, 2006). This study therefore intends to focus on the protein transition, which aims to rebalance the ratio between animal and plant protein in people's diets. Assessing the transition towards new sustainable technological systems is indubitably a complex endeavour as innovation depends on the co-development of new socio-technical configurations, market structures, actors and institutional settings (Markard & Truffer, 2008). Technological transitions have been a long-standing traditional field of research in the innovation system literature. The theory of *Technological Innovation Systems* (TIS) offers a well-defined framework to understand and assess diffusion of innovation and transition processes by analysing an innovation system's structure and its functions (Hekkert, Negro, Heimeriks, & Harmsen, 2011). The TIS has been

applied successfully to study processes of technological transitions (Hekkert & Negro, 2009). A common critique of TIS analyses, however, relates to the poor conceptualisation of the broader context, and in their narrow geographical focus (Binz, Truffer, & Coenen, 2014; Coenen, Benneworth, & Truffer, 2012). The wider *Context Structures,* conceptualised by Bergek et al. (2015), define four key interactions between a TIS and its surroundings, namely the technological, sectorial, geographical and political context factors. The geographical context structure specifically intends to respond to the shortcoming regarding the interactions between the TIS and spatial dynamics and gain a better understanding of uneven geographical landscapes in innovation and technological change. Concommitently, other strands of innovation studies have highlighted the significance of *Regional Innovation Systems* (RIS) in developing a competitive advantage in a globalized economy (Bjorn T Asheim, Lawton Smith, & Oughton, 2011; Bjørn T Asheim, Moodysson, & Tödtling, 2011; Cooke, 2002). However, whilst previous TIS analyses have attempted to reconcile the interplay of TIS and its national context, the impact of the regional scale has so far not been addressed and constitutes a gap in the innovation system literature (Bergek et al., 2015; Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007; Wieczorek, Hekkert, Coenen, & Harmsen, 2015).

This thesis empirically explores the influence of the regional dimensions on the development of a global TIS, by studying the structure and functional performance of two regionally delimited TIS for plant proteins, located in the East Netherlands and the Hauts-de-France. It is contented that a closer attention to the regional influences will help gain a better understanding of how and why a technological innovation is occurring at specific places, help compare their respective contributions to the broader protein transition, and identify possible relationships between these two sub-systems. Consequently, more refined policy recommendations can be drawn for future improvement. These two regions were selected as they both have explicit ambitions to become leaders in the development of plant-based proteins. In East Netherlands, the Provinces of Gelderland and Overijssel, have identified plant proteins as a strategic area for innovation as part of their circular economy strategy. They are key founding partners of The Protein Cluster (TPC) established in 2017. This cluster of SMEs aims to accelerate the transition towards sustainable plant proteins through the development of ingredients and products for the food industry (TPC, 2018). On the other hand, the region of Hauts-de-France, in the north of France, has also clear ambitions to develop plant proteins as a source of sustainable economic growth through its newly adopted bioeconomy masterplan (Région Hauts-de-France, 2018), making it an interesting case to study along with East Netherlands. By appraising both innovation systems, it is intended to identify opportunities to contribute to the acceleration of plant protein adoption. By applying a TIS framework supplemented with a regional contextual perspective, this research, therefore, aims to answer the following question:

What drivers and barriers facilitate or hinder the protein transition in East Netherlands and Hauts-de-France, and which lessons learned can help accelerate the transition?

From a societal perspective, this research aims to improve the understanding of how protein transition is progressing in a key economic sector in France and the Netherlands. This is important as new insights can have substantial implications for governments, food producers, their suppliers and consumers. The results of this research would therefore inform and support future policy directions for the Province of Gelderland on possible ways to accelerate the uptake of plant proteins as part of more sustainable food systems. From a scientific standpoint, this research would consolidate the limited number of studies that investigate how a TIS is coupled to other innovation systems in order to augment its explanatory power. By investigating these geographical influences, it intends to discriminate territory-specific strengths and barriers underlying the protein transitions in these areas, and consequently isolate individual success factors (Bergek et al., 2015). It constitutes a first step to remedy the frequent neglect of interrelated spatial scales in which cases of sustainability transitions are situated (Bergek et al., 2015; Binz et al., 2014; Coenen et al., 2012).

The remainder of this thesis is structured as follows. In Section 2, the theoretical embedding is delineated. Section 3 elaborates on the research design methods. The results of the structural and functional analysis are presented in Section 4, and discussed in light of the theoretical framework in Section 5. This paper ends with concluding remarks and recommendations for decision makers in Section 6.

2. Theoretical Framework

The theoretical framework is structured as follows. First, the delineation of various innovation systems are explained. The TIS approach, which intends to understand how innovation systems for a particular technology operate, is described. Next, a brief overview of the RIS theory is given, as a means to understand why certain innovation activities emerge in a particular region. Finally, the theoretical framework will draw on the Contextual Structures proposed by Bergek et al. (2015) to integrate key issues pertaining to the regional influences and multi-scalar dimensions.

2.1 Innovation Systems: Definitions and Delineation

An innovation system (IS) is defined as set of actors and rules that influence the speed and direction of technological change in a specific technological area (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008; Edquist & Lundvall, 1993; Hekkert et al., 2011). Innovation systems can be delineated at various levels, national, regional, sectoral or technological. Although the system boundaries differ, they share common features (Jacobsson & Bergek, 2011). First, a central tenet of all innovation system theories is that innovation and the diffusion of technology is a collective act that takes place simultaneously within individual firms and in their surrounding innovation systems (Hekkert et al., 2007). As a result, firms interact with each other as well as with organizations such as universities, research centres, government agencies, financial institutions and so on (Malerba, 2002). Second, the different innovation systems are interdependent. A technological IS is located within a broader context and will span across national, regional, and/or sectoral systems (Jacobsson & Bergek, 2011; Markard & Truffer, 2008).

National and regional innovation systems (respectively NIS and RIS) take geographical boundaries as a given and analyse the innovation actors and processes within that particular area – that is a country or a region (Breschi & Malerba, 1997; Cooke, Gomez Uranga, & Etxebarria, 1997). These theories do not focus on a particular technology, but on all the industries and supporting institutions within that geographical space, placing a particular emphasis on governments (Breschi & Malerba, 1997). *Sectoral innovation systems* (SIS) can be defined as groups of firms active in developing and making a sector's products and in generating and utilizing a sector's technologies; such a system of firms is related in processes of competition or collaboration. The study of SIS is mostly concerned about the competitive relationships among firms and the processes of competition and selection (Breschi & Malerba, 1997). *Technological innovation systems* (TIS) on the other hand, focus on the development of a specific technology or industry. Technological system was defined as 'a network of agents interacting in a specific

economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology' (Carlsson & Stankiewicz, 1991, p. 111). TIS can span across geographical and sectoral boundaries (Markard & Truffer, 2008).

The TIS has become a prevalent analytical approach to analyse the development and diffusion of sustainable technologies and their role into broader sustainability transitions (Wieczorek et al., 2015). As opposed to other lenses of analyses (national, regional, sectoral), which are more static in nature, a TIS analysis thrives to understand emerging technological fields within their dynamic environment. The aim is to create insights on the weaknesses of the innovation system and identify preferred ways to improve and steer the development and diffusion of the technology (Jacobsson & Bergek, 2011; Wieczorek et al., 2015). The protein transition, as a sustainability transition, requires both innovation and socio-institutional changes, that will span across countries, regions, and sectors (e.g. food industry, primary sector, retail), and innovation can impact all or part of the value chain. In terms of system delineation, the TIS is therefore well-suited to study this specific transition. However, a single focus on technology comes with a risk of overlooking the broader context within which a TIS emerges (Jacobsson & Bergek, 2011). A better understanding of the influence of other innovation systems on the emergence of a TIS has therefore been identified as an avenue for further research by Jacobsson & Bergek (2011). Additionnally, in the case of a comparative analysis between different innovation systems, the necessity to investigate the broader context will be accrued in order to identify local-specific drivers or bottlenecks.

The TIS will therefore provide the main focus of analysis for this study, and it will be complemented by characteristics specific to the RIS approach in order to take into account the possible regional differences in the development and diffusion of plant protein innovations. Indeed, the RIS has been a growing area of research, as local resources are seen as critical for firms to innovate and gain competitive advantage in a globalised economy (Bjørn T Asheim & Coenen, 2005; Bjørn T Asheim & Isaksen, 2002). Within this place-based prism for innovation, it is contented that the proximity of actors and institutions, interacting within clusters, facilitate the generation and exchange of knowledge and therefore accelerate innovation and responses to global challenges (Bjørn T Asheim & Isaksen, 2002; Malmberg & Maskell, 2002). To identify the regional-specific influences, a comparison of these two TIS will be performed, by taking into account their respective regional contextual structures. The delineation of the innovation system studied here is illustrated in Figure 1. The two technological systems in Hauts-de-France and East Netherlands (also part of a broader TIS for global protein transition) are delineated in TSa and TSb.

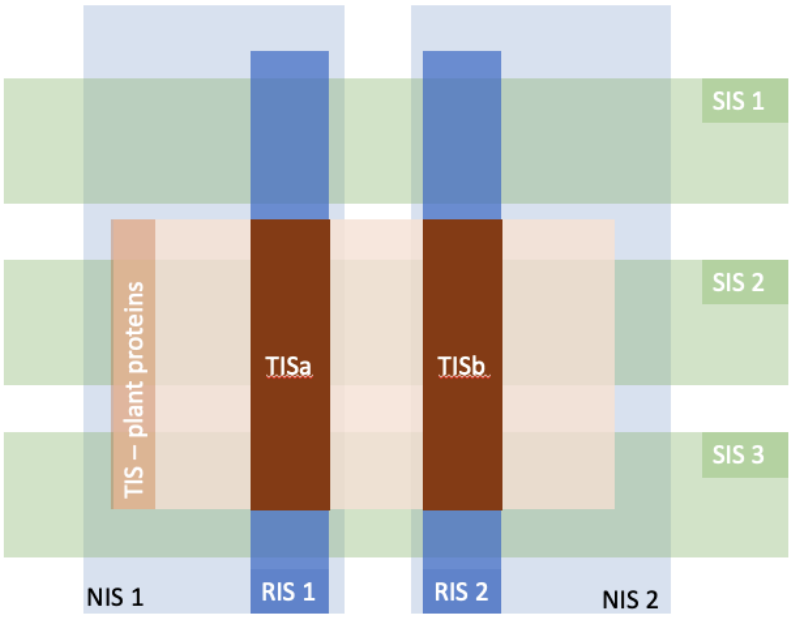


Figure 1. Technical Innovation Systems Delineation (adapted from Markard & Truffer, 2008)

2.2 Technological Innovation Systems (TIS)

TIS are socio-technical systems that are concerned with the development, diffusion and use of innovative technologies (Bergek et al., 2008). The TIS provides an analytical framework, which helps understand the complex structural configuration of an emergent innovation system, and the main processes and connections that lead to the emergence of new industries, with an emphasis on the potential barriers impeding their breakthrough (Bergek et al., 2015; Wieczorek et al., 2015). These barriers, also called system failures, occur to a great extent because of the intrinsic weaknesses of the system structure and inadequate development of activities, or functions, within the system (Hekkert et al., 2011). Mapping and evaluating these shortcomings can in turn assist in the development of tailored policy measures (Bergek et al., 2015; Musiolik, Markard, & Hekkert, 2012).

2.2.1 Structure of the TIS

The structure of a TIS consists of four key components. These structural components include the actors, networks, institutions and technology contributing to the development, diffusion and utilization of new products and processes as defined in Table 1 and illustrated in Figure 2 (Bergek et al., 2015, 2008; Hekkert et al., 2011).

Table 1. TIS Components (adapted from from Hekkert et al., 2011)

TIS Components	Definitions
Actors	They generate, diffuse and utilize technologies, such as knowledge institutes, educational organizations, industry, market actors, and government bodies and other supportive organizations. They all play a different role.
Institutions	Formal institutions consist of codified rules enforced by an authority (such as legislation), while informal institutions refer to more tacit codes and norms between actors.
Networks	The functioning of a TIS depends on the relations between actors. The network component refers to the interactions between actors, through formal or informal network and individual contacts.
Infrastructures	Infrastructures necessary to the development and diffusion of innovation comprise physical infrastructure (technology artefacts and infrastructures), knowledge infrastructure (knowledge, expertise, and know-how), and financial infrastructure (e.g. subsidies, investment, grants)

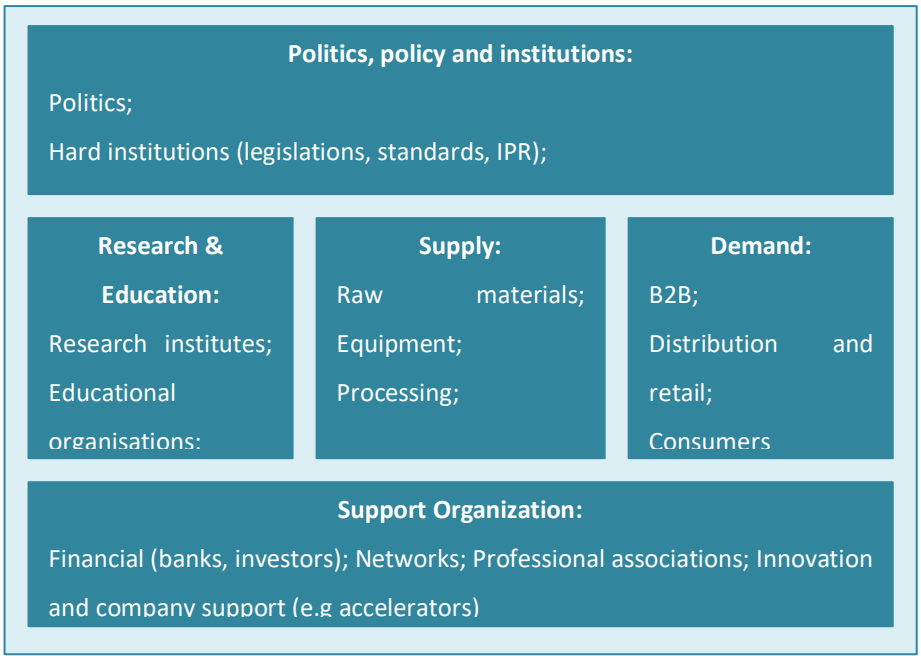


Figure 2. Structure of the TIS (adapted from from Hekkert et al., 2011)

Although different innovation systems exhibit similar components, they may perform differently (Bergek et al., 2008; Hekkert et al., 2011). Therefore, in order to evaluate how these TISs are performing, assessment criteria, or functions, are developed.

2.2.2 Functions of the TIS

Technological innovation is a dynamic process, which requires transformations in the innovation system (Hekkert et al., 2007). To understand these dynamics, it is necessary to have a deeper look at the activities that are executed by and between the actors and institutions in the

innovation system. These activities can be categorised into seven innovation functions, which have a direct impact on the development, diffusion and use of new technologies, and overall, on the performance of the TIS (Bergek et al., 2008). By mapping these functions over time, insights in the dynamics of innovation systems can be gained. These functions are defined in Table 2.

Table 2. Functions of a TIS (adapted from from Hekkert et al., 2011, Wieczorek et al., 2015)

Function	Definitions
Entrepreneurial Activity	Refers to the ability to exploit the potential of new knowledge, networks and markets into new business opportunities. Through exposure to market dynamics, entrepreneurs will learn about the products, processes and services developed.
Knowledge Development	The creation of new knowledge development is at the start of new innovations. It can be generated through science-based research and through activities such as "learning by searching" and "learning by doing".
Knowledge Exchange	Besides generation of new knowledge, the diffusion of technological knowledge to potential entrepreneurs can be used to develop innovations.
Guidance of the Search	Refers to the activities that positively affect the visibility, vision and expectations that stakeholders can have around a new technology. It is necessary to identify and select the direction for technological development. This guidance can occur through expressed visions or expectations, strategies and policies by institutional and industry actors.
Market Formation	When innovations are brought to the market, their acceptation and adoption is still uncertain. The more disruptive the innovation is, the greater the need to form, or generate new markets, for instance through niche markets.
Resource Mobilisation	Refers to the allocation of resources needed to support the innovation, such as infrastructures, financial capital or human resources.
Creation of Legitimacy	Refers to the perceived resistance to set up a new and unfamiliar technology in the market and the actions taken to counteract or overcome resistance to change

The system functions provide insights on which activities and dynamics are present and whether those are sufficient to enable successful innovation (Hekkert et al., 2011). These functions are interrelated and influence each other, either positively or negatively, and this will ultimately influence the performance of the overall system (Hekkert et al., 2007; Negro, Hekkert, & Smits, 2007a). Although system functions can interact in multiple ways, specific patterns are observed which are dependent on the development stage of the technology and innovation system. This development follows five stages (Figure 3). In the first stage, the *pre-development* refers to the phase where first evidence of the new technology exists (e.g. prototype) with no market change. The *development phase* is characterised by initial commercial applications without subsidy. In the *take-off* phase, the technology is diffused on a larger extent. As the market grows further, the *acceleration* phase is reached, until market saturation occurs and the degree of diffusion stabilizes

during the *stabilization* phase (Hekkert et al., 2011). As a TIS matures, some system functions become more relevant than others, and this affects the structure and the interaction patterns between its functions over time (Markard & Truffer, 2008; Negro et al., 2007a). The analysis of these patterns is crucial to assess how well the innovation system is performing. Indeed, in order to move along the diffusion curve, the TIS needs to fulfil specific functions and interactions. If those functions or interaction patterns are not met, this leads to the emergence of failures which will hinder the development of the innovation system (Hekkert et al., 2011). For instance, when assessing innovation functions for the development and take-off phase, the specific functional patterns in Figure 4 are expected to appear. In the development phase, all seven functions are significant, with entrepreneurship and knowledge development being of paramount importance. In the take-off phase however, the interactions between functions shift with entrepreneurship and legitimacy becoming critical for successful diffusion.

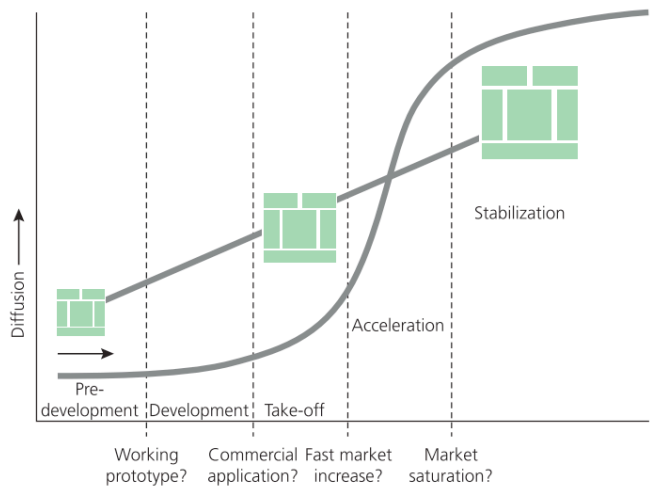


Figure 3. Phase of Development (Hekkert et al., 2011)

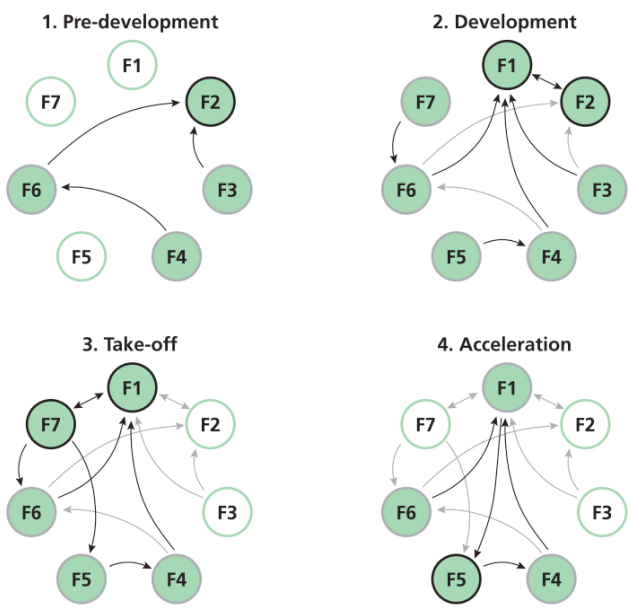


Figure 4. Expected Functional Patterns for the Diffusion Innovations (Hekkert et al., 2011)

2.2.3 Limitations of the TIS

The TIS focuses on the dynamics and context of a particular innovation. This approach, however, has been criticised as being 'myopic' and potentially unable to explain broader technological transitions (Bergek et al., 2015; Markard & Truffer, 2008). Indeed, the locus of analysis being on the system of innovation itself, its surrounding context is eluded. Consequently, external processes affecting the innovation may be missed, such as strategic interventions from incumbents or developments from competing innovation systems. Critics argue that TIS analyses have developed with an inadequate treatment of spatial dimensions, overlooking where these transitions occur and the spatial dynamics and the TIS' interconnectedness with other innovation systems (Coenen et al., 2012; Jacobsson & Bergek, 2011; Wieczorek et al., 2015). The pitfall that ensues, is that the comparability between cases is reduced. This is a critical omission as innovation literature has demonstrated the role played by place-based innovation systems, in particular regional innovation systems, to explain the competitive advantage that certain firms have developed to compete on the global stage. The next section will therefore shed light on the key features of regional innovation systems, and their significance for TIS studies.

2.3 Regional Innovation Systems

The RIS emphasises the importance of regions as key innovation drivers. According to this approach, regional innovation becomes a key factor to develop competitiveness in a globalizing knowledge economy, and it has therefore enthused several countries to introduce a regional dimension in their innovation policies (Bjorn T Asheim, Lawton Smith, & Oughton, 2011; Bjørn T Asheim, Moodysson, & Tödtling, 2011; Cooke, 2002). Regional systems are characterised by the geographical proximity between actors, which facilitate knowledge diffusion and interactions, and in turn lower transaction costs and stimulate innovations (Bjørn T Asheim, Boschma, et al., 2011). The European Union is an example where specific policies were developed to stimulate regional competitive advantages across EU member states, to support regional economic development in the face of globalisation (Bjørn T Asheim, Moodysson, et al., 2011). According to Cooke (2002), the RIS commonly exhibit five key interacting features. First, *agglomeration economies* relate to the local concentration of actors, which are deemed to lower the transaction costs for innovation thanks to economies of scale, localised skill-pools and information spill overs. Second, *institutional learning* reflects the capacity of organizations to acquire new knowledge, skills and capabilities and integrate them in their rules and routines (Cooke, 2001). Thirdly, *associative governance* results from the propensity of regional governance mechanisms to be more inclusive and interactive. Fourth, *proximity capital*, refers to relevant

forms of infrastructures for regional innovation, such as hard, soft, human or financial infrastructures. Typically, there is a convergence between the regional economic performance and previous investments in those infrastructures. Finally, *interactive innovation* reflects the opportunities for interaction between industry, government and universities (the so-called 'triple helix').

2.4 Context Structures

To overcome the lack of explicit attention to the dynamics of surrounding contexts, scholars have looked into to the relationship between TISs and contextual systems (Coenen et al., 2012; Gosens, Lu, & Coenen, 2015; Markard, Hekkert, & Jacobsson, 2015; Markard & Truffer, 2008; Suurs & Hekkert, 2009). Bergek et al. (2015) proposes a more nuanced TIS approach with the elaboration of complementary context structures that conceptualises the types of TIS-context interactions.

2.4.1 Typology of Context Structures

By design, the TIS is primarily a technology-centred framework. Building on the notion of regime and niche from Geels (2002b), and the interaction of a focal TIS with different innovation systems, Bergek et al. (2015) identify four key types of context structures -namely technological, sectorial, geographical and political. The *technological context* takes into consideration the different emerging technologies can complement or compete with each other. These interactions can occur vertically along the value chain of a TIS or horizontally across related TISs, for instance between TISs that utilize similar inputs. The *sectorial context* recognises that a TIS operates within a sector, which provides a stable context with mature technologies, a high degree of institutionalization and dominant norms and values such as user preferences (Geels, 2002a). An emerging TIS need to adapt to or challenge these dominant sectorial norms. Then, the *political system* and its dynamics will support or hinder large-scale transitions by shaping socio-institutional alignment. Finally, the TIS is embedded in a *geographical context* and in existing political, social and economic structures specific to the territory. These local actors, networks and institutions will influence innovation. As such, similar technologies related to plant proteins emerging in East Gelderland and Hauts-de-France may evolve very differently. The present study focusses on the impact of the geographical context, to identify how plant protein may develop and diffuse unevenly between the two regions under study.

2.4.2 Geographical Context Structures

In its traditional approach, a TIS analysis implicitly acknowledges that structural elements are embedded in an area, which is why TIS boundaries often coincide with territorial limits (Bergek et al., 2015). The TIS will then consider the geographical background to understand how a TIS

relates to resources or structures located in a specific territory. However, a more explicit and in-depth consideration of the geographical context needs to take into account the territory-specific institutional embeddedness and the linkages across different geographical scales (Truffer & Coenen, 2012; Wieczorek et al., 2015). First, a geographical territory will display distinctive organizational and institutional alignment processes and natural contexts, which have evolved over historical time periods (Bergek et al., 2015). The structure and functions of a TIS may therefore be structurally linked to these territory-specific institutions, culture, local actors and so on, which in turn will shape the technological trajectories in that specific local context (Bergek et al., 2015; Wirth, Markard, Truffer, & Rohracher, 2013). This research will therefore consider the intersect between the TIS and the regional innovation system (characterised by interactive innovation, institutional learning, agglomeration economy, associative governance and proximity capital) to identify the specific dynamics and synergies that justify the development of plant protein innovation in the regions under study.

The other source of complexity refers to the issue of multi-scalarity and the interactions across different geographical scales (regional, national, supranational) (Binz et al., 2014). Mapping all those interactions would be far too complex for the scope of this study, yet it is evident that some of the TIS structures and functions need to be analysed at a supra-regional scale. In particular, the activities of some actors, such as industry or knowledge actors, may have a broader national or international outreach. When identifying the institutional influences and the market development of plant proteins, a strict regional lens is also ill-fitted. Specifically, the influence of key European, national and regional policies will be investigated, while the consumer preferences and market development will be appraised at a national level.

2.5 Integration of the Regional Dimension in the TIS

The conceptual framework will integrate the geographical context considerations and RIS characteristics into an extended scope of the TIS structures and functions, as described in Table 3.

Table 3. Extended Scope of TIS Structures and Functions

TIS Structures and Functions	Geographical Scale	RIS Perspective
Actors	Regional/National/European/ Global	
Institutions	Regional/National/European	Includes broader regional innovation strategies that drives specialisation
Networks	Regional	
Infrastructures	Regional	
F1-Entrepreneurial Activities	Regional	Includes *Agglomeration economy*: to what extent the co-location of actors facilitates knowledge diffusion within the system. In the context of this study, the presence of knowledge or industrial hubs would be explored.
F2-Knowledge Development	Regional	Includes *Institutional learning:* do firms demonstrate a particular inclination to develop new knowledge and adapt, for instance demonstrating ambidexterity.
F3-Knowledge Exchange	Regional	Includes *interactive innovation:* to what extent the presence of clusters promotes cross-fertilisation and joint projects on plant proteins among industry, universities and governments.
F4-Guidance of the Search	Regional	Includes *Associative governance*: do regional administrations display a collaborative approach in their activities.
F5-Market Formation	National	
F6-Resource Mobilisation	Regional	Includes *Proximity capital*: Are there regional-specific resources that are mobilised to innovate on plant proteins.
F7-Creation of Legitimacy	Regional/National	

3. Methodology

3.1 Research Design

The function of this study is primarily designing and aims at practical recommendations to accelerate the uptake of plant-based proteins. The main methods employed include a multiple-case study method, and the research steps are adapted from the methodology developed by Hekkert et al. (2011) and Bergek et al. (2008).

3.1.1 System Boundaries and Case Studies

3.1.1.1 Geographical Boundaries

This study focuses on two European innovation systems for plant proteins: the East Netherlands and the Hauts-de-France. Both regions have defined strategies that recognise plant proteins as a key priority for sustainable economic development. Additionally, the agri-food sector is a prominent economic sector for both regions. The region of the East Netherlands comprises the province of Gelderland and the province of Overijssel (Figure 5). Combined, they welcome a population of 3.2 million inhabitants over a surface 8,300 km^2 (CBS, 2019). Agri-food is also a strong economic sector in East Netherlands with over 2,600 related companies including several international agro-food companies. It is estimated that the agri-food sector in Gelderland alone provides over 79,000 jobs and is valued at €3.5 billion (Oost NL, n.d.; Province of Gelderland, n.d.). The Food Valley ecosystem in East Netherlands is seen as a leading agro-food centre for knowledge and innovation in agriculture, food and nutrition.

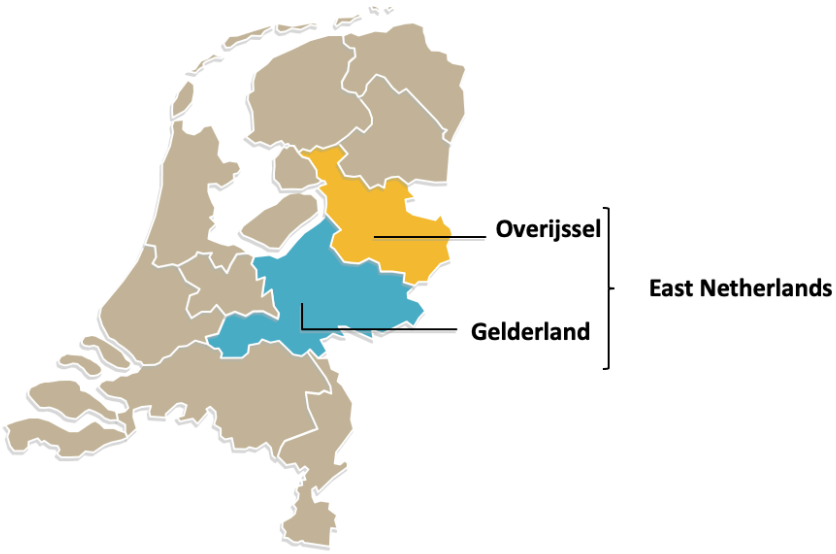


Figure 5. Map of East Netherlands

The Hauts-de-France is a newly formed region resulting from the merger in 2016 of the two previous regions of Nord-Pas-de-Calais and Picardie (Figure 6) (French Government, 2016). With 6 million inhabitants over 31,800km^2, this region has twice as many inhabitants and an area that is about four times as large compared to the East Netherlands (Insee, 2017). It is the first agricultural region of France (excluding viticulture) with over 2 million hectares of agricultural land devoted to crops such as wheat, barley, flax, potatoes, beets, rapeseed, fava beans and peas. With an annual turnover estimated at €10 billion and nearly 11% of the national employment of agri-food industries, the agri-food sector is a large contributor to the dynamism of the local economy and a vector of competitiveness, (Agroé, 2017; French Ministry of Agriculture and Food, 2018; Nord France Invest, 2019; Région Hauts-de-France, 2019).

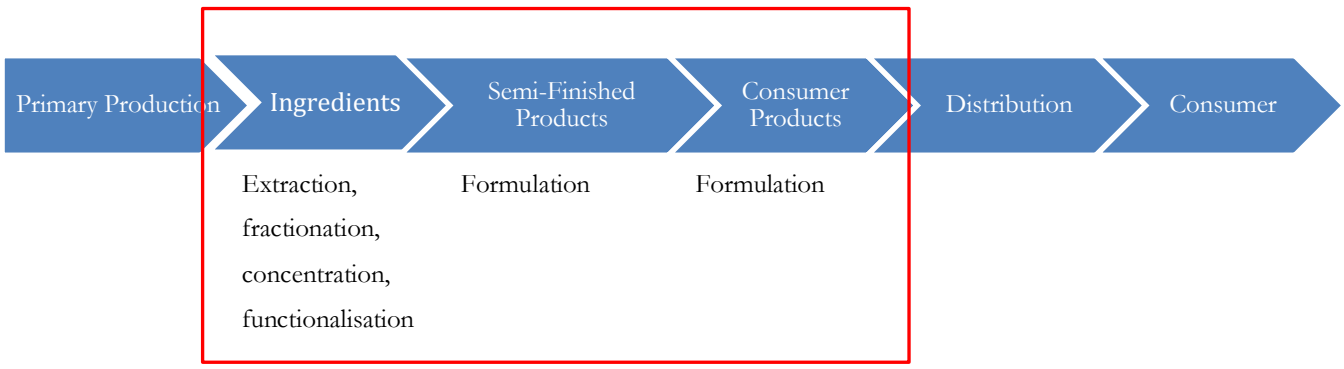
Figure 6. Map of the Hauts-de-France

3.1.1.2 Technological Boundaries

To achieve the protein transition and strike a sustainable balance between animal and plant proteins in people's diets, innovation is needed to provide plant-based alternatives to consumers. There is a wide range of plant sources that contain proteins suitable for human consumption, from soy, wheat, pulses, oilseeds, algae and other grains. Although most of the plant proteins worldwide are consumed directly, part of them are extracted and purified to be used as ingredients by the food industry. The latter is of great importance in order to augment the offer of plant-based products to the consumers, while overcoming some limitations that plant proteins have in terms of nutritional properties and digestibility (Chéreau et al., 2016; NIZO, n.d.). The formulation of products and ingredients from plant-based proteins requires different processing steps and technological factors. A simplified value chain is presented in Figure 7. In a first step, proteins are usually extracted from the crops through wet or dry fractioning methods (wet fractioning being most common). This results in concentrates or isolates ingredients with a high concentration of proteins and specific functionality (e.g.

emulsifying or gelling properties). Extrusion techniques can be applied to produce meat-like structures. These ingredients can then be utilized to develop semi-finished ingredients and consumer products. This system analysis will focus on the ingredient and food processing activities that develop plant-based alternatives to animal products. The primary sector is excluded from this analysis.

Figure 7. Plant Proteins Value Chain and TIS Focus



3.1.2 Research Steps

The research steps of this study are adapted from the methodology developed by Hekkert et al. (2011) and detailed in Table 4.

Table 4. Research Steps (adapted from Hekkert et al., 2011)

Step	Description
1. Structural Analysis	The components (actors, networks, institutions, infrastructures) were mapped for both innovation systems.
2. Phase of Development	The phase of development for each TIS was determined using diagnostic questions in interviews
3. Functional Analysis & Geographical Context Analysis	For each TIS, the seven extended functions were analysed to determine how they are fulfilled, how they perform and how they interact with each other. The key RIS characteristics conducive to a competitive advantage for plant protein innovation, were considered and embedded in the functional analysis by assessing regional-specific cultural and historical aspects that influence actors' decisions and institutional structures.
4. Identification of Barriers and Drivers	Key barriers and drivers inherent to each TIS, were identified. Similarities and differences between both innovation systems were compared.
5. Policy Instruments	Recommendations are drawn for the Province of Gelderland on regional improvements, and opportunities of collaboration with the Hauts-de-France.

3.2 Data Collection

The data collected for the Hauts-de-France case were based on primary data, using desktop research and interviews. For the East Netherlands case, primary data based on interviews from local actors was complemented by secondary data collected through previous research

conducted at Utrecht University.

3.2.1 Interviews and Sampling Strategy

Primary data were gathered by means of semi-structured interviews. Using semi-structured interviews gives minimal direction to the participants so that unanticipated drivers and barriers can emerge (Bryman, 2015). Among the interviewees were representatives of industries, clusters, regional governments, financial organisations, and knowledge institutes in the two studied regions. The interviewees were asked to assess the regional plant protein TIS. Interviews were conducted with 29 people representing 31 organisations between February and June 2019, either face-to-face or by phone, for a duration varying between 45 minutes to two hours depending on the availability of the respondents. An overview of the interviewees is presented in Table 5. For the East Netherlands case, only a fraction of actors was sampled. Companies were selected to represent the diversity of plant protein innovations, including the variety of products or protein sources they are working on, as well as their role in the value chain, either as ingredient manufacturers or producers of consumer-ready products. Insights from three other SMEs were included from previous research. For the Hauts-de-France case, initial interviewees were identified from existing contacts from the Province of Gelderland and the mapping of the TIS structure. Additional experts were then identified through snowballing sampling. Interviews were conducted either in English or French to minimize language barriers, and interviews were recorded upon explicit agreement of the person. Finally, one company demanded a confidentiality agreement.

The interview guide, presented in Appendix A, was designed to cover the seven TIS functions and the regional context, adapting the diagnostic questions from Bergek et al. (2008). Through these questions, interviewees were asked to identify the key barriers for the development and diffusion of innovation. Interviewees were asked to evaluate the performance of each function using a five-point likert scale from 1 (absent) to 5 (excellent). However, depending on their roles, some interviewees could not provide answers and scores to all systems functions. Finally, on one occasion, two experts were not asked to provide scores due to the short time available to conduct the interview. The interviews will be referenced in the results section based on the reference number in Table 5.

Table 5. List of Interviewees

No	Organisation Type	Title
CASE 1: EAST NETHERLANDS		
NL1	Regional Government	Project Leader
NL2	Regional Government	Project Leader
NL3	Support organisation	Manager
NL4	Support organisation	Managing Director
NL5	Support organisation	Director
NL6	Support organisation	Project Manager
NL7	Support organisation	Co-founder
NL8	SME	Founding Partner
NL9	SME	Founder
NL10	SME	R&D Manager
NL11	SME	Founder
NL12	SME	Founder
NL13	Large Company	Vice President
NL14	Partnership	Business Member
NL15	Partnership	Director
NL16	Research & Education	Program Manager
NL17	Research & Education	Division Manager
CASE 2: HAUTS-DE-FRANCE		
FR1	Regional Government	Project Leader
FR2	Regional Government	Project Leader
FR3	Regional Government	Project Leader
FR4	Research	Managing Director
FR5	Research	Project Manager
FR6	Support Organisation	Project Officer
FR7	Support organisation	Deputy Director
FR8	Support organisation	Project Officer
FR9	Support organisation	Project Manager
FR10	Partnership	Secretary
FR11	Start-up Incubator	Project Officer
FR12	Start-up Incubator	Manager
FR13	Start-up	Founder
FR14	Start-up	Partner
FR15	Start-up	Development Manager
FR16	Large Company	R&D Manager
FR17	SME	Commercial Director

3.2.2 Literature Review

Besides previous research on the Dutch plant protein innovation system, desktop research was performed to gather data specific to the French case. To map dynamic changes, data were collected by reviewing scientific and grey literature, newsletters and websites dedicated to the agro-food industry, using terms such as plant-based déli ('traiteur végétal' a popular and growing food segment for meat alternatives), flexitarian, vegan, vegetarian. The events captured were stored in a database and were allocated to a specific function, using the set of indicators in Table 6 (Negro, Hekkert, & Smits, 2007b). Using these indicators allowed to operationalise the functions and enable to reconstruct some of the key events in the Hauts-de-France innovation system.

3.3 Analysis

The analysis of data collected is done in accordance to the step-wise methodology described above. First, the structure of both TISs is analysed by identifying components that compose the systems. Second, the phase of development of the two TISs is determined using diagnostic questions. In the third and fourth steps, the analysis focus on how the system is functioning and on the influence of regional context factors using indicators in Table 6 and expert opinions. Each function and the interaction between functions is analysed. The score given by interviewees helped determined whether functions are underdeveloped relative to other functions. Then, the transcripts of the interviews were manually coded using a qualitative content analysis approach and following three coding steps (open, axial and selective coding) as defined by Corbin and Strauss (1990). The initial coding categories are based on the seven functions and context factors. In the fifth step, the findings from steps 1-4 are analysed to identify key drivers and barriers in both systems. Finally, recommendations for future policy and research development is drawn.

*Table 6. List of Indicators (in **bold**, are indicators relating to territory-specific influences)*

System Function	Indicators
F1. Entrepreneurial Activities	Numbers of projects that succeed or fail **Presence/absence of knowledge and industrial hubs**
F2. Knowledge Development	Number of patents and publications Investment in research **Presence/absence of learning organisations**
F3. Knowledge Diffusion	Presence or lack of networks Number of dedicated events **Presence / absence of active clusters**
F4. Guidance of the Search	Presence/absence of regulations Expressed expectations **Presence/absence of associative modes of governance**
F5. Market Formation	Presence/lack of favourable tax regimes Share of plant-based products in the market
F6. Resource Mobilisation	Presence /absence of infrastructure Presence / lack of human resources Presence / lack of financial resources **Presence/absence of region-specific capital**
F7. Creation of Legitimacy	Presence /absence of lobbying activities Presence/absence of media exposure Presence /absence of standards

3.4 Data Quality and Limitations of the Methods

The quality of a research can be measured against the criteria of measurement validity, internal and external validity, and reliability (Bryman, 2016). To ensure the validity in this research, triangulation was applied by cross-referencing data from multiple sources, including scientific literature, policy documents, and interviews (Golafshani, 2003). Consequently, the bias from the

researcher's subjectivity in the interpretation of data is reduced, and the confidence in the validity of the findings increases (Yin, 2009). External validity is concerns with the generalization of the results (Bryman, 2016). External validity is limited since the two cases were not randomly chosen, and they both present unique circumstances that explain the findings. Thus, the results are mostly representative of the two regions studied. Reliability concerns the repeatability and replicability of a research (Bryman, 2016). To ensure the reliability of this study, the research steps followed methodological steps developed and already tested by several studies. Interviews were recorded and transcribed to increase the traceability of the information collected and used. By being transparent on the theoretical framework and method of operationalisation, the reliability is also increased. Although the findings cannot be generalised, the theoretical and analytical framework can be used as a template for future research.

4. Results

4.1 The Protein Transition in East Netherlands

4.1.1 Structure of the TIS

The structure of the innovation systems aimed at the development of plant proteins are described in order to understand who is active in the system and what structures and technology support their activities. The system consists of four structural elements: institutions, actors, networks and infrastructures. The details of these elements are further elaborated below.

4.1.1.1 Actors

The East Netherlands harbours a wide array of actors, which play a role in innovating or supporting innovation around plant-based proteins (Appendix B). The actors subsequently described are located in this particular region; however, it must be noted that most of them have a broader sphere of influence. Conversely, actors outside the geographical scope of East Netherlands, such as consumers, national or supra national governments, lobbies and companies also have an influence on the developments occurring in this region. The list of actors in Appendix B does not intend to be exhaustive but rather highlight some of the most prominent regional players in this field.

Industrial actors

The **entrepreneurs** are the actors who experiment and bring change by innovating new ingredients, products and processes. The Protein Cluster alone comprises about 30 **SME** members (as of June 2019), most of them located in the East Netherlands. There are also several other SMEs located in the provinces of Gelderland and Overijssel. These companies devise new products and ingredients from a variety of protein-rich plant sources ranging from soy, peas, pulses, microalgae, quinoa, hemp, duckweed and so forth, predominantly meat analogues. There are also meat-processing SMEs such as Vivera and Zwanenberg Food Group, which are active in developing plant-based meat alternatives either to broaden their portfolio or with the aim to move out of the meat sector entirely. All **food majors** are now stepping into the plant-based meat alternatives and become key players in this sector. One of the most prominent actors in the East Netherlands is probably Unilever, which is relocating its R&D centre in Wageningen in late 2019, and has recently acquired the Dutch company De Vegetarische Slager. Kraft Heinz and Royal FrieslandCampina are two other major food companies with R&D centres in Gelderland, that are developing plant-based alternatives.

Research and Education

A second group of actors includes the applied and fundamental research and education. These actors help bring new knowledge and ideas needed for the development, dissemination and use of innovations. The universities and research institutes are engaged in the research and development of new technologies for extracting proteins and developing new applications and formulations. The leading academic institution in the region is **Wageningen University and Research**, including through its Food & Biobased Research team. The private contract research centres **NIZO** and **TOP** BV are service providers in food and process technologies, and are particularly active in plant proteins extraction and applications. The newly established **Green East Centre** complements the services provided by these actors, by providing pilot plant facilities for entrepreneurs and researchers on extraction processes. Furthermore, the **companies** themselves contribute to the development of applied knowledge for the development and scaling-up of plant-based ingredients and products and related production processes.

Policy Makers

Supporting the industry and research actors, regional policy makers with the **Province of Gelderland and the Province of Overijssel,** set normative frameworks as indicated previously, which provides direction to the innovations taking place.

Support Organizations

Finally, supporting organizations, such as investors and clusters, also facilitate innovation from entrepreneurs. First, **The Protein Cluster** has been established a couple of years ago to bring together ingredient suppliers, food manufacturers, and other actors seeking plant-based solutions to stimulate innovation business growth. TPC is hosted by the agrifood cluster **Foodvalley NL**. The **StartLife** incubator based at Wageningen University and Research provides a favourable environment for the emergence of start-ups developing plant-based protein ingredients and products. Finally, **Oost NL** is a key agency for regional economic development, supporting among others The Protein Cluster and the Green East Centre, as well as channelling investment.

4.1.1.2 Networks

There are a few formal networks and partnerships active in East Netherlands accelerating interactions of actors and innovation around plant-based proteins. One primary role of the Foodvalley NL and TPC clusters is to facilitate cooperation between their members. Besides, the **Protein Competence Centre**, hosted at WUR, is a public-private partnership for collaborative research into proteins bringing together academic institution and eight industry

partners (Friesland Campina, Nutricia, Darling, Cosun Dunyie, AVEBE, DSM, Foundry group and Agrifirm). However, due to challenges in its funding model, the partnership is currently in a fragile state, and it is yet uncertain if it will continue (NL16, Personal Communication 2019). The **Sustainable Food Initiative** is another public-private partnership with large corporates, academia, knowledge institutes and smaller companies, whose ambition is to drive innovation for sustainable food production. Yet again, WUR constitutes the physical hub for this network. One of the challenges on the SFI's agenda relates to the protein transition, more specifically to reduce the environmental impact of current manufacturing processes, develop new techniques, ingredients and products to ensure a broader adoption of plant-based proteins (NL1, NL14, Personal Communication, 2019). Innovation is intended to occur through collaboration, field labs and living labs settings. Finally, the other public-private partnership **TiFN** conducts a couple of projects on the nutritional properties of plant proteins. National networks active in promoting plant protein such as Green Protein Alliance are also influencing the regional innovation system through their lobbying activities (Jong et al., 2018). Finally, the mapping of actors and organisations show two strong network revolving around WUR and Foodvalley NL which act as centres of gravity for knowledge-based organisations and knowledge users respectively (Figure 8).

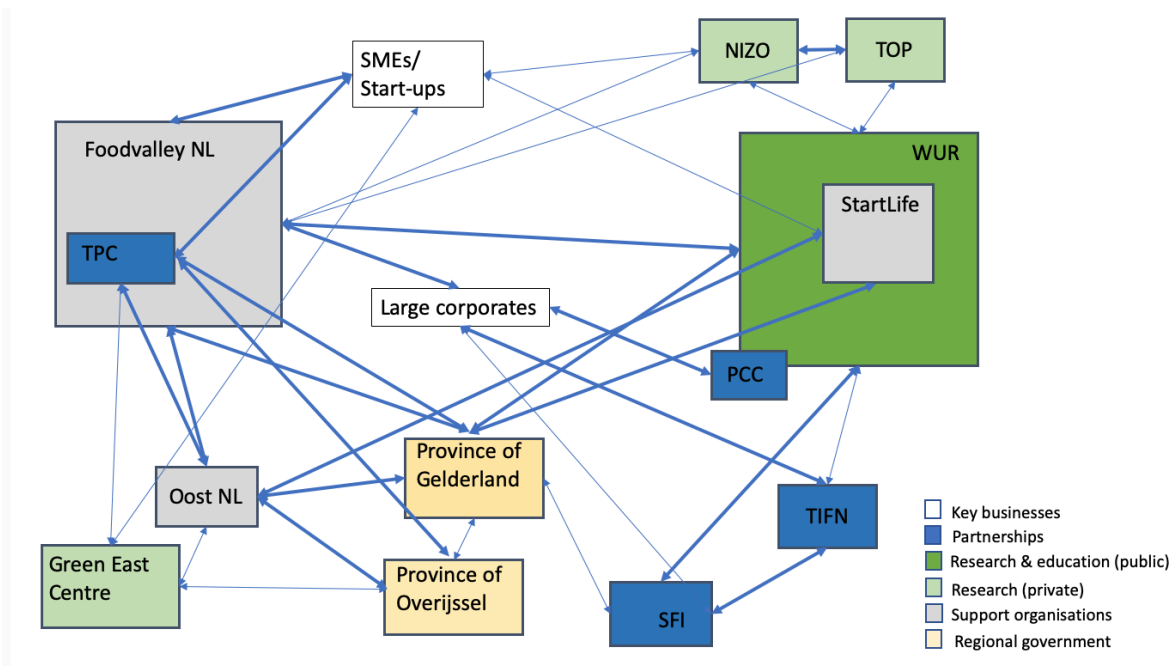


Figure 8. Simplified Relationship Network for plant Proteins in East Netherlands

4.1.1.3 Institutions

First, the regional smart specialisation strategy sets the overarching innovation context for East Netherlands. Next, various economic policies at European, national and regional levels are specifically directed towards the development of plant proteins. Finally, institutions relating to food safety also stimulate plant protein adoption and shape consumers norms and habits.

Regional Smart Specialisation

Both Provinces have developed a joint **smart specialisation strategy**, developed as part of the EU Cohesion Policy investment for 2014-2020, which defines common objectives to strengthen their regional economy (Staten provincie Gelderland en Overijssel, 2013). Smart specialisation is an approach promoted by the European Union to boost growth and jobs in Europe, by enabling each region to identify its own competitive advantages and develop long-term growth strategies supported by EU funds (European Commission, 2012). The smart specialisation for East Netherlands focusses on four key economic sectors, including agro & food, health, high tech systems and materials, and energy and environmental technology (including bio-based economy), and the cross-over between them. It emerges from this strategy that the East Netherlands has a long history of collaboration between entrepreneurs, knowledge institutions and governments, resulting in soft infrastructures for innovation that are strongly embedded within the region. The East Netherlands attracts several international companies and SMEs in these priorities sectors. It is also a leading knowledge centre due to the presence of several large knowledge institutions on technology, health and agro & food, including the University of Twente, Radboud University and the University Medical Center St. Radboud Nijmegen, WUR, and several technical universities of applied sciences. In addition, the region also has numerous intermediary organizations supporting innovation by companies. Those assets are key to defining regional innovation for a sustainable agro & food sector, with contributions to population health and well-being, food security and reducing the environmental impact of food production (Staten provincie Gelderland en Overijssel, 2013).

Economic Development

At European level, the **EU Protein Plan** released in 2018 aims at increasing plant protein production in premium feed and food sectors, and stimulating research and innovation on agronomic and environmental benefits (European Commission, 2018c). Additionally, one goal of the **EU Bioeconomy Strategy** relates to food and nutrition security, and the transition towards "sustainable, healthy, nutrition-sensitive, resource-efficient, resilient, circular and inclusive food and farming systems" (European Commission, 2018a, pp. 8–9).

The food and biomass sector is a priority area for the transition to a circular economy in the Netherlands, with specific objectives for protein transition (Ministry of Infrastructure and the Environment, 2016). Under the Dutch policy programme *A circular economy in the Netherlands by 2050* (Ministry of Infrastructure and the Environment, 2016), food and biomass is one of the five key priority area with a strategic goal revolving around the implementation of new modes of production and consumption. The subsequent ***Transitie Agenda Circulaire Economie - Biomassa & Voedsel*** (2018) sets to reverse the ratio between animal and vegetal proteins in people's diet from 60% animal - 40% plant-based today to 40% animal and 60% plant-based in 2050. Recent policy developments by the department of agriculture are also underway to implement the EU Protein Plan nationally (NL1, Personal communication, 2019).

At provincial level, the **regional economic policies of Gelderland and Overijssel** support many innovation activities taking place in their regions. In its strategy *Out with the Disposable Economy* the Province of Gelderland set the protein transition as a key objective to support efficient and sustainable use of raw materials (Provincie Gelderland, 2016). The *2016 – 2019 Agro & food implementation program* of Overijssel (Provincie Overijssel, 2016) aims at stimulating innovation towards healthy and sustainable food production from paddock to plate. Through these instruments, the provinces have, among others, supported the creation of The Protein Cluster.

Food and Safety

One key legislation, which impact the market development of some of the plant-based food alternatives is the European **Novel Food legislation** (Regulation (EU) 2015/2283), implemented in the Netherlands food and consumer product safety authority. A Novel Food is defined as food that had not been consumed to a significant degree by humans in the EU before 15 May 1997, when the legislation first came into force, as well as emerging technologies in food production processes (European Commission, 2018b). For those products, a pre-market authorisation is required to assess consumer safety (e.g. allergenic potential), labelling, and nutritional contents for products that intends to replace another food.

Dietary guidelines are communicated by the Netherlands Nutrition Centre (Stichting Voedingscentrum Nederland) through the Wheel of Five tool (Schijf van Vijf). These guidelines recommends less meat and more plant-based food such as pulses in their most recent edition (Netherlands Nutrition Centre, 2017b). Additionally, the Nutrition Centre provides information on the sustainability impact of the typical Dutch diet, which can help educate consumers and citizens (Netherlands Nutrition Centre, 2017a). In terms of products labelling, the European legislation has recently adopted a more restrictive approach to labelling plant-based products

(upon instigation from the French government), and terms like milk, yogurts, and steaks can no longer be applied to plant-based products (Limagrain Céréales Ingrédients, 2019).

Consumption and Norms

Besides hard rules, informal institutions such as traditions, norms and habits also play an important role. They determine the mutual relationships between individuals and within organizations. Dutch eating habits are deeply rooted in the national culture (with the typical vegetables, potatoes and meat menu). The consumption of animal consumption has risen dramatically after the second world war, primarily due to the increase in agriculture productivity and decrease in prices combined with European agricultural subsidies (Jong et al., 2018). Dutch people eat on average 77kg of meat per year (ABN AMRO, 2018). In the period 2010-2016, consumption per person has fallen by of 3%, but meat consumption rose again in 2016, as the economy improved. There has traditionally been 1-3% of the population being vegetarians and vegans, however, a growing proportion of consumers now described themselves as flexitarians, denoting an intention to reduce their consumption of meat (Jong et al., 2018). Meat has been at the centre of a social debate among environmental and animal welfare organizations, political parties, entrepreneurs and consumers, influencing consumer intentions. Recent survey shows that 37% of consumers eat less meat than five years ago and 34% of meat eaters think they will eat less meat in the next five years (ABN AMRO, 2018). The main drivers are health, animal welfare and the environment, but also a desire to diversify meals (ABN AMRO, 2018). However, although consumers are looking for healthier food and more plant-based products, convenience and price remain critical factors in consumer choice (NL4, NL10, NL13, Personal Communications, 2019).

4.1.1.4 Infrastructures

Technological Infrastructure

There are several technological facilities located in East Netherlands that can be used by entrepreneurs. The **Shared Research Facilities of WUR** provide access to analysis equipment for universities, research institute and companies. The joint **Centre of Excellence for Sustainable Food Processing from NIZO and TOP** is a food grade plant for innovation in research, development and production. In 2018, the **Green East Centre,** a pilot plant focusing on protein extraction, opened in Raalte. Entrepreneurs also support each other. In particular, the company **Bobeldijk** provides access to its production lines, as an experimental space, to other SMEs and start-ups which do not have access to a production facility.

Funding Infrastructure

Various financial sources support the development of research and innovation. For start-ups, investment can be provided by banks or investors. Usually, early R&D is funded through public investment, such as the Provinces **TopFonds Gelderland**, managed by Oost NL. Research is often subsidized via national funds such as the **NWO** as well as **European funds** (e.g. Interreg, POP 3, BBI). The **SBIR** (Small Business Innovation Research) instrument is another national funding mechanism that stimulate innovation (RVO, 2017). Additionally, **Invest-NL** has become operational in 2019, acting as the national public investment institution focusing on financing social transition challenges through investments in areas such as energy, sustainability, mobility and food and social areas such as care, safety and education. As such, it may become a relevant funding mechanism for future development in plant proteins (NL1, Personal Communication, 2019). **Private investors** are also active in funding business ventures. One example is CQ Green protein Fund BV, based in Wageningen, which has invested in the Dutch Duplaco. Banks with a focus on the market for meat substitutes include Triodos Bank, ING bank and Rabobank (Jong et al., 2018). Finally, in large companies, innovation is usually financed from the company's own cash flow.

Knowledge Infrastructure

The knowledge infrastructure is a distinctive feature of the East Netherlands. The Food Valley knowledge ecosystem is an internationally recognised knowledge centre that supports innovations in the field of agri-food and revolves around Wageningen University & Research and the knowledge providers described in the previous section. This provides a fertile ground for innovation activity around plant proteins.

4.1.2 Phase of Development

This TIS analysis focuses on the final products that the consumer buys. Depending on the raw material used and the technological innovations required for this specific source of protein, these products are in different stages of development. Different sources of plant proteins can be distinguished that are in a different development phase, as illustrated in Figure 9. Overall, the experts have identified that, although a lot of R&D is still needed to improve the diversity and quality of products on the market, the adoption of plant proteins is rapidly growing and reaching a tipping point (NL6, Personal Communication, 2019). The TIS has entered the take-off phase and gearing towards accelerating the production of plant-based products.

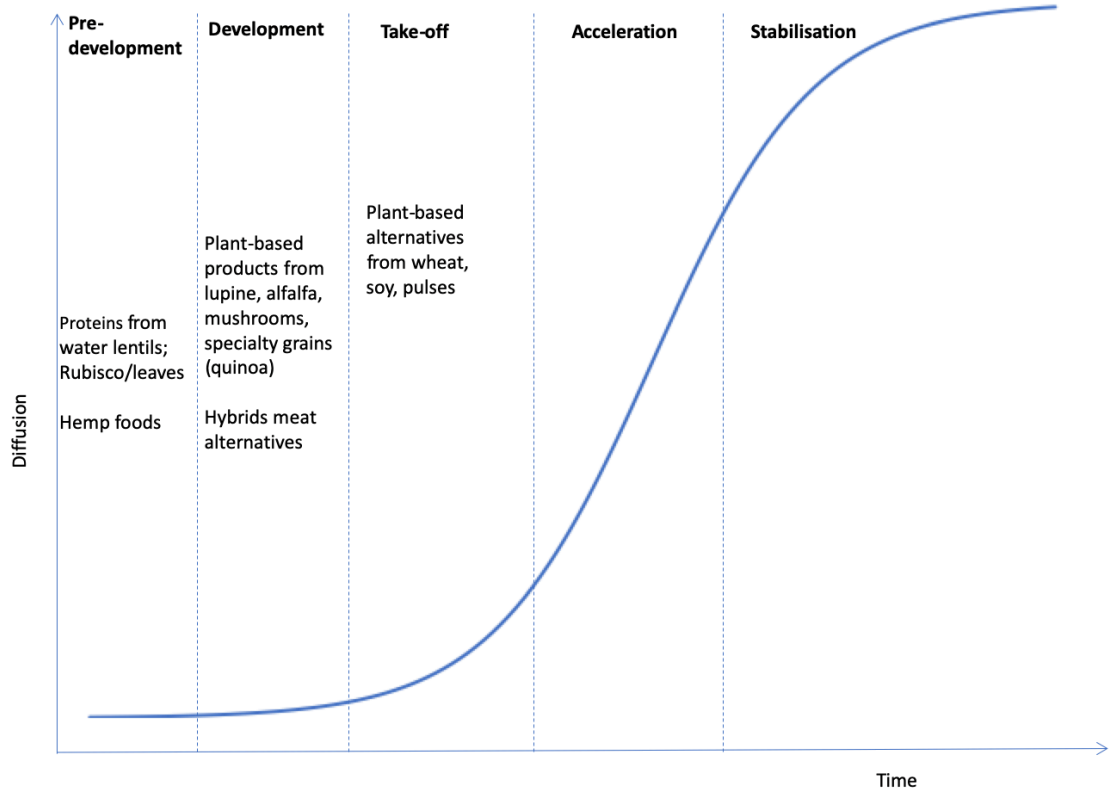


Figure 9. Phase of Development East Netherlands TIS

4.1.3 Functional Analysis

This section an in-depth overview is given on the performance of the system function according to the interviewed key stakeholders.

4.1.3.1 F1- Entrepreneurial Activities

Based on the findings of the structural analysis, it appears that the entrepreneurial activity in East Netherlands is primarily focused on developing consumer products (NL1, NL6, Personal Communication, 2019). Although some companies are developing hybrid products (e.g. MeatLess), most of the innovation projects revolve around 100% plant-based products. The Protein Cluster was founded in East Netherlands, due to the relatively dense entrepreneurial activity in this region. It aims at further stimulating interactive innovation by facilitating the exchange of knowledge, experiences and facilities (NL6, Personal Communication, 2019). Besides, the WUR incubator StartLife facilitates the emergence of new entrepreneurs and projects, such as Green Food 50 and Duplaco, which are also TPC members. Thus far, little connection between TPC and the student incubator StartHub has been observed, although the recent student challenge Rethink Proteins hosted by WUR in partnership with TPC may emulate new projects (NL6, NL16, Personal Communication, 2019). These SMEs and start-ups have historically been the pioneers in the development of plant-based alternatives. More recently, big food companies are stepping up through their internal R&D activities as well as through

partnerships and acquisitions. Besides the example of Unilever previously mentioned, Cosun has recently acquired Green Protein BV, a start-up that extracts rubisco proteins from leaves. To remain competitive and innovative, many SMEs are experimenting with novel protein sources, such as quinoa, colza, hemp or lupine which are not as widely used as soy and wheat (NL9, NL10, NL12, Personal Communications, 2019). For producers of ingredients and semi-finished products, the importance of demonstrating potential applications to customers or co-developing products with them, was raised (NL8, NL9, NL12, Personal Communications, 2019).

Key barriers for entrepreneurial activities are often rooted in other functions, including further improving collaboration (F3), difficulty to access resources (F6) including primary ingredients as well as research and production infrastructures. These issues will be elaborated in greater detail in subsequent sections. The regulation on Novel Food is also an obstacle for the commercial development of the most novel sources of proteins (NL8, NL11, Personal Communications, 2019). Moreover, as other regions are also developing their innovation and production capacity, it might get harder for East Netherlands to maintain a lead advantage and an attractive environment for entrepreneurs who want to expand their activities (NL9, Personal Communication, 2019).

> *"The challenge is that (…) it is more the initial phase activities that will be here, but when it really gets to big volumes it will move to other areas." (NL9, Personal Communication, 2019)*

4.1.3.2 F2 - Knowledge Development

The research and knowledge development are focused on protein extraction, functionality of ingredients, and the formulation of semi-finished products and consumer products. Across the universities, research institutes and industry actors, there is a common agreement that there is a vast amount of fundamental and applied knowledge, which is quite unique in Gelderland (NL1, NL2, NL6, NL17, Personal Communications, 2019). Besides knowledge specific to plant proteins, there is also great expertise and knowledge in dairy, meat and food technology in general which supports the formulation of plant-based alternatives. The presence of several public-private partnerships also indicates a predisposition from large firms to acquire new knowledge and adapt (NL14, NL 15, Personal Communications, 2019). Overall, the knowledge is deemed sufficient at this stage. However, some specific knowledge gaps were identified during the interviews to further improved current products and processes.

Better understanding of plant proteins is still needed to further improve their functionality (NL5, NL10, NL, 12, NL13, NL17, NL16, Personal Communications, 2019). While dairy, wheat and soy proteins have been the subject of research and development for over five decades, pea proteins have been studied for a couple of decades, and other sources for a lot less. Improving

the functionality of those ingredients is key to improve the quality and palatability of plant-based foods. Besides, and although the main goal is the promote a flexitarian rather than a fully vegetarian diet, there were still a lot of questions raised by interviewees around the nutritional values of plant-based options for some segments of the population especially children and elderly people (NL5, NL17, NL16 Personal Communications, 2019).

Knowledge on primary production is lacking, in particular to optimise the protein contents and yields of crops. Pulses production in the EU has been declining since the 70's and is mostly used as ground cover and fodder (NL1, NL2 Personal Communications, 2019). The Netherlands is too small to be self-sufficient and to date, it relies on exports within and outside the EU. Besides agronomic improvements of crops, there is also a need to demonstrate the market potential to farmers, to convince them to include those crops in their rotation patterns. This will be a critical step to strengthen the whole value chain and ensure that enough raw material is available for large-scale production.

All actors agree that plant-based foods are a long-term trend and not just a temporary fashion. However, in-depth understanding of consumer insights for different segments of the population is clearly lacking (NL7, NL13, NL16, Personal Communications, 2019). Despite mounting awareness and curiosity for plant-based alternatives, meat consumption is not decreasing much and consumers have not yet significantly changed their purchasing habits (NL7, NL16, Personal Communications, 2019). Behavioural research into what motivate or repel different segments of consumers, and what would trigger them to buy is missing. Furthermore, there is a clear focus on meat analogues. However, several interviewees have indicated that consumer expectations are difficult, if not impossible to predict, and demand could possible shift to other types of products (NL1, NL11, NL13, NL17, Personal Communications, 2019).

Finally, a gap around the sustainability performance and cost-benefit assessment of plant proteins was identified. Although they globally perform better than red meat alternatives, potential health and environmental issues relate to the sourcing of primary resources, the current extraction processes and the nutritional profile of some products (Het Financieele Dagblad, 2019; NL4, NL17, Personal Communications, 2019). Not enough attention is brought on the environmental performance of the fractionation processes, different protein sources and overall impact of consumer products (NL4, NL8, NL10, NL14, NL16, Personal Communications, 2019). Therefore, it would be beneficial to assess which solutions are worth scaling up, in terms of feasibility, optimising health benefits while minimising environmental impacts (NL16, NL13, Personal Communications, 2019).

"Unfortunately, the focus is not yet enough on, yeah fine for the animals that it is plant-based, but from an environmental perspective, plant proteins, if you look at the current way of producing them, are still environmentally quite unfriendly. They could, if you don't watch out, have a higher environmental footprint than a chicken burger (…) For example, current meat analogues or plant proteins that are processed to make them into novel type of plant protein foods, they all start with an isolate. And the isolation process is still the standard isolation processes, that are basically quite environmentally unfriendly" (NL13, Personal Communication, 2019)

4.1.3.3 F3 - Knowledge Exchange

Overall, most actors active on plant proteins know each other, or know how to find each other due to the agglomeration hub around the Wageningen Campus and the Business Science Park. Yet, several barriers hampering knowledge exchange were identified by interviewees. Academic interactions could be strengthened or established to expand knowledge. For instance, collaboration between WUR and Twente University and TU Delft could stimulate knowledge on fractionation processes (NL11, NL13, Personal Communications, 2019). Besides, silo work between different parts of WUR impede an integral approach of knowledge generation around plant proteins and their applications. Some industries are urging for a more user-driven, or knowledge pull, approach to knowledge generation, to strengthen knowledge transfer between small and large companies, knowledge centres, and universities (NL4, NL17, NL 16, Personal Communications, 2019). For small entrepreneurs, however, several difficulties arise to collaborate with research institutes because of prohibitive costs, IPR issues, and the applicability of fundamental research outcomes (NL6, NL 8, NL10, NL16, NL17, Personal Communications, 2019). The TPC aims to remediate in part to these issues. The main motivation to join for its members is to meet other innovative entrepreneurs, keep abreast of developments in the sector and potentially develop collaborations (NL8, NL9, NL10, NL11, Personal Communications, 2019). Generally, there has been a strong willingness to cooperate among TPC members, learn from each other and find applicable and cost-effective solutions to their issues. However, to date, collaboration between TPC and other knowledge providers is fairly limited and not actively pursued. The need to communicate better or "speak the same language" was raised by a two of interviewees (NL8, NL17, Personal Communications, 2019) to enable more fruitful interactions between actors from different backgrounds and skills (i.e. research, business, food technology, process technology).

"The value of TPC for me is easy networking. You know what is going on, and for us, we know the parties that are working on novel proteins. And if you see an opportunity where we can play a role (…) to develop a novel application for somebody." (NL10, Personal Communication, 2019)

"For me, the main motivation [to be a member of TPC] was to get in contact with innovative consumer food producers. That worked well (…). For us that's the key thing, it is to get into one-to-one contact (…) Then we want to be in contact with them to see how we can help them do that." (NL9, Personal Communication, 2019)

4.1.3.4 F4 – Guidance of the Search

The overarching policy goal set in the national transition agenda and aims at reversing the protein balance ratio between plant and animal intake to 60:40 by 2050 (*Transitie Agenda Circulaire Economie - Biomassa & voedsel*, 2018). This goal is accepted and shared by all actors and give a shared purpose to work towards. However, the path to achieve this goal is yet to be agreed upon. Although those national targets were set, no dedicated resources were put in place to implement them and the government still support the meat sector through its agricultural policies (Jong et al., 2018). Interviewees had mixed reaction towards the 'Kringlooplandbouw' approach advocated by the minister for agriculture (NL2, NL6, Personal Communications, 2019). For one interviewee, it is a positive and integral approach to sustainable farming and food production, while for another, it is another policy directed at primary producers rather than consumers. Although policy support would be welcome, industry actors believe that the transition towards more plant-based diets will happen none the less. The role of governments therefore is to identify how they can influence the direction and speed of innovation to benefit their region.

> *"Around 60-40 and 40-60, we can all agree, but what those two pots look like; what does the 40 looks like and what does the 60 looks like. Are we happy if we start eating 60% from plant proteins but it is all based on soy isolates and wheat gluten? I would not be." (NL16, Personal Communication, 2019)*

> *"I think the vision can be much clearer. If the government says, and also if the eastern part of the Netherlands says, for us plant proteins or protein transition is a spearhead, that's already good, because now you speak a common goal. But then it comes down to what it really means, and then you have to be listening to each other. Small companies have a different need, they move at another speed than the big companies. And that I think is a big struggle. Whenever there is a big company on the table, they have to understand the small companies, and also with the knowledge institutes. But if there is one opportunity, I think, again, that the Netherlands has, is we have a culture of sitting down and speaking to each other." (NL17, Personal Communication, 2019)*

At regional level, the relatively good interconnection between actors and the supportive existing policies provide a good basis to strengthen the realization of protein transition. The Agrifood 2030 programme in Gelderland aims to further strengthen the region as a global centre of innovation in the agri-food sector, whereby protein transition, circular agriculture, healthy food and technology will play a key role (Provincie Gelderland, n.d.). As such, it could stimulate better knowledge transfer between industry and research actors (NL1, NL13 Personal Communications, 2019). However, the lack of clarity of the Province's current objectives with regards to economic development was pointed out, specifically, whether the government wants to support the implementation of production facilities or focus solely on R&D and knowledge transfer (NL9, Personal Communication, 2019).

> *"The challenge for the region is what role to play, because if it is only a role of R&D and technology transfer, then that will be a limited role because once things are developed, what you see is the key benefits for the region would be employment, knowledge development, and also being able to innovate. But (…) the majority of the employment is where you produce the end product (…) Most of the time, [with] R&D [and] knowledge transfer (…) there will not be a big benefit for the region." (NL9, Personal Communication, 2019)*

Furthermore, the protein transition issue has emerged in national and regional policies through circular economy strategies. It can indeed be seen as a high circularity strategy as it aims to reduce the consumption of animal proteins. Despite this policy framing, an integral approach to sustainability and circular production is absent from policy considerations. While some companies valorise agricultural residue streams or utilise all parts of the crops, other face co-product overflows (NL8, NL11, NL11, Personal Communications, 2019). The overall focus remains on developing ingredients and consumer products and improving their qualities, rather than looking at the sustainability impacts across the value chain. Another key bottleneck for the protein transition concerns the lack of primary resources. Encouraging crop production will necessitate broadening the policy focus to encompass the entire production chain, from primary producers, to the food processing industry, retailers and consumers. Finally, the impact of a protein transition on the meat sector and rural areas is another topic that is yet to be addressed (NL13, Personal Communication, 2019).

Lastly, as the TPC membership grows, some experts have expressed a need to reconsider its role and objectives, including how it will service its members and how it should connect to external parties (NL 3, NL4, NL9, NL14, Personal Communications, 2019). For instance, one entrepreneur fear that the level of knowledge shared might reduce resulting in less innovation coming out of this network.

> *"You get another complication that the cluster is growing and you see that direct competitors are in, so that will slow down the exchange of information. At the beginning it was more or less a group which were working on different things. Then, there was a lot of exchange. But now some bigger parties are entering at least from the sidelines. And these parties are more looking for what is available and what can be used. (…) So, it is going to a different phase, more like a branch, or an organisation which represent a group of people in the same activities (…). Therefore, the knowledge exchange will be more general, looking together at trends and moving more to one to one conversation outside the group." (NL9, Personal Communication, 2019).*

4.1.3.5 F5 - Market Formation

The evolution of the market for meat alternatives in the Netherlands is seen very positively by all producers. The turnover of meat alternatives, although marginal compared to the meat turnover (less than 2%), is still growing rapidly and has reached 100 million euros in 2018 (NL6, Personal communication, 2019). The market for meat substitutes is still relatively small. The brands Vivera, De Vegetarische Slager, Valess, Quorn and Tivall hold around half of the market

and the other half is dominated by private label products and major brands (ABN AMRO, 2018). However, this niche market is developing fast and it is expected to grow by 6% in 2018 and by 8% in 2019 (ABN AMRO, 2018). The interest of big food groups, such as Unilever, Danone, or Nestlé as well as the growing attention from retail chains indicates that plant-based alternatives gradually start to shift into mainstream products.

> *"Companies like Unilever or Rabobank or other big companies like Avebe and others are now fully focussing on this area. So, you see there that the innovations that were created by these start-ups are now turning from niches to mainstream." (NL6, Personal Communication, 2019)*

Consumer demand is the biggest driver for market growth, providing that taste, price and convenience expectations are met. However, the price of plant protein alternatives is still much higher than that of meat, mostly due to the lack of economies of scale on the production side, and high margins from retailers (NL1, NL4, NL9, NL12, Personal Communications, 2019). A key barrier to access market for many entrepreneurs is the capacity to scale-up production in this fast-growing, fragmented and competitive market. Retails, although interested in putting new products on their shelves, have high expectations in terms of volumes and quality and the turnover of products is quick if new products do not sell well enough (NL2, NL11, NL4, Personal Communications, 2019). The competition from big companies is getting more pressing, as they are positioning themselves in the market. On the one hand, some entrepreneurs see it as beneficial, as it will help increase the overall demand for those products, but competition for price and shelve space will increase (NL11, NL12, Personal Communications, 2019). This will also force SMEs to keep innovating further to differentiate themselves.

4.1.3.6 F6 - Resource Mobilisation

Overall, entrepreneurs have access to a pool of financial, technical and technological resources to start new ventures. Some resource limitations were nonetheless identified. Conflicting views about the availability of funding were expressed. For some, there not enough funding and venture capital available to start-ups who want to move into commercial phase (NL3, NL8, NL9, Personal Communications, 2019). Other interviewees are of the opinion that a lot of public and private funding sources can be found for good projects with a sound business case (NL6, NL10, NL11, NL13, Personal Communications, 2019). Overall, it seems that the first stages of development (R&D) can find public funding relatively easily, and companies that have demonstrated the market potential can find venture partners or acquisition opportunities. Financing options are more precarious in the stage in-between where commercial applications need to be demonstrated (NL4, Personal Communication, 2019).

> *"I think at this moment, if you cannot find financial means, you are not a good entrepreneur or you don't have a good proposition, or you don't have the entrepreneurial talents or you don't have a good team. If you have a good idea or a good concept, then you must be able to find the money." (NL6, Personal Communication, 2019)*

This challenge is further compelled by the lack of pilot or demonstration facilities (such as shared kitchens) accessible to produce samples for the market. As more companies are reaching their full capacity it becomes more difficult for entrepreneurs to use each other's equipment. Ongoing discussions to establish a field lab in East Netherlands could counter to this shortcoming (NL1, NL3, NL14, Personal Communications, 2019). Finally, the lack of primary processing and new isolates available in sufficient quality and quantity impediments the ability of companies to scale up industrial production as well as innovate further (NL1, NL6, NL10, Personal Communications, 2019).

> *"There are not enough affordable proteins. Lots of initiatives and when it will scale up it will improve. So, in that sense, the market is ready for it and it is asking for it. On the other hand, there are also still big issues for industries to really make it bigger." (NL10, Personal Communication, 2019)*

> *"What is very important, for retailers and large producers, is that they have certainty of volumes and quality of products that are delivered, so we cannot afford that quality is changing or that there is a lack of supply, so scalability is very important. So, you need, take for example soy, or faba beans, you need equipment to mill the bean and extract the proteins. Those kinds of facilities are lacking at the moment in the Netherlands and that's a critical part in this quest we have." (NL6, Personal Communication, 2019)*

4.1.3.7 F7 - Legitimacy Creation

All experts indicated that consumers have a positive image of plant-based proteins, which are seen as healthier and more sustainable. The challenge for greater adoption is the required change in behaviour and eating habits (NL7, NL16, NL13, Personal Communications, 2019). Most of the awareness raising activities around plant-based proteins in the Netherlands are bottom-up actions, such as the Week without Meat started two years ago and other social media influencers (NL2, NL4, NL6, NL10, NL17, Personal Communications, 2019). Through their marketing and advertising campaigns, retail and large food companies also play an important role in communicating to consumers (NL6, NL10, NL13, NL17, Personal Communications, 2019). Besides, the Green Protein Alliance is the main lobby nationally (NL6, NL11, Personal Communications, 2019), along with political parties (NL1, NL2, NL4, Personal Communications, 2019). At regional level, the Party for Animals, for example, has urged the Province of Overijssel to include plant proteins in their agro-innovation policies. Conversely, other more conservative parties in Gelderland are pushing back. The meat and dairy sector is also a powerful lobby that could challenge the adoption of plant proteins. However, at this stage, it is not felt as an issue. On the contrary, many producers of meat and dairy products are embracing the movement and diversify their product range with plant-based alternatives (NL2,

NL3, NL6, NL10, Personal Communications, 2019). Some experts anticipate, however, that the resistance from the meat and dairy sector will accrue as plant-based products get more popular (NL4, NL8, Personal Communication, 2019).

> *"I am engaging also with meat companies and dairy companies and what I see is that they are all working to embrace this. You see meat companies interested in pursuing hybrid products, so combination meat-plant. You see dairy companies who are pursuing be able to make plant-based foods as part of their portfolio." (NL16, Personal Communication, 2019)*

Governments and the Nutrition Centre, on the other hand, are not actively and explicitly promoting diet changes to consumers, as it is seen as a private choice that they shouldn't influence. Although the Wheel of Five from the Nutrition Centre provides information for plant-based diets, no educational or promotional campaign to reduce meat consumption and increasing plant-based protein is expected to occur (NL6, Personal Communication, 2019). Moreover, how to engage with consumers is still seen as a challenge by several experts (NL1, NL2, NL13, NL16, Personal Communications, 2019). In that respect, the flexitarian approach appears less confrontational and therefore more positive. But with a lack of clear and in-depth consumer insights, it is difficult to judge how to communicate effectively in order to prompt behavioural changes. Additionally, some experts expressed concerns about the quality of the information available and identified a lack of independent and trustworthy source of information (NL10, NL16, NL17, Personal Communications, 2019).

> *I think on both sides you can argue a lot about the truthiness of everything that is now on the media. That makes it difficult to really have a clear story" (NL10, Personal Communication, 2019)*

> *"There is a never-ending debate, not so much if consumer should be involved, but on how they can be involved. The power of the consumer, how to use it. So, it is a difficult question, because 'the' consumer does not exist and you cannot pinpoint one individual. But everybody agrees that consumer involvement is key. (…) But I think it would be wise to respect more and look for more of those involved consumers or civilians. (…) we are in an era where it is no longer necessary or realistic to look just to the governments or the companies for that respect." (NL6, Personal Communication, 2019)*

> *"You see more than half of Dutch consumers call themselves flexitarians. But what you do also see if that our meat consumption is not really declining. I don't think the bottleneck is explicit. People are not anti-plant-based food. I think it is deeper and more implicit. Like oh, I ate a veggie burger on Tuesday so I can have a second helping of ribs on Friday (…) I think we are already trying to talk to consumers without understanding how shall we talk to consumers. I think that's a mistake." (NL16, Personal Communication, 2019)*

4.1.3.8 Performance of the East Netherlands TIS

Ratings for each function were derived from the average scores given to the functions by the experts (Figure 10). In the case of East Netherlands, the best performing functions were knowledge development (F2), entrepreneurial activities (F1), legitimacy creation (F7), and market formation (F5). With a phase of development of the focal TIS still in take-off phase, the

predominance of entrepreneurship and legitimacy creation are indeed expected to occur, acting as a motor for innovation. Consolidating those functions is critical to ensure a successful take-off and transition to the next phase. In the next phase of acceleration, the market formation (F5) becomes pivotal. The relatively high score for this function is therefore promising. Yet, it must be noted that this score reflects the self-growth of the market, driven primarily by consumer demand. Little action to support the market for plant-based products or to reduce the consumption of animal proteins is taking place nor is anticipated to occur. In contrast, the guidance of the search (F4) and resource mobilisation (F6) are less developed. Those are both essential, however, to support entrepreneurial activities in the take-off and acceleration phase. The lack of a common vision and common goals across the different stakeholders and restricted access to resources (in terms of primary resources and shared production facilities) constitutes the main barriers to the effective development of this innovation system. Knowledge development (F2) scores the highest, even though this function is relatively less important in the later phase of development. This certainly reflects the influence of the Food Valley as a knowledge hub (proximity capital) that can be utilised for further incremental improvements of imperfect products on the market, as well as attracting new entrepreneurs over time to develop new products in accordance to the evolution of consumer demand.

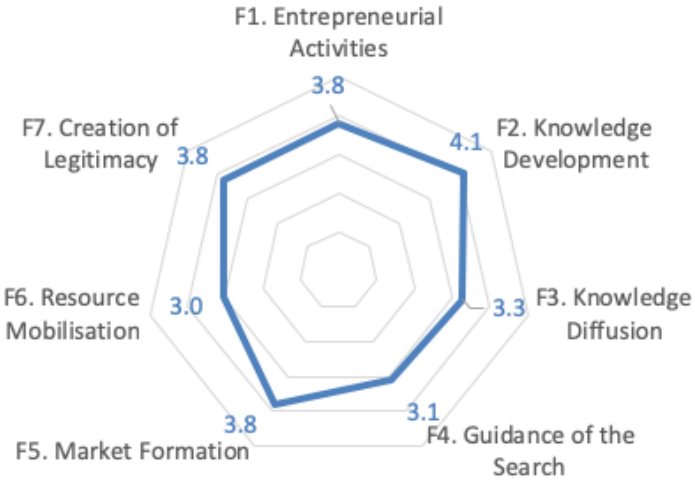


Figure 10. Function Scores in East Netherlands

4.2 Protein Transition in the Hauts-de-France

4.2.1 Structure of the TIS in the Hauts-de-France

4.2.1.1 Actors

As this is the first study of the plant protein innovation system in this particular region, the structure analysis aimed to be as exhaustive as possible. However, with many actors and involved, the most prominent ones only are described and summarised in Appendix C.

Industrial actors

The region includes several **global leading companies in the agri-food industry**, mostly ingredient manufacturers, which influence the development of innovative protein sources. Roquette is a global player in the starch industry and processing corn, wheat, potato, and peas. It is a major supplier of pea protein ingredients, often used in the development meat alternative products (Picardie, 2013). Tereos is a cooperative that transforms agricultural raw materials (sugar beet, sugar cane, cereals) into sugar, alcohol and starch. It is one of the largest producer of wheat proteins and is now developing its own range of meat analogues (Process Alimentaire, 2015; Tereos, 2017). Limagrain Céréales Ingredients develops and manufactures functional flours and cereal ingredients and is involved in the world of plant-based proteins. Other large companies include Sofiprotéol (part of the Avril group), active in valorising oleaginous and protein crops such as rapeseed, as well as the cooperatives InVivo and Vivescia. The industry fabric is historically oriented towards ingredient production and less towards agro-food industry. Bonduelle, as a world leader in ready-to-use vegetables, is the major agro-food company active in the region in this area. The entrepreneurship landscape is quite diverse, with seven **start-ups** identified, all developing different types of plant-based products, ranging from snacks, biscuits, drinks, desserts, spreads, and meat replacers.

Research and Education

There is a plethora of educational and research centres involved in various degrees in plant proteins. Several public and privates universities offer education in agricultural and agro-industrial sectors and process engineering, including **Polytech Lille**, the **ISA** in Lille (part of the Catholic University of Lille and Yncrea network of engineering schools). Other universities are the **Picardie Jules Verne's University** in Amiens**, UniLaSalle** in Beauvais, and the **Technological University of Compiègne**, which also have research expertise in agro-resources and biorefineries. The research unit Biopi at the Picardie Jules Verne's University works on plant biology and innovation and involved on agronomic projects around pea and flaxseed. The **Charles Viollette Institute,** attached to the University of Lille 1, regroups seven

research units across different institutions in the region. It conducts research on agro-food and biotechnology to improve food safety and quality.

With regards to private contract research, the region is well-equipped with several industrial technical centres. First, **Improve** is a major R&D platform dedicated to the valorisation of plant proteins. It was founded in 2013 and count four major companies (Tereos, Sofiproteol, Vivescia and InVivo) as shareholders (Picardie, 2013). It offers expertise as well as laboratories and pilot facilities for plant protein extraction and characterisation for customers within the region and beyond. Similarly, **Extractis** is a technology centre specialised in extraction processes, which can complement Improve's services on larger scale projects. With regards to the food development and processes, **Adrianor** and the **CTCPA** are the main technical institutes supporting product development projects from start-ups, SMEs or large companies.

Policy Makers

The **Région Hauts-de-France** leads the development and implementation of the bioeconomy masterplan. With respect to the specific priority on proteins, the region coordinates a working group that is tasked to develop a dedicated action plan, and which includes representatives from other administrative agencies, the research and the industry.

Support Organizations

Two major competitivity clusters stimulate innovation around plant proteins. **IAR** (the Bioeconomy Cluster) through the development of the bioeconomy sector, and **NSL** (Nutrition Health and Longevity Cluster), which supports projects at the interface of health and nutrition. Next, two start-up incubators can be found in the Lille area, namely **Euralimentaire** and the **Village by Crédit Agricole** (Village by CA), respectively public and private organisations. Euralimentaire was established two years ago to support innovation around fresh produce and their logistics. It is also part of the national 'FoodTech' network. It is also worth noting that both NSL and Euralimentaire are part of the broader Eurasanté, a leading cluster in the field of health. Village by CA Hauts-de-France is part of the national incubator network from the bank Crédit Agricole and has identified plant proteins as a key priority. Other key supporting and advisory organisations for innovation in the agri-food sector include the **Certia-Interface** and **Hauts-de-France Innovation Development** (HDFID).

4.2.1.2 Networks

Several informal and formal networks of actors have emerged through the structure analysis of the innovation system (Figure 11). Although actors interact relatively well across the entire region overall, the historical ties developed in the former administrative regions can still be seen. Food tech actors are mostly based in the ex-Nord-Pas-de-Calais (Lille area) while the agro-

resources players are connected to the ex-Picardie area. The clusters are themselves networks of industrial, research and institutional actors. For instance, IAR has a specific working group on ingredients, which encourages collaborating projects on plant proteins. IAR was also involved in the creation of a national network called Protéines France in 2016, wich has a strong membership originating from the Hauts-de-France. The NSL cluster has particularly close connections with the Charles Viollette Institute on food safety and quality themes. Next, the regional government has set up a working group to develop a dedicated action plan for novel proteins as part of the implementation of the Bioeconomy masterplan. This group, co-piloted with IAR, regroups some of the main actors in the region, such as Bonduelle, Roquette, NSL, Village by CA, as well as seed companies, the Aquimer competitivity cluster (for its potential on algae proteins) and other institutional partners. Through their protein initiatives, the Village by CA has also established partnerships with NSL, Bonduelle, the catering company Sodexho, Eurasanté, Université Catholique de Lille Yncréa (with ISA Lille), and IAR. The Certia Interface coordinates a network of food tech organisations, through regular meetings to exchange and collaborate when necessary. Structures such as the two incubators, NSL, Adrianor and CTCPA, and the BPI are involved.

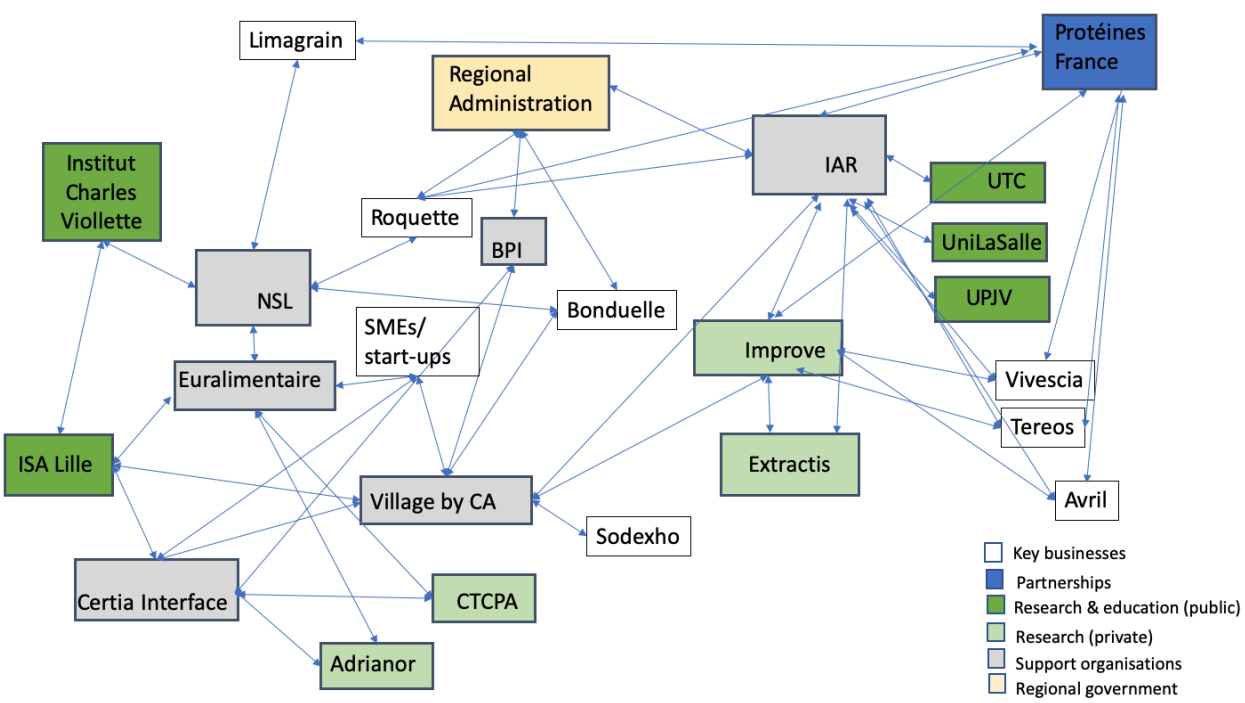


Figure 11. Simplified Relationship Network for Plant Proteins in Hauts-de-France

4.2.1.3 Institutions

The legislative institutions influencing the development of plant proteins in Hauts-de-France are developed at European, national and regional level. Such as for the East Netherlands, the European legislation and strategies such as the EU Protein Plan, the Bioeconomy strategy and the Novel Food and Product labelling regulations are also influencing the development of plant proteins.

Regional Innovation Context

The regional innovation and competitivity context is facilitated by the creation of competitivity clusters. The regional competitivity clusters IAR and NSL, dedicated to bioeconomy and to health and nutrition respectively, were established in 2005 through France's 2004 industrial policy (France Clusters, 2017). These clusters are based on the concept of regional innovation, to structure actors around a particular theme and promote synergies between industrial, research and institutional actors. Although over time most clusters tend to broaden their geographical scope, they still keep a strong anchor in their initial region and contribute to the local economic development. The themes carried by these networks directly result from the smart specialization strategies developed by the former Nord-Pas-de-Calais and Picardie regions (Picardie, 2013). In the former Nord-Pas-de-Calais, smart specialisation revolved around health and nutrition. Picardie's strategy focuses on bioeconomy and biorefineries to develop new uses for its abundant agro-resources, and reach out to new markets (NFID, n.d.; Picardie, 2013). The valorisation of agro-resources has been a long-standing regional policy in Picardie and the neighbouring Champagne-Ardenne, which resulted in a strong concentration of expertise in the valorisation of biomass. Within this context, the region has launched in 2013 a regional economic strategy called the Third Industrial Revolution (Rev3), which supports innovation, energetic transition and circular economy (Nord-Pas de Calais & CCI Region Nord de France, 2013). With an estimated 500 million euros of private and public investment annually, it generates a stimulating environment for the use of bioresources (Rev3, n.d.).

Economic Development

At regional level, the Hauts-de-France, the **Bioeconomy Masterplan** adopted in September 2018 lays out explicit ambitions to become a European leader in protein production, including from plant, insect, algae and milk sources (Région Hauts-de-France, 2018). One of the four key objectives is to become the European leader for plant proteins by 2025 (French Ministry of Agriculture and Food, 2018; Région Hauts-de-France, 2019)

Several national legislations have also been enacted to support plant proteins. The **Egalim Act** was adopted in November 2018 (French Government, 2018). Its purpose is to balance trade

relations between agricultural producers and major distributors and it also includes specific provisions to support the market for plant proteins. In Article 24, an obligation is set for school catering services to offer a vegetarian or vegan menu at least once a week as of November 2019, as part of a trial. Also, public schools, universities, hospitals and prisons serving more than 200 daily meals are incentivised to include plant-based alternatives in their menus and need to present a plan for protein diversification that includes plant proteins. The **Contrat Stratégique de Filière Agroalimentaire** is a national strategy driving the economic development in the agri-food sector (Conseil National de l'Industrie, 2018). Its aims to reinforce the innovation capacity of companies around four priorities, which include the 'Protein of the future'. The goal here is to make France a world leader in new protein sources, to reduce dependency on exports and support existing companies invested in this sector. The implementation of this strategy is facilitated by a call for large-scale projects launched through a major national investment initiative (PIA 3) to promote innovation and the structuring of sectors (Conseil National de l'Industrie, 2018; FranceAgriMer, 2018).

Health and Safety

The **National program for nutrition and health (PNNS)** now promotes reduced consumption of animal proteins (in particular red meat) and recommends eating pulses twice a week in its most recent guidelines (FranceAgriMer, 2015; PNNS, 2019a, 2019b). The current protein sources in people's diet is estimated at 60% of animal origin and 40% of vegetable origin, similar to the Netherlands. The PNNS recommends shifting this ratio to 50:50 (Guéguen, Walrand, & Bourgeois, 2016). Besides, the newly introduced nutritional logo **Nutri-Score** provides easily readable information on the overall nutritional quality of the products to direct consumers to choose healthier foods, which can favour plant-base products (Santé publique France, 2018).

Norms and Habits of French Consumers

The average French diet has followed the nutritional transition characteristic of developed countries, with less grain but more meat (about 86kg per person per in 2014), fruits and vegetables and dairy products than in 1950 and more processed products (ADEME, 2014; FranceAgriMer, 2015). The evolution of this diet has become an issue of public health with the development of diet-related diseases such as obesity. Food is also responsible for an important share in the environmental footprint and account for about 23% of the French household's carbon footprint (ADEME, 2014). The consumption of animal proteins is strongly embedded in the French culture (GEPV, 2018d). However, clear signs show an evolution in people's perception, acceptance and habits, and these social norms are slowly changing. From products deemed nutritious, healthy and synonym of wealth, animal products are increasingly seen as

suspicious, as more awareness is gained on their impacts on health, environment and animal welfare (Frioux, Hardy, Pech, & Vincent, 2017). The long trail of scandals in the meat industry have eroded its image, from the bovine spongiform encephalitis in the years 18986-1998, the high dioxin levels found in meat and eggs in 2010, the was falsely labelling of horsemeat as beef in meat-based dishes in 2013, to regular outbreaks of avian influenza since the early 2000. This has led consumers wanting more transparency on the origin and manufacturing processes of their food.

Consumer surveys show a growing interest, understanding and demand for plant proteins (GEPV, 2018a; Kantar WorldPanel, 2017; Observatoire des Cuisines Populaires, 2017; Tavoularis & Sauvage, 2018). The profile of adopters is generally defined as urban, young, female, and upper middle class. Consumers habits are changing, with meat consumption slowly decreasing over the past ten years (Tavoularis & Sauvage, 2018) and about a third of French consumers indicating their desire to reduce meat intake (FranceAgriMer, 2015; GEPV, 2018a). However, the share of vegetarians and vegans remains at about 3% of the population; rather flexitarian practices are on the rise (FranceAgriMer, 2015; GEPV, 2018a; Tavoularis & Sauvage, 2018). Overall, 60% of French consumers have tried plant-based products, including meat analogues and other popular products include plant-based drinks, desserts, and ready-made meals (GEPV, 2018a; Sojaxa, 2018). Plant-based drinks, in particular, are very popular with sales rising by 22% in 2017 compared to 2016 (GEPV, 2018e). Meanwhile, 45% of consumers declare being interested in products combining meat and plant proteins (GEPV, 2018c). However, it also seems that French consumers associate plant-based products with natural products, and would prefer less processed alternatives (LSA, 2018; Observatoire des Cuisines Populaires, 2017). The taste, the authenticity (naturalness, without GMO) and the geographical origin are other additional key criteria at the time of the purchase. To that end, consumers are looking for labels providing a sense of quality, mostly organic labels (DSM, 2018; GEPV, 2019). Surveys show that French are more and more knowledgeable about plant proteins. For instance, 70% of consumers know about lupine in 2018, as opposed to 35% in 2011. And although meat, eggs and fish are still considered the richest sources of proteins, pulses are more and more recognised as a source of protein. Conversely, the main reasons indicated for not consuming plant proteins relates to taste, lack of habits, or because consumers find those products too transformed (GEPV, 2018b). Overall, there is a strong trend towards adopting plant-based products as alternatives to meat and dairy, attracting start-ups, SMEs and major food companies and retailers alike.

4.2.1.4 *Infrastructures*

Technological Infrastructures

The most distinctive technological infrastructures that can be found in Hauts-de-France are **technological platforms for protein extraction and characterisation** at Improve and Extractis. **Biorefineries** are a key technological infrastructure specific to the region. These territorialized biorefineries were developed in a broader bioeconomy context, to transform the local agro-resources into a range of products intended for food and feed, the manufacture of chemical products, materials or energy production (IAR, 2018). Tereos' starch mill , for example, processes more than 900 000 tonnes of wheat per year (Picardie, 2013). Next, some **R&D equipment** are accessible to start-ups at the incubators and ISA university. Meanwhile, the Euralimentaire incubator was established on the site of the Lomme's **wholesale food market** near Lille, facilitating access to logistical resources and to markets in France and Europe.

Financial Infrastructures

Although no dedicated protein funds exist, several financial tools can be mobilised to support innovation for plant-based proteins. The French public investment bank **BPI** is particularly active to financing of innovation mainly in the form of innovation and seed loans and grants. It is the primary tools used by local entrepreneurs (FR11, FR13, FR14, FR15, Personal Communications, 2019). Other **regional funds** include Finorpa, Finovam, Picardie investments, and the IAR cluster also has an investment program to support its members.

Knowledge Infrastructures

Building on the technological and research infrastructures, the knowledge infrastructures span across the entire value chain from agronomic to nutrition, yet with a particular emphasis on transformation and extraction processes for renewable resources.

4.2.2 Phase of Development

Here again, companies and entrepreneurs are experimenting with diverse sources of plant proteins which are in a different development phase (Figure 12). Although adoption of plant proteins of the French market really started about three years ago, it is now progressing fast. Looking at the specific activities developed in Hauts-de-France, most are still in early stages of development.

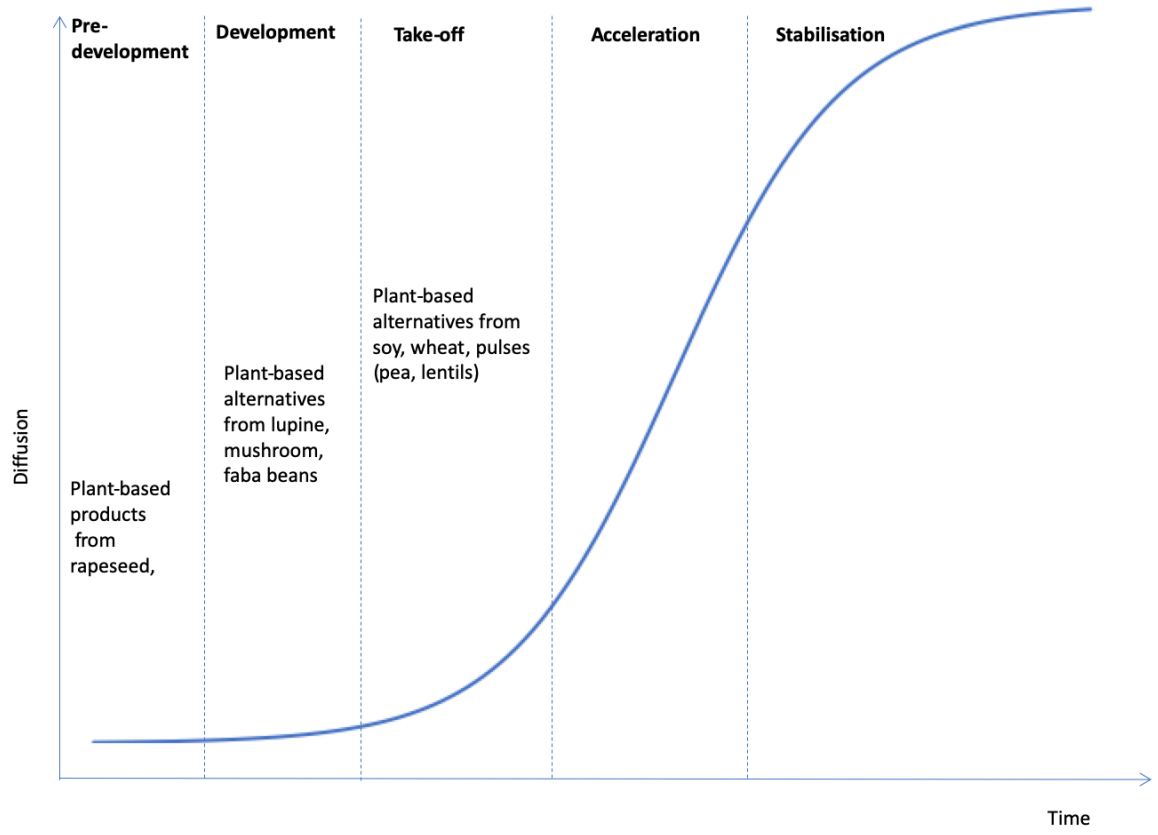


Figure 12. Phase of development in the Hauts-de-France TIS

4.2.3 Functional Analysis

4.2.3.1 F1- Entrepreneurial Activities

Incumbent industries in the ingredient sector are active in the development of both new ingredients and consumer products. For instance, in the mid-2000, Roquette has developed in collaboration with Sotexpro a textured pea protein ingredient which is particularly suited for meat analogues. They are, for instance, a supplier of the Beyond Meat burger and they've also recently invested in an Isreali start-up innovating in crops breeding (Agfunder News, 2019; Les Echos, 2019). The other historical industry actor in the region, Tereos, is also actively innovating in this field and developed meat analogues using its textured wheat proteins. The group was awarded the 2030 global innovation contest for this project (Process Alimentaire, 2015; Tereos, 2018). The group Bonduelle also recently put on the market new plant-based products, such as plant-based burgers, pasta made of pulses, and fresh salad mix (La Voix du Nord, 2018). Besides, they also develop prospective R&D activities to search for novel protein sources and experiemtn new applications.

> *"Let's say that Hauts-de-France is a very productive region for agricultural products. Historically it is the region that has the best yields of wheat, beetroot, potatoes, etc., in France, but also often in Europe. It is a very rich region at the agricultural level, which naturally has for a very long time hosted large sugar groups, millers, groups that grind oil. So,*

the agribusiness is very developed and that's why these big players wanted to develop and reorient their work on proteins. But it is also a territory where we can host startups." (FR4, Personal Communication, 2019)

For entrepreneurs, all people interviewed consider that Lille generally offers a dynamic environment for start-ups with structures such as incubators and clusters mainly active in the health and tech sector. The region is also closely linked to other European markets, including Belgium, Luxembourg and the United Kingdom (FR12, FR15, Personal Communications, 2019). The activities of Village by CA, Improve, and big groups are seen as important drivers to stimulate plant protein innovation in the region. However, the focus on food tech in general, and plant protein in particular, is recent and not prominent on the local start-up scene. As such, only seven start-ups were identified in the region, yet with little focus on meat analogues. Innovation projects revolve around nutritious, environmentally-conscious and protein-rich foods, responding to different lifestyle needs, such as drinks, snacks, spreads, and dairy alternatives (FR6, FR8, FR11, FR12, Personal Communications, 2019). It was mentioned that, among the projects submitted to one of the incubators, many are not selected due to the lack of technical background of proponents (FR12, Personal Communications, 2019). Another challenge for existing agro-food SMEs is an apprehension that diversifying their activities to vegetarian or vegan products will raise difficulties in the logistics and processes in place (FR6, Personal Communication, 2019).

4.2.3.2 F2 – Knowledge Development

Improve is an internationally recognised technical centre for extraction process and characterisation, and the only knowledge provider dedicated to processes for plant proteins. The Charles Violette Institute was created to better coordinate the activities of academic research in the ex-Nord-Pas-de-Calais region, yet no coordination with academic actors in the ex-Picardie region seems to occur. No academic actors agreed to participate in this study, however, the sentiment is shared among several experts interviewed, that research activities are small-scale and scattered across the region, with little coordination and visibility on each other's focus or specialty (FR4, FR12, FR16, Personal Communications, 2019). Major industry groups with and international outreach are probably not affected, but this could impede the R&D activities of local entrepreneurs (FR12, FR16, Personal Communications, 2019).

"There are high quality technological platforms that exist, Extractis, Improve. However, you do not really have any coordination or unique university structure. If I take Holland [sic], there is Wageningen, that's it. Then, there is Utrecht and there are plenty of others. But if I want to work on plant protein issues, I think it's obvious that I'm going to Wageningen. If I go to Hauts-de-France, in Lille on proteins there is almost nothing. There is a little bit in Compiègne, in LaSalle Beauvais, at the University of Amiens... Today it is completely diffuse, and I do not have in mind that there is a big unit specialist in plant proteins." (FR16, Personal Communication, 2019)

"I know today, there is UTC Compiegne where there is a small team (…) who works on certain vegetables. UniLaSalle Beauvais will be very agricultural practices. Polytech Lille does a bit of everything as well. There is no focal. I was talking with the regional manager of INRA, he told me there is a card to play on plant proteins in your area, so I think that it should actually be stronger." (FR12, Personal Communication, 2019)

A strong trend, aligned with other developments in Europe, is the growing use of pulses such as lentils and chickpeas (FR5, FR13, FR16, Personal Communications, 2019). Yet, their use is limited by the lack of primary production. The need to diversify and increase the availability of high-quality ingredients is certainly a global knowledge gap, identified as well in East Netherlands. Overall, there is still a need to better understand various protein properties and their application potentials. Taste, functionality and solubility, allergenic potentials, and protein contents in particular are the most important challenges identified by the industry (FR3, FR4, FR5, FR7, FR10, FR16, Personal Communications, 2019).

"There is still a lot of research to do. If I draw a parallel, the world of milk has been working on these proteins for 40 years. The world of soybeans for a good thirty years, the rest, well peas started 10-15 years ago and the other proteins start now. So, we are at the very beginning, and there is still a lot of work to be done to understand the properties of these proteins and how can they be extracted and purified in the best conditions." (FR4, Personal Communication, 2019)

"We work a lot in [our] ecosystem on processes. That's one of the strengths, it's one of Improve's strengths too. Roquette, Tereos is their war secrets, that's where they make money. Clearly yes, there is a way to optimize the means of extraction, so that they are both more profitable and more sustainable." (FR7, Personal Communication, 2019)

4.2.3.3 F3 – Knowledge Exchange

There are overall a lot of structures and paths for knowledge exchange among actors, although not necessarily dedicated to plant proteins. The activities of the two competitivity clusters and incubators are certainly key to promote the exchange of knowledge and cross-fertilisation of ideas. Nevertheless, some experts mentioned the lack of intra-industry collaboration and lack of sharing culture as a hurdle to R&D and innovation (FR14, FR16, Personal Communications, 2019).

"If you go to Germany or the Netherlands, working in a cluster or in a network is something that is part of the culture, which is not the case in France. We are in competition, since you have a market that is big and we are fighting in the same market. So that's an issue. We are not really used to work in a cluster. It came with the competitiveness clusters; it is improving but it is complicated." (FR16, Personal Communication, 2019)

"We try to talk with other companies. But I still feel that there is a climate of mistrust, there is no real sharing between companies in the region or France in general. The incubator too, there is really a climate of mistrust already between the various start-ups. It's a little locked for R&D, there is not much sharing. It's complicated to have industrial partnerships. It's easier to have university partnerships, but industrial it's a bit lacking" (FR14, Personal Communication, 2019)

Technical research centres regularly organise events that contribute to the exchange of knowledge (FR4, FR5, FR6, Personal Communications, 2019). For instance, Improve organises regular workshops, and is considering developing a community of practice with industry actors to exchange pre-competitive knowledge. Adrianor organised a technical day on vegan food in June 2018. Besides, the region hosts an annual international conference, The Protein Summit, which promotes networking and high-level exchange.

4.2.3.4 F4 – Guidance of the Search

The activities of entrepreneurs and industry is primarily guided by an increasing demand from consumers for healthier plant-based products. The diversification towards protein ingredients and consumer products is a key motivation for primary processors to limit their exposure to highly volatile prices of agricultural raw materials (Picardie, 2013; Tereos, 2019a; FR4, FR8, Personal Communications, 2019). Overall, start-ups have a more integral approach to sustainable food production, as opposed to focussing primarily on meat alternatives. They look at reusing food waste, producing local or gluten-free products, or positioning themselves at the intersect between plant-based and nutraceutic segments (FR6, FR8, FR12, FR13, FR14, FR15, Personal Communications, 2019). The Village by CA is particularly active to raise the awareness of potential entrepreneurs on the importance of plant proteins as an innovation area. Specifically, they launched a call for projects in 2017, followed by a student challenge, and started annual protein awards in 2018 concomitant to the Protein Summit. The Certia Interface organises the Food Creativ challenge every 2 years. Although not dedicated to plant proteins as such, it recognises the best innovations that have been developed in the region in the food sector. Another example is the Prot'Eat Challenge, a national challenge organised outside the Hauts-de-France region, and which had previously benefitted a local start-up. All these events contribute to raise the profile of innovation for plant proteins (FR10, FR6, FR7, FR12, Personal Communications, 2019).

The regional policies certainly play a role in setting proteins as a key priority for the local economy. The recent regional Bioeconomy masterplan sets an ambitious goal, identifying the Hauts-de-France as a future European leader for innovative proteins. For some actors, it has already been a positive endeavour, giving legitimacy to their initiatives (FR8, FR10, FR11, Personal Communications, 2019). For others, the lack of concrete action thus far means that no impact can be seen at this stage (FR4, FR16, Personal Communications, 2019). The priorities and resources allocated to implement this strategy are yet to be identified and this will shape the opportunities to scale-up the development of plant proteins across the value chain. The global scope of the master plan across several sources of proteins (insect, milk, plants) is seen either as a complementary approach by some (FR2, FR3, FR7, Personal Communications, 2019), or as a

risk to disperse focus and resources for others (FR16, Personal Communications, 2019). Institutional actors are also clear that the development of new sources of proteins is not meant to be in opposition to the animal protein sector, but done in complement to respond to the global increase in demand. At national level, Protéines France promote collaboration within industry across the value chain to overcome key innovation bottlenecks and to speed up the development of the protein sector, in France (Protéines France, 2018). However, yet again, a couple of actors interviewed regretted the lack of concrete actions and impact thus far (FR4, FR16 Personal Communications, 2019).

> *"There are a lot of speeches, a lot of things, but they do not translate into anything effective. I will give you two examples. For at least 2 or 3 years the region has put proteins as a priority. But concretely, (…) we do not see anything. And second example, you may have heard about an initiative called Protéines France, (...) and after two years nothing has happened. It's a little schematic, if you go see the people Protéines France, they will tell you that they do a lot of things, but concretely nothing happens. (…) So, there is a real curiosity and a real attractiveness of the subject but there are not many real concrete projects." (FR4, Personal Communication, 2019)*

> *[about the regional working group on novel proteins] "We only had one meeting yet and what we said was that we had to refine our strategy (…) At this stage we have a list of about 40 actions that range from seeds to cultural routes, through social acceptability, training, hygiene and environmental safety. It goes in every direction (…)" (FR3, Personal Communication, 2019)*

4.2.3.5 F5 – Market Formation

Although the French market is seen as behind other countries like the Netherlands, it has been rapidly growing for the past three years. Driven by a wave of innovations, vegetarian ranges were launched starting with the retail brands from Carrefour at the end of 2015 in 2016 by Monoprix in 2016, followed by other incumbent companies, including Herta, Fleury Michon and poultry specialist Le Gaulois. The turnover of the meat alternative segment almost doubled in volume in 2016 compared to 2015 (+92%) (Frioux et al., 2017; Limagrain Céréales Ingrédients, 2019). The sales from plant-based products in French supermarkets in 2018 generated an increased revenue of 24% (380 million euros) with an estimated progression of 17% between 2019 and 2021 (Xerfi, 2018). Consumer and market surveys also highlight the importance of other attributes, in particular, organic labels as well as the region of production (GEPV, 2019). Additionally, the reluctance against genetically modified food had boosted the French production of soy and other pulses (FR17, Personal Communication, 2019). Overall, the offer is increasing fast, which is positive, but it creates strong market entry for new entrepreneurs (FR14, FR15, Personal Communications, 2019). Most start-ups in the Hauts-de-France started their activities after 2016, at the same time that major brands and retailers were launching their products on the market. Entrepreneurs are therefore in direct competition with

incumbents' products, whereas they do not have the same production and sales capacity. This has been identified as a key issue for the local start-ups (FR12, Personal Communication, 2019).

> *"It's so hard. We have partnerships with Leclerc, Auchan [supermarkets], people swear that it's great. But when you deal with the buyers, they take the big brands and you are the last product. (…) because the big brands are those who pay, that's all. And there, I have start-ups who have to have the same sales force as a large international group (…) It is very difficult to support them in commercial development strategy." (FR12, Personal Communication, 2019)*

To support the market development for plant-based foods, the regional government is investigating the possibility to use its purchasing power to introduce plant-based meals in high-school canteens (FR1, FR3, Personal Communications, 2019). This should also be facilitated by the Egalim legislation. These types of initiatives can create volumes and markets for suppliers of catering companies, and provide an avenue to educate consumers in plant proteins.

> *"There is also the whole question of acceptability. There we are really on the human part, popularisation, awareness etc. and I do not know how the region will play the game, but we also have this idea of massification. Since it is true that there is innovation, but if there is not a market that goes with or at least a certain volume of market to make it viable for the company, we will go around in circles for a long time." (FR3, Personal Communication, 2019)*

4.2.3.6 F6 – Resource Mobilisation

Entrepreneurs in the region benefits from a relatively dynamic environment to start a project, although there are no resources specific to plant proteins as such (FR6, FR8, FR9, FR11, FR12, FR16, Personal Communications, 2019). Financing mechanisms for R&D are available (FR9, FR12, Personal Communications, 2019), and the difficulty here as well lies in finding investors at later stage of development (FR13, FR15, Personal Communications, 2019). The region has several technical centres on the extraction and formulation aspects. Similar to the East Netherlands, the main issue is the costs associated with their services (FR4, FR15, Personal Communications, 2019). Furthermore, the lack of pilot or demonstration facilities is also lacking, limiting the ability of entrepreneurs to progress to the industrialisation stage (FR12, FR13, FR14, FR15, Personal Communications, 2019). To respond to their R&D and manufacturing needs, two start-ups are looking for partners outside the region (FR13, FR14, Personal Communications, 2019).

> *"The subcontractor who helped us in the development of our products was expensive because, precisely, it helps with the industrialization so there is an expertise that is quite important. It was useful to us at the beginning, but now it is no longer necessary and yet we still had to continue with them for the following productions because there is nothing else available." (FR15, Personal Communication, 2019)*

The respond to the growing demand for primary ingredients, Roquette invested a new production unit for specialty pea protein in Vic-sur-Aisne in 2018, increasing their production capacity for the global meat substitutes market (Nord France Invest, 2017; Roquette, 2018). The

production capacity is far less consequent than their production facility in Canada, however this will increase the production capacity for the European market.

4.2.3.7 F7 - Legitimacy

Plant-based products have in general a positive image, and the main sources of information for consumers are mostly social medias, influencers and communication from businesses. In its Plant Protein award, the Village by CA has included a 'Consumer impact' category, for innovations which support consumers make better and more informed choices when purchasing protein foods (Village by CA, 2018). The Lundi Vert initiative ('Meatless Monday') was launched in January 2019 by a group of scientists and celebrities to encourage consumers encouraging to shift their eating habits one day a week ("Lundi Vert," 2019). The impact of this initiative is still uncertain, however (FR4, Personal Communication, 2019). Another example of the role of influencers comes from the world of gastronomy. For its 2016 edition, the Bocuse d'Or, one of the most prestigious gastronomic competition, only plant-based products were allowed (Bocuse d'Or, 2016; Le Monde, 2016). Most experts interviewed estimates that there is still a need to inform consumers on the benefits of plant proteins through more fact-based yet accessible campaigns (FR3, FR4, FR6, FR12, FR16, Personal Communications, 2019). The democratisation of plant-based products was also raised by two experts (FR6, FR16, Personal Communications, 2019). These products are mostly demanded by specific categories of the population, that are younger, urban and often wealthier and the communication around those products is directly oriented towards them. The increasing range of retailer brand's products may help disseminating plant protein alternatives to a wider audience. To date, there are no public campaigns from public authorities or the PNNS. Besides, with a growing interest in plant-based products, critics are also on the rise. Publications from consumer associations exposed the lack of nutritional qualities of some products and the high amount of isoflovones in certain soy foods, which may have health impacts (60 millions de consommateurs, 2017; UFC-Que Choisir, 2019). Also, recent attacks against a butcher in Lille by an anti-specist group also drew criticism against those extreme pro-vegan actions (La Voix du Nord, 2019).

4.2.3.8 Performance of the TIS

Ratings for each function are based on the average scores given by the experts and is illustrated in Figure 10. All functions were rated average, around 2.9 and 3.3. This reflects the willingness within this region to support protein transition, and the presence of many actors, networks, and infrastructures that could be leveraged, but that are not specifically dedicated to plant proteins. The TIS being still at a relatively early stage of development, all functions are expected to be important. However, key barriers to consolidate the development phase lie in the functions of entrepreneurial activities (F1) and the knowledge development (F2) and their linkages. Although

multinational companies can source knowledge anywhere, new knowledge developed in the region is a source of potential business opportunities and entrepreneurial projects, as demonstrated by the specialised knowledge hub in Gelderland. Furthermore, to prepare for the take-off phase, particular attention must also be brought to the creation legitimacy (F7). The prospect to introduce plant-based meals in canteens is an interesting first step as it provides an avenue not only to create market demand (F5), but also to educate consumers (F7). Besides these priority functions, other functions also play an important role. It is too early to assess the impact of the bioeconomy masterplan, but the upcoming protein action plan (F4) developed by the regional administration in association with other key regional players is expected to clarify priorities. The abundant local primary resources and primary transformation activities (F6), coupled with strong expertise on extraction processes (F2) are certainly key resources to leverage. Yet, the development of agro-food activities is still lagging behind.

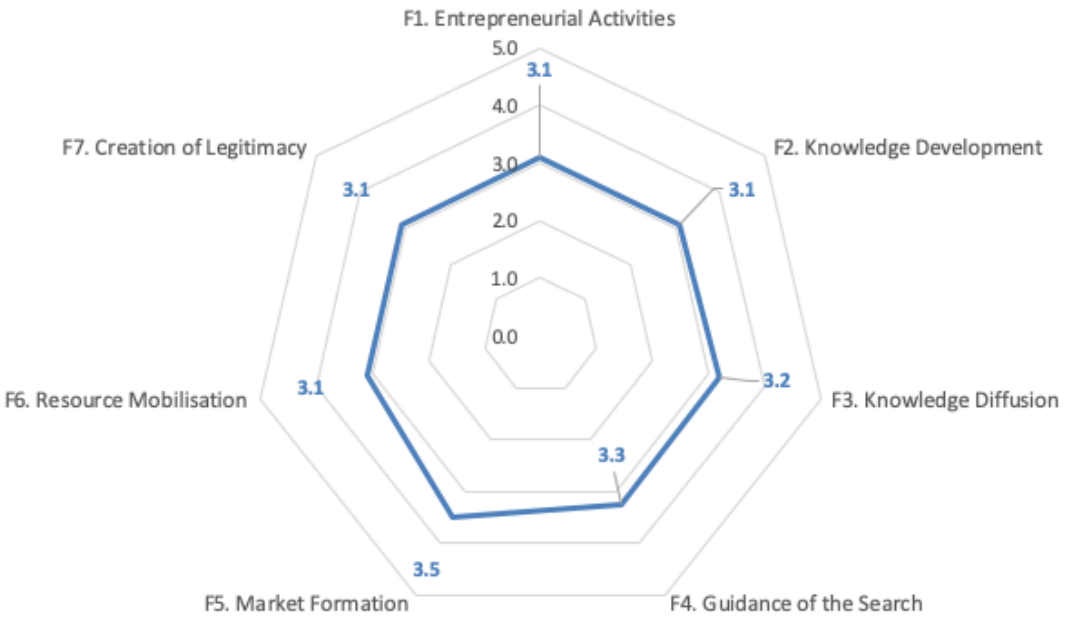


Figure 13. Function Scores in Hauts-de-France

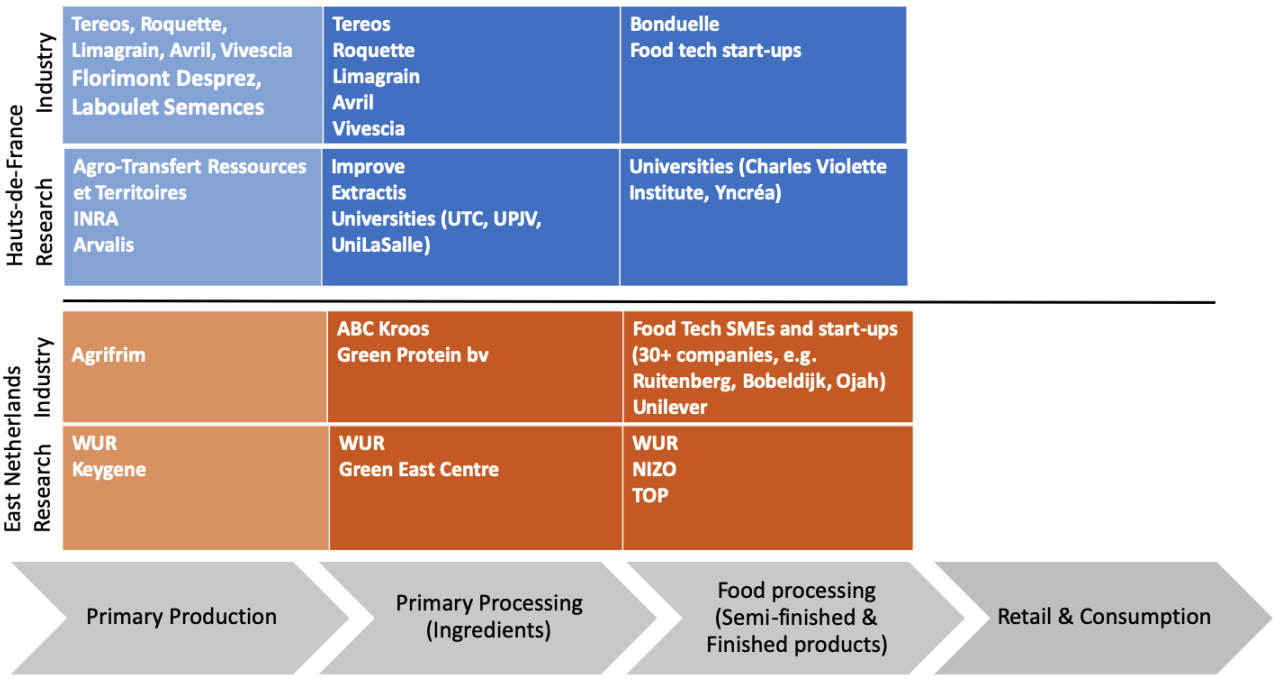
4.3 Comparing East Netherlands and Hauts-de-France

This section highlights key similarities and contrasting aspects between the two cases. Looking at the two TIS structures and functions, and their regional contexts, it becomes quickly apparent that, although both regions have similar inclinations to become European leaders in plant proteins, their respective focus is gravitating on different parts of the production chain. The ambition of the French region is to cover the whole value chain, however the historical focus on agricultural production and primary processing means that activities are predominantly oriented towards ingredient production. In contrast, the East Netherlands boasts a strong

knowledge hub on agrifood resulting in activities mostly oriented towards the production of semi-finished products or consumer-ready products. Figure 14 summarises the main research and industry actors in each region operating in plant protein primary processing and food processing. The primary production stage is beyond the scope of this research, yet interviewees mentioned several industry and research actors they engage with (NL1, NL2, FR3, Personal Communications, 2019). As it is a key bottleneck for the protein transition, those are also indicated.

With respect to the TIS functions (Figure 15), distinctive differences appear with the entrepreneurial activities (F1), knowledge development (F2) and creation of legitimacy (F7). The East Netherlands exhibit a stronger entrepreneurship. Although it may not be as strong as in other parts of the world (United States or Israel) and could be improved (NL2, NL4, NL8, NL17, Personal Communications, 2019), it is relatively active compare to other parts of Europe (NL3, NL6, NL9, NL10, NL11, Personal Communications, 2019). Besides, Dutch entrepreneurs started exploring protein alternatives earlier, with several companies now active in this field for 10 years or longer. Consequently, they have built a wealth of experience and knowledge especially on meat alternatives. However, very few entrepreneurial activities are developed on extraction processes. In comparison, efforts to stimulate entrepreneurship in Hauts-de-France started in earnest about three years ago, with projects stimulated by different student challenges and call for projects. Great expertise on extraction processes can be found in this region, yet the knowledge base on plant proteins and their food application is relatively weak with a lack of visibility and coordination among academic research. In addition, a certain competition or lack of collaboration between industrial actors further hinder the emulation and transfer of explicit and tacit knowledge in the innovation system. Finally, with regards to legitimacy creation, more efforts to create awareness seems to occur in the Netherlands. However, in both regions, there is a lack of clear and explicit governmental engagement to raise consumer awareness and promote plant proteins, as it is seen as a sensitive, if not "unethical" issue (FR6, Personal Communication, 2019). Instead, efforts are either coming from bottom-up civilian initiatives and marketing campaigns from the food and retail industry. Without discounting these efforts, it entails a lack of objective and independent sources of information accessible to the public. Other common issues encountered in both regions reflect the global challenges in the protein transition. Overall, there is a need to consolidate a fragmented supply chain and respond to specific knowledge gaps to stimulate crop breeding, improving extraction processes, and gaining better understanding of new proteins' functional and organoleptic properties. Finally, entrepreneurs in food technology face common barriers to industrialisation, namely the access to pilot production facilities and access venture capital.

Figure 14. Plant Proteins Value Chains in East Netherlands and Hauts-de-France



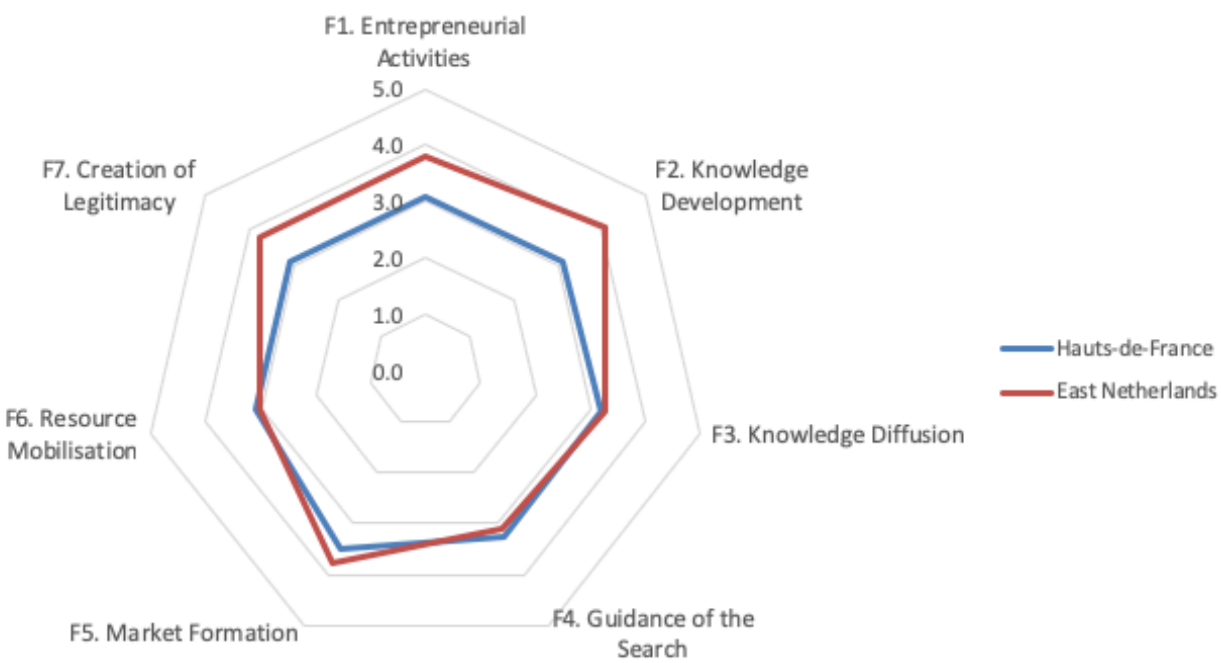


Figure 15. Comparative Scoring of TIS Functions

5. Discussion

5.1 Theoretical Considerations

The findings revealed several interdependences between the technological innovation system for plant proteins and its regional embedding, supporting the argument made by Coenen et al. (2012). Although this had been illustrated by comparing different national TISs, the importance of the regional level has not been explored hitherto (Wieczorek et al., 2015). Applying a regional analytical lens helped put the findings into context, shedding light on how technologies, institutions and regional contexts co-evolved over time in these particular regions. In turn, this information coalesced into a coherent set of conditions that explain the predisposition for plant proteins innovation in these specific areas (Coenen et al., 2012). Both regions display distinct regional assets, such as infrastructures and accumulation of specific skills and knowledge which form the basis of their competitive advantage. Consequently, a path-dependent development and co-evolution of institutions and organisations led to the emergence of plant proteins as a strategic area of innovation in both regions. Each innovation system contributes to the local economies by both utilising and contributing to these regional assets. As an early mover in the field of plant-based food, East Netherlands is valorising on its strong knowledge and expertise on food production to develop consumer-oriented products, specifically meat alternatives, and has been accumulating knowledge and experience for over a decade. In the French region, the desire to create value through agro-resources had been at the heart of regional economic development for over three decades. With recent institutional reform and the merger of two former regions, one rich in agricultural resources, and the other oriented towards industrial activities, the potential for developing new proteins came to the fore. By integrating element of RIS in the analysis, it appears that interactive innovation plays an important role in both cases. This is facilitated by clusters and the agglomeration of research and industry actors in food technology in the case of East Netherlands, and in bioeconomy in the Hauts-de-France, leveraging specialised proximity capital. This in turn stimulate institutional learning for the most innovative companies. A greater openness to sharing and collaborating in the Netherlands was observed, exemplified by the activities of the TPC and the various public-private partnerships such as the SFI. The diversification of some primary processors in Hauts-de-France to produce plant protein ingredients and consumer products also indicate efforts to adapt their core activities. Finally, both systems exhibit interactive and collaborative governance mechanisms to support regional economic development. The research enabled the identification of region-specific barriers to the wider diffusion of plant proteins. With limited access to agricultural resources and primary processing, entrepreneurs in East Netherlands are limited in their capacity to both innovate with novel sources of proteins and scale up production of foodstuffs already on the market. The later interest of the food industry in plant protein innovation

in France means that food tech entrepreneurs there are lagging behind, and are now competing directly with incumbent market actors. Those considerations, in addition to the structural and functional analyses of the plant protein TIS help takes into account the differences in institutional and organizational structures between both regions, clarifying how technological change may develop differently in different contexts (Bergek et al., 2015). Therefore, the inclusion of these region-specific relationships in the TIS contributed to richer outcomes on the strengths and barriers within these innovation systems (Carlsson & Stankiewicz, 1991; Coenen et al., 2012).

With a choice of a regional scale, the connections with other geographical scales become acutely important. Most of the institutional actors and supporting organisations are regionally oriented, however, most public and private knowledge providers and business actors develop activities that span outside the limits of the region. Following the common principle 'think global, act local', the integration of the regional perspective has allowed to shed light on the respective contributions of each regional system to the global diffusion of plant proteins. Indeed, the regional focus did not intend to identify ways for each region to be self-sufficient across the whole value chain. The development of novel sources of nutritious and sustainable proteins is a global challenge that will require efforts internationally. Therefore, by expanding the analytical scale, the relative strengths of each system could be combined to overcome some of the barriers they face (Wieczorek et al., 2013). Both innovation systems have developed rather independently from each other, and each region has the ambition to create economic value through the development of these new food products. Therefore, some level of competition can be expected. Besides, it is trivial to say that these regions are part of a country, and as such, each region will most likely endeavour to develop collaborations at national level as suggested by the creation of Protéines France and the development of a dedicated Dutch national strategy. Yet, European institutions strongly favour trans-regional collaborations across member states, and provides an avenue for each region to leverage their relative advantages. In that respect, the TIS analyses performed give an inkling of potential areas for collaboration, starting with a focus on non-competitive issues including improving the quantity and quality of primary resources and increasing the functionality of protein ingredients. Downstream, coordinated action to educate consumers could be envisaged.

For future research it would be recommended to also incorporate a more holistic approach encompassing the entire value chain would be appropriate, using insights from Potting et al. (2017). At this stage, the value chain is still highly fragmented. Focus on agricultural production and retail and consumer engagement would not only favour the diffusion of plant proteins, but also help design an integral approach to sustainability and circular production throughout. This issue is not front of mind for most actors yet. As production will scale up, and as connection with primary production and consumers will increase, this is becoming a pressing challenge.

5.2 Limitations

Several limitations were encountered during this research. Firstly, a limitation to the validity of this research relates to the accessibility of the interviewees. To allow the study of the two cases within the given timeframe, the interviewees for the Dutch cases were purposefully sampled to a limited number of experts across all types of actors. Indeed, with a relatively developed innovation system, the East Netherlands harbours a vast number of actors active in the field of plant proteins. The feasibility of an exhaustive analysis would have been beyond the scope of this study. With regards to the French case, the lack of response from some key actors from academic research and large ingredient companies resulted in a skewed distribution of the interview sample. This may have had an influence of the overall scoring of the system's function, in particular those of knowledge development and entrepreneurial activities. To improve the validity of the research and reduce these sampling biases, triangulation methods were applied, using desktop research to document research and business' activities such as publications, patents, or companies' annual reports. Besides, the viewpoints of other actors on their activities were sought during interviews and confronted to desk research findings. A second limitation of the methods lie in the focus on one part of the supply chain. This reduced the complexity of the research but led to a less specific analysis. This study would certainly gain in validity, however, by including the expertise from the missing stakeholders. A second limitation of this study pertains to the ambiguous definition of plant protein as a technology. Several plant-based sources are explored to develop alternatives to animal proteins, and they required different technologies to be extracted and processed, all at different stages of development. Consequently, the phase of development was difficult to assess and based on the adoption of meat alternatives on the market. Next, the reliability was ensured by following the methodological steps developed by Hekkert et al. (2011). The chosen theoretical approach combining the TIS and RIS is rather new and was designed to increase the explanatory power of the TIS when comparing the similarities and differences between the two regions. Therefore, additional case studies would help consolidate the theoretical construct proposed in this research. Finally, with only two cases studied, the generalisation is limited reducing the external validity of this research beyond the two locations studied.

6. Conclusions

This research examined the drivers and barriers that facilitate or impede the protein transition in two European regions, the East Netherlands and the Hauts-de-France. To this end, a TIS approach was applied in combination of regional context elements drawn from the RIS theory. This research has two theoretical implications. First, the chosen theoretical approach proved valuable to investigate the influence of regionally-bounded assets and gain a more nuanced understanding on the emergence of hotspots for the development of plant proteins. It also shed light on how the innovation processes were organised between interrelated spatial scales and therefore how the activities within both regions contribute to the global plant protein TIS and could complement each other. The findings show that, in the French case, the TIS for plant proteins is mainly structured by incumbent's ingredient firms and is driven by a need to valorise agro-resources and the presence of existing biorefineries. Whereas in the Dutch case, the strong knowledge base and entrepreneurial culture led to a focus on the development of meat alternatives for consumers by new entrants and meat companies. Key barriers were identified in East Netherlands, that pertain to the guidance of the search and the resource mobilization functions. The lack of a shared vision across all actors, and the shortage of technical pilot infrastructures along with scarcity in primary resources constitute the key bottlenecks for the East Netherlands innovation system. Also, and albeit scoring well, the legitimacy and market formation functions are essential and must be considered carefully to consolidate the take-off phase and move on to the acceleration phase. They are both closely interconnected as they relate to the engagement with consumers (and citizens). In the Hauts-de-France case, limitations relate to the entrepreneurship, knowledge development and the legitimacy functions. The knowledge base is dispersed, lacking a clear and explicit priority on plant protein and gravitate towards extraction processes rather than food technology. This limits the exposure of local entrepreneurs to potential business opportunities that could be exploited. Several organisations are structuring the entrepreneurship effort in the food tech sector, yet the plant protein focus is relatively recent explaining why this regional TIS is at a less advanced stage of development. Finally, legitimacy needs to be reinforced to trigger other key functions including the market formation, entrepreneurship, and in turn, the mobilization of resources.

Recommendations

Recommendations for policy and businesses are drawn based on the findings of this research.

As it reviews its circular economy policy, the province of Gelderland can outline clearer and commonly agreed objectives to support the development of plant proteins, in coherence with national and European goals. First, it is an opportunity to reaffirm its ambitions to design truly circular food production systems. In the case of plant proteins, this necessitates collaborating within and outside

the region to stimulate circular production of agricultural resources, utilisation of residue and co-product streams, evaluation of the environmental performance of extraction and food production processes, among others.

By tapping into the agronomic and biotechnology expertise existing in the Food Valley ecosystem, as well as building on pilot projects with Agrifirm to stimulate local soy production, it can support initiatives for improving the quality and yields of pulses and other protein-rich crops in Netherlands and in Europe.

To overcome the resource bottleneck and encourage production scale-up, structural changes in the innovation system are required. This research identified the lack of a shared food grade technical pilot platform that can be used by the industry, collaboratively or independently, to facilitate passage to the industrialisation phase. The current project of setting up a field lab in the region could respond to this concern, providing it is planned as an independent structure that is financially accessible to small entrepreneurs, for instance through subsidies.

Another important aspect relates to the stimulation of the market and engagement with consumers. Despite a growing interest from consumers, behaviours are changing slowly and the consumption of animal proteins is not reducing significantly. Using public procurement, education campaigns, collaboration such as with local chefs and influencers, there is an opportunity to develop the market size for producers while raising awareness for consumers.

Finally, as The Protein Cluster grows in size, its role and services provided to its members is evolving and becomes more complex. The primary aim to establish the TPC was to leverage the applied knowledge, the experience and resources of entrepreneurs to stimulate further innovation and business growth. This is extremely beneficial and should remain as part of their core activities. As the adoption of plant protein is on the cusp of accelerating, the need to increase production capacity and improve the quality of products intensify. To that end, TPC should consider increasing transversal collaborations by strengthening outward linkages with knowledge institutes, universities, local incubators and large companies, with a focus on identified knowledge gaps (chiefly processes, protein functionality, diversification of protein sources, and in-depth consumer insights).

Although it is a competitive and strategic market, coordination can be sought with the Hauts-de-France on non-competitive issues to avoid doubling efforts. The next European funding programs for the period 2021-2027 provide the perfect opportunity to set up collaborative initiatives in areas such as:

- the mutualisation of expertise to develop crop breeding programs.

- combining complementary expertise on protein extraction and product formulation to improve transformation processes and protein functionality, organoleptic qualities and nutritional values.
- Develop fact-based independent communication tools to complement existing efforts from the industry and civil society.

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Appendix A. Draft Interview Guide

Introduction

The purpose of my master thesis is to research the key drivers and barriers for plant protein innovation in France and the Netherlands, and identify how to optimize market prospects. This interview shall take approx. 45 minutes and will be recorded if there is an agreement from the interviewee. Findings can be anonymised upon request. Before the interview starts, a general explanation of the TIS functions is provided.

General Questions

- Could you please briefly introduce yourself and explain your role in the company/organisation.
- What is the core activity of your company/organization with regards to protein transition?
- In your views, what are the main reasons/motivations to develop plant-proteins?

Development Phase:

- In what stage of market development are plant-protein innovations? Is upscaling of solutions already taking place?
- Are there working prototypes of solutions?
- Are there commercial applications without subsidy?
- Is there fast market growth or market saturation?

F1. Entrepreneurial Activities

- Is the number of industrial actors in the system sufficient?
    a. If not, which actors are lacking?
    b. Are they mostly new entrepreneurs or incumbents?
    c. Have you seen any industrial actors failing/abandoning the market?
- Do they innovate sufficiently in terms of experimenting with technology, business model/revenue, product design?
- What raw materials or ingredients are used and sourced?

F2. Knowledge Development

- Is the knowledge available sufficient to develop adapted technical solutions?
    a. How many patents, projects, publications are there?
- Is there enough knowledge available on consumer and chain actor behaviour?
- Who is most active in developing knowledge?
- How is knowledge development mostly funded?

F3. Knowledge Exchange

- Is the level of knowledge exchange on plant protein solutions high enough within the system, in particular between scientists and market actors?
- Is the level of knowledge exchange on plant protein solutions high enough in the product chain?
    b. Do you think the level of information available on the market is sufficient?
- Are there particularly strong relationships within the system?
- What are the key drivers for knowledge exchange?
- What are the key barriers/ issues for knowledge exchange?

F4. Guidance of Search

- Is there a clear vision on how the industry and market should develop (e.g. with regards to growth perspectives, technologies &products design)?
- If so, is this vision broadly shared by different actors?
- How does it structure activities of actors in the supply chain?
- Are there policy goals supporting or impeding the development of plant proteins?

F5. Market Formation

- How would you assess the current market plant proteins (niche of developed)?
- Who are the leading actors/institutions?
- Are market actors active in creating consumer awareness?
- Are companies investing sufficiently?

- Does the government have supplementary policies, which help in opening markets?
- What are the key barriers to the uptake of plant proteins?
- What key actions should be taken to overcome these barriers?
- Do you foresee any opportunities for the French and Dutch innovation systems to collaborate or join forces, in order to increase the uptake of plant proteins?

F6. Resource Mobilisation

- Are all relevant product chain partners actively involved in realising plant protein solutions?
- Is there sufficient funding for realising these solutions?
- Are there specific physical means hindering the realisation of these solutions?

F7. Legitimacy Creation & Overcoming Resistance

- Is there resistance against plant proteins for human consumption? (system partners, mainstream consumers, regulation)?
- Is sufficient action being taken to overcome these forms of resistance?
- Are there any advocacy group/coalition being formed?
- How would you assess consumer perception of plant protein products?
- Is the level of consumption of plant-based protein increasing/ What is the relative consumption of plant protein compare to animal proteins?

Closing.

Appendix B. Key Actors in East Netherlands

Category	Name
Government Organisations	Province of Gelderland
	Province of Overijssel
Support Organisations (Public)	Foodvalley NL
	TPC
	Oost NL
	StartLife
Research & Education	WUR (Public)
	NIZO (Private)
	TOP bv (Private)
	Green East Centre (Private)
Industrial Actors (TPC Members)	BIC Protein
	Biobite
	ABC Kroos
	Bobeldijk Food group
	Colzaco
	Duplaco
	Dutch Soy
	Freggies
	Green Meat Products
	Green Food 50
	It's Greenish
	Meatless
	MFH_Pulses
	Multiflour
	De Nieuwe Melkboer
	Ojah
	Pulse Shack
	Ruitenberg Ingredients
	The Green Table
	Lactotrade
	Contined Food Ingredients
	Phycom
Industrial Actors (outside TPC)	Vivera
	Zwanenberg Food Group
	2B Different
	UmaMeats
	Algreen
	Algae Factory
	Frank Food Products
	Hulsof Protein Technologies
	Kagim Group
	Mol Fresh Food
	CDC Food Physica
	Nevidon BV
	Unilever

Appendix C. Key Actors in Hauts-de-France

Category	Name
Government Organisations	Region Hauts-de-France
Support Organisations	Pôle IAR
	Pôle NSL
	Village by CA
	Euralimentaire
	Certia Interface
	BPI France
	HDFID
Research & Education	Université de Lille
	ISA / Yncrea
	Universitéß Jules Verne Picardie
	Université Technologique de Compiègne
	UniLaSalle Beauvais
	Institut Charles Violette
	Improve
	Extractis
	Adrianor
Industrial actors	Youpeas
	Pleurette
	Dosecore
	Alterfoodie
	Sweet Pumpkin
	Tartimouss
	Roquette
	Bonduelle
	Tereos
	Limagrain Céréales Ingrédients
	Sofiprotéol (Groupe Avril)
	Vivescia