FOOD COST

Mapping lock-ins to the internalization of externalities in agri-food systems

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FOOD COST | Redefining the value of food

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Content

EXECUTIVE SUMMARY **4**

1 INTRODUCTION **5**

2 OBJECTIVES AND ACTIVITIES **7**

2.1 OVERVIEW OF FOODCOST WORK PACKAGE 3 7
2.2 SPECIFIC OBJECTIVE OF FOODCOST SUBTASK 3.1.3 – MAPPING LOCK-INS 7
2.3 OVERVIEW OF IMPLEMENTED ACTIVITIES 8
2.3.1 From gap to opportunity – Development of a guidebook *8*
2.3.2 Mapping lock-ins in the context of FOODCoST – Application of the guidebook's methodology *8*

3 A GUIDEBOOK TO MAPPING LOCK-INS **9**

3.1 THE SIGNIFICANCE OF MAPPING LOCK-INS 9
3.2 PRESENTATION OF THE GUIDEBOOK 10

4 BARRIERS IMPACTING THE INTERNALIZATION OF EXTERNALITIES **11**

4.1 COLLECTING DATA 11
4.1.1 Literature review *11*
4.1.2 Case studies *14*
4.2 ANALYZING DATA 17
4.2.1 Comprehensive overview of barriers to internalizing externalities in food systems *18*
4.2.2 Assignment of barriers to the FOODCoST case studies *29*
4.3 EXPLORING BARRIERS ACROSS CONTEXTS 34
4.4 VALIDATING FINDINGS 37

5 CONCLUSIONS **38**

6 REFERENCES **39**

7 APPENDIXES **43**

7.1 APPENDIX 1. ANALYSIS OF RESULTS FROM THE PRELIMINARY ONLINE QUESTIONNAIRE 43
7.2 APPENDIX 2. STRUCTURE OF THE FOODCOST CASE STUDIES' IN-DEPTH ONLINE SURVEY 46
7.3 APPENDIX 3. COMPREHENSIVE LIST OF BARRIERS TO THE INTERNALIZATION OF EXTERNALITIES 49
7.4 APPENDIX 4. SPECIFIC BARRIERS' ELEMENTS MENTIONED IN THE FOODCOST CASE STUDIES (THROUGH PRELIMINARY QUESTIONNAIRE, ONLINE SURVEY AND INTERVIEW), BY MAIN CATEGORIES OF BARRIERS 51
7.5 APPENDIX 5. GUIDEBOOK TO MAPPING LOCK-INS 60

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Executive summary

Our current food systems are plagued by significant environmental, social, and health externalities that are not accounted for by actors of our food systems. This failure perpetuates unsustainable practices by incentivizing short-term profits over long-term sustainability. Recognizing and acting upon these externalities is critical for transforming food systems, but the implementation of such strategies faces major barriers that impede the adoption of more sustainable alternatives.

Through the FOODCoST project, we aim to shed light on the locked-in status of our agrifood systems by mapping the diversity of barriers obstructing greater internalization across food value chains. A key output of this process was the development of a guidebook methodology for systematically identifying the barriers generating lock-in situations. Applying this guidebook, the study identified, through both case studies exploration and literature review, 58 barriers spanning technical, organizational, financial, market-related, governance-related, knowledge-related, relational, socio-cultural and external dimensions. While context-specific, certain barrier categories like governance, technical, financial and socio-cultural issues appeared consistently across cases, providing valuable insights into common challenges that must be addressed at both policy and implementation levels. The diversity at all levels of the value chains and the interconnectedness of these barriers underscore the systemic nature of lock-in obstructing externalities identification and management.

To unlock more sustainable trajectories, actors must holistically address this web of reinforcing barriers. In this endeavour, our mapping offers a valuable checklist for identifying specific barriers likely to obstruct internalization efforts, serving as a foundation for finding effective solutions. Understanding interconnections between barriers can then reveal key leverage points where efforts should be concentrated.

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1 Introduction

In an era marked by increasing environmental concerns, social disparities, and health crises, our current food systems have come under the spotlight as unsustainable and in need of urgent reform. The manifold challenges posed by our food systems have garnered widespread recognition due to their significant environmental, social, and health implications. These challenges persistently result in considerable costs, all the while falling short of ensuring accessible, affordable, and nutritious food options for everyone (World Bank 2016; FAO 2020; WHO 2023). At the heart of the problem lies the externalization of production costs. These costs, encompassing environmental degradation, social inequalities, and adverse health effects, are not factored into market prices, and therefore not in decision making (UNFSS 2021). Consequently, decision-makers across food value chains often prioritize short-term profits over the long-term well-being of the environment and human population. This market failure perpetuates a situation where the costs of unsustainable practices are borne by society as a whole, while the benefits of healthy diets go largely unrecognized. Efforts to establish sustainable food systems are likely to face obstacles as long as sustainably produced, nutritious foods remain costlier and less profitable than their unsustainable, less healthy counterparts (UNFSS 2021).

Addressing these externalities issues necessitates a profound shift in perspective. First, to pave the way towards sustainable food systems, externalities should be identified and (to some extend) quantified. It is essential that all stakeholders within food value chains, from producers to consumers, gain increased awareness of the externalities they are responsible for. Armed with this information, we can begin the process of internalizing externalities, leveraging a variety of public or private mechanisms to encourage responses that promote sustainable production and foster healthier consumption patterns. The FOODCoST project can play a role in this shift in perspective. It focuses on clarifying methods for quantifying and assigning monetary values to both positive and negative externalities of food systems. Moreover, it explores policy and business-level strategies aimed at embedding the true cost of these externalities into market prices. By doing so, it not only underscores the importance of recognizing the full economic impact of our food choices but also provides actionable solutions to drive the transformation towards sustainable and equitable food systems.

However, moving towards effective internalization of externalities is a complex agenda that must confront the numerous barriers obstructing the transition to more sustainable food value chains. While developing innovative frameworks for the internalization of externalities through policies and business models and strategies (as explored in Work Package 2 and Work Package 3) is essential to lay the groundwork for sustainable food systems, it is equally essential to comprehend the factors that can either facilitate or hinder the adoption of these frameworks. Such impeding factors are what we term ‘barriers’ to the internalization of externalities. Collectively, these barriers can reinforce one another, resulting in a system that is locked in its current state, resistant to change. Failure to adequately address these lock-ins can render ineffective strategies aimed at integrating true cost of food along the value chains, whether at the policy or business level.

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Beyond the commonly assumed barriers to internalization, such as the low willingness of actors – particularly consumers – to pay more for sustainable products, we suspect the existence of many forms of barriers throughout every stage of the value chains. This highlights the necessity to adopt a systemic approach in studying barriers locking-out internalization strategies. In this report, we will thoroughly examine the diverse manifestations of these barriers within various components of the food system. Through this analysis, we aim to explore their profound implications for endeavors aimed at internalizing externalities within agri-food systems.

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2 Objectives and Activities

2.1 Overview of FOODCoST Work Package 3

The focus of Work Package 3 within the FOODCoST project is on exploring business and value chain models in the context of the internalization of externalities (IOE). It stems from an initial observation: *while the importance of internalization is widely acknowledged, its implementation seems to remain limited in practice* (Brett et al. 2001; Buttel 2003; Pieper, Michalke, and Gaugler 2020; Rastoin 2022; von Braun and Hendriks 2023). Our aim is to delve into the reasons behind this gap. In WP3, we test two explanatory hypotheses:

1. The concept of internalization remains vague and requires clearer identification and characterization.
2. Current systems are locked into dominant, well-established pathways, hindering change towards potentially superior alternatives, including the internalization of food externalities.

Our objectives are thus twofold:

1. To address the two hypotheses presented above by creating knowledge (Task 3.1).
2. To equip practitioners with tools and recommendations to facilitate the scaling-up of internalization efforts (Tasks 3.2 and 3.3).

In Task 3.1, we tackle the first hypothesis by compiling an inventory of business models and strategies that facilitate the internalization of externalities (sub-task 3.1.1) and by providing a detailed characterization of these models and strategies (sub-task 3.1.2). The outcome of these sub-tasks can be found in the FOODCoST Deliverable 3.1. Addressing the second hypothesis involves identifying the multiple barriers creating a lock-in situation that prevents actors and systems from transitioning towards greater internalization (sub-task 3.1.3). The outcome of this last sub-task is presented in the present report.

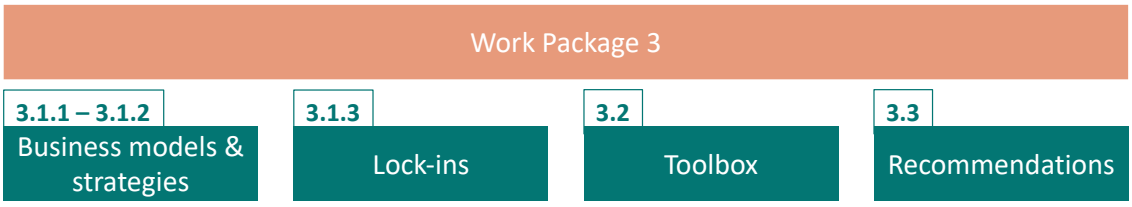

Figure 1. Structure of the FOODCoST WP3

2.2 Specific objective of FOODCoST Subtask 3.1.3 – Mapping lock-ins

Within the FOODCoST Subtask 3.1.3, we specifically aim at pinpointing the lock-in situation faced by agri-food actors when they want to internalize negative externalities, turn positive externalities into valuable asset or develop sustainable food value chains.

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This is achieved through the identification of the barriers structuring the lock-in across various levels of the value chain.

2.3 Overview of implemented activities

2.3.1 From gap to opportunity – Development of a guidebook

At the start of the project, we noted a gap in the existing research landscape regarding lock-ins phenomena, as there was no commonly accepted methodology for their identification. The work initiated as part of the FOODCoST project offered the opportunity to pave the way by proposing general guidelines for mapping lock-ins and identifying levers for overcoming them.

The first activity undertaken was to draw up a guide to mapping lock-ins. This guidebook is briefly presented in section 3 (A guidebook to mapping lock-ins) and is accessible in full in Appendix 5.

2.3.2 Mapping lock-ins in the context of FOODCoST – Application of the guidebook's methodology

We then applied the proposed guidelines to identify barriers generating lock-in' situations within the context of internalizing externalities within food systems. Section 4 (Barriers impacting the internalization of externalities) presents the steps performed and the results obtained.

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3 A guidebook to mapping lock-ins

3.1 The significance of mapping lock-ins

Lock-ins are a fundamental concept in understanding the dynamics of agri-food systems. They refer to situations where various factors within the system, such as policies, technologies, cognitive frames, infrastructure, and social systems, become intertwined, creating stability and resistance to change (Truong, Trencher, and Matsubae 2022). As a result, lock-in reproduce the status quo and hinder other pathways of development, maintaining many systems, including agri-food systems, in their current unsustainable states (De Herde, Maréchal, and Baret 2019; Weituschat et al. 2022). For instance, despite increasing advocacy in favor of agroecology, this agricultural narrative is kept at bay by numerous factors (Vanloqueren and Baret 2009; Conti, Zanello, and Hall 2021). These individual factors, which we refer to as “barriers”, include not only dominant research priorities in support of industrial agriculture, but also behavioral preferences towards historically established production modes, infrastructure that supports the most profitable crops, institutional settings and policies that still favor industrial agriculture, and power players that dismiss agroecology (Conti, Zanello, and Hall 2021). Collectively, these barriers impede the change of or within the system and create a situation of lock-in.

Lock-ins often emerge from path-dependent processes. Path-dependency refers to a situation where current decisions or choices are influenced by past decisions, and these past decisions constrain or limit future choices (Conti, Zanello, and Hall 2021; Cowan and Gunby 1996). In other words, the path taken in the past can have a significant impact on the options available in the future. While initial decisions may have been rational at the time they were made, they can lead to inefficiencies along the path (Lecocq and Shalizi 2014), resulting in an unsustainable trajectory that becomes extremely difficult to dislodge.

Moving beyond current patterns of unsustainable food production and consumption therefore requires a systemic understanding of how agri-food systems can be unlocked, so that change becomes possible and a reconfiguration of systems into more sustainable forms can actually take place (Conti, Zanello, and Hall 2021). The first step of this process is to understand how the system is blocked. We achieve this through the identification – or ‘mapping’ – of lock-in. Mapping lock-in involves uncovering the multifaceted barriers within the system, as well as examining how they interconnect. By doing so, we aim to provide a diagnostic tool that can identify obstacles and challenges to a transition in a given system. Subsequently, the identification and understanding of lock-ins serve as a foundation for recognizing opportunities for innovation and change, thereby highlighting the necessary levers for change.

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3.2 Presentation of the guidebook

In this guidebook, we introduce a ten-step methodology designed to facilitate the identification of both barriers and levers to transition. These steps draw on the extensive research conducted by Sytra, a research team from the Université catholique de Louvain (Belgium), informed by studies spanning various contexts (Vanloqueren and Baret 2008; 2009; Baret et al. 2013; De Herde, Maréchal, and Baret 2019; De Herde, Baret, and Maréchal 2020; Morel et al. 2020; Amrom et al. 2021). The methodology's implementation is further refined through a thorough review of existing literature, consultations with experts, and insights gained from our practical experience. This guidebook, designed as a working paper, serves as a supportive tool for identifying barriers creating a lock-in situation, thereby hindering the transition of any agri-food system. It will be subject to continuous improvement as feedback comes in.

The ten-step methodology unfolds across three levels: scoping, implementing, and finalizing the lock-in research. The scoping phase aims to precisely define the boundaries of the system under consideration (step 1) and map the involved actors (step 2). Recognizing that barriers creating a lock-in can vary based on the system's limits and its actors, these initial steps serve as the indispensable foundation for a rigorous investigation of lock-ins. Once the system and its actors are clarified, the methodology progresses to the second level: identifying individual barriers contributing to the lock-in, as well as levers to overcome them. This implementation phase emphasizes close collaboration with key informants representing actors of the system to ground the identification process in collective intelligence (steps 3 to 9). Lastly, at the finalization level, we underscore key considerations for synthesizing and reporting results. Figure 2 provides an overview of the proposed ten-step methodology and its main outputs. The full guidebook can be found in Appendix 5.

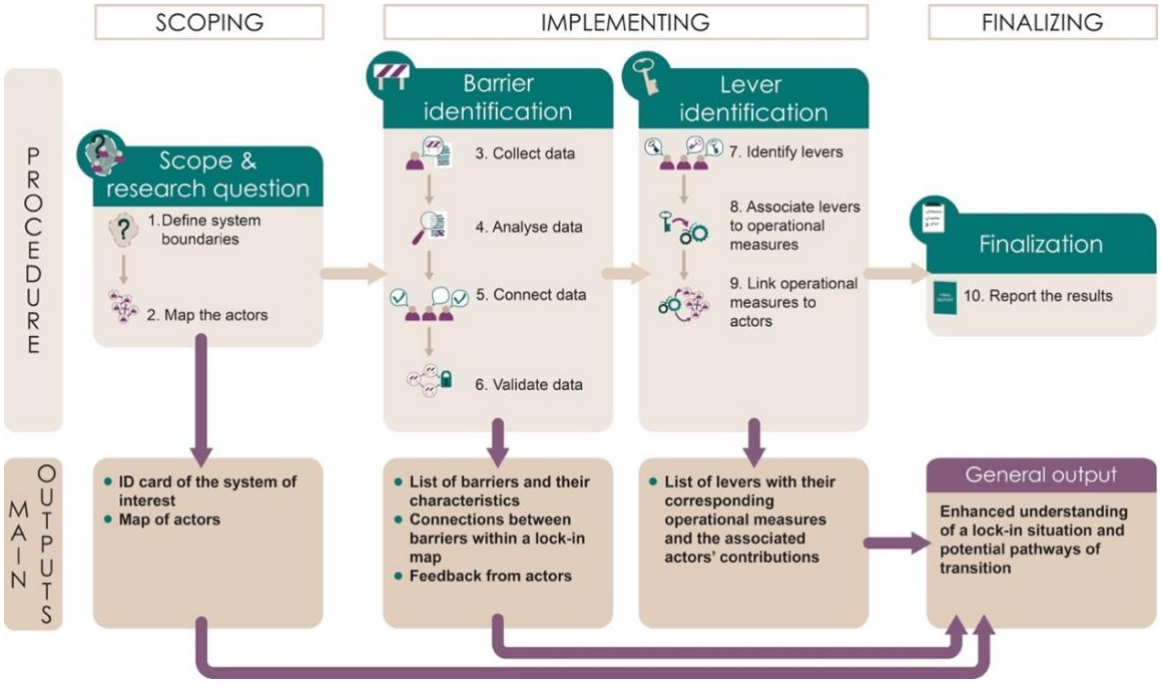

Figure 2. Overview of the ten-step methodology and its main outputs to map lock-ins

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4 Barriers impacting the internalization of externalities

This section presents the process and results of applying the guidebook's methodology to identify barriers to the FOODCoST context of internalizing externalities in food systems.

4.1 Collecting data

The investigation into barriers to the internalization of food externalities is based on data sourced from both established literature and project's case studies.

4.1.1 Literature review

We conducted a comprehensive literature review with a specific focus on the interrelated concepts of "lock-ins" or "barriers" and "internalization of externalities". Our research strategy was structured in two main phases: (1) systematic database search, (2) addition of articles through snowball identification.

Firstly, we executed a systematic search of relevant scholarly literature on Scopus using the following search terms: "TITLE-ABS-KEY (("lock-in" OR "barrier") AND internali* AND externalit*)". We deliberately excluded the concept of "food system" at this stage, in order to encompass all articles discussing barriers to the internalization of externalities across various research fields. The search was conducted to include articles up to our research date in October 2023. The search yielded 49 results in Scopus (Figure 3).

Subsequently, we employed a snowball identification method to further enrich the pool of articles relevant to our research objectives. We critically examined references used in the articles identified in the initial search, allowing us to uncover additional pertinent articles that may have been missed by the primary database query. This second strategy added 20 records to be integrated in the in-depth evaluation. After removing duplicates, we screened the titles and abstracts of the remaining records to identify those relevant to the investigation of barriers to strategies of internalization. This screening led to the selection of 31 records for further in-depth assessment. Among these, six articles were excluded for failing to provide specific insights into barriers within the context of internalization. Consequently, the synthesis incorporated the findings from the remaining 25 studies.

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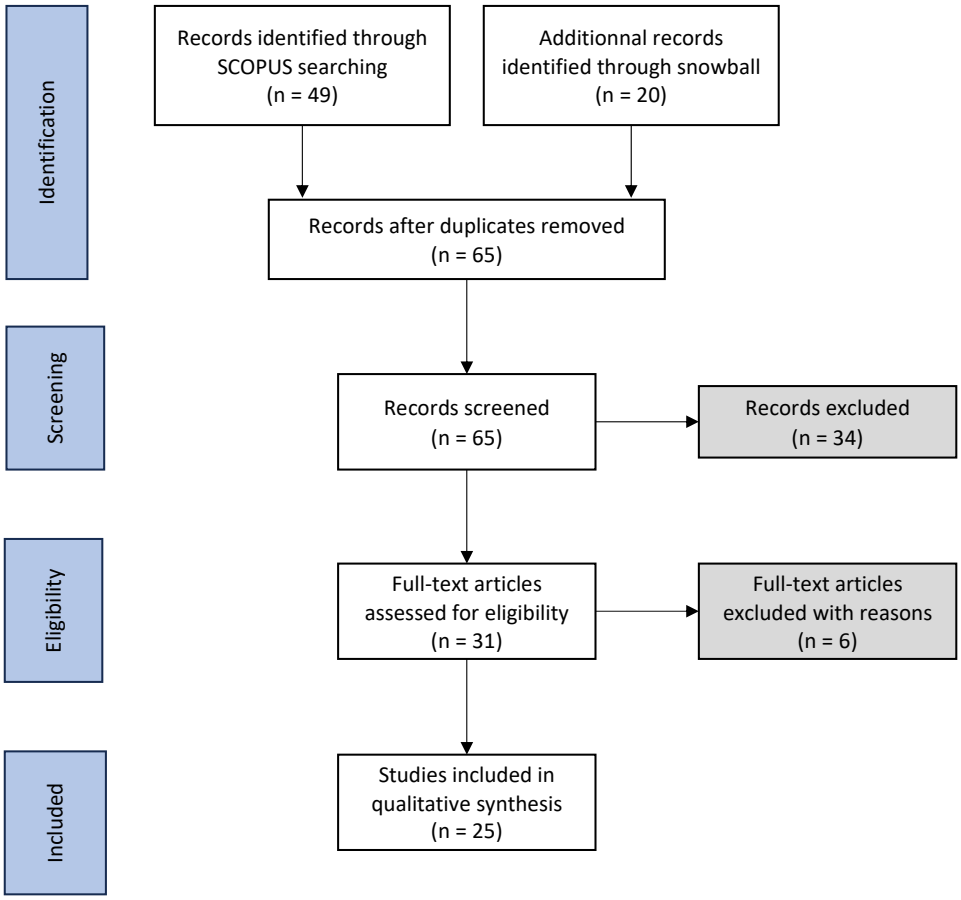

Figure 3. PRISMA workflow diagram. Four review phases are outlined, along with corresponding article numbers.

In total, 135 mentions of factors impeding the implementation of an internalization strategy were identified in the reviewed articles. These internalization strategies most often referred to circular economy (six articles among the 25 studied; Table 1) and technological innovations (six articles). Other internalization strategies included certification (three articles); market-based policy instruments (three articles); recycling and waste reduction (two articles); carbon markets (two articles); corporate sustainability (two articles); voluntary regulations (one article).

The 135 barriers were filtered to remove repetitions, then classified into distinct categories –following the taxonomy outlined in the guidebook– during the subsequent analysis phase.

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Table 1. Overview of the 25 articles included in the qualitative synthesis of barriers affecting internalization of externalities, and the main internalizing strategy they discuss.

Internalization strategy discussed	Number of articles	Articles
Circular economy	6	(Revoyron et al. 2022; Weituschat et al. 2022; Messner, Johnson, and Richards 2021; Conti, Zanello, and Hall 2021; Sopjani et al. 2020; De Herde, Maréchal, and Baret 2019; Meynard et al. 2018; Magrini et al. 2016; Fares, Magrini, and Triboulet 2012; Stassart and Jamar 2009; Vanloqueren and Baret 2008)(Azcarate-Aguerre et al. 2022; Barquet et al. 2020; Briguglio et al. 2021; Desrochers 2002; Farooque, Zhang, and Liu 2019; Takacs, Brunner, and Frankenberger 2022)
Technological innovation	6	(Del Rio 2004; Kurdyukov and Kanurny 2021; Levidow et al. 2016; Mosier, Iverson, and Humphrey 2023; Anthony D. Owen 2006; Yaqoot, Diwan, and Kandpal 2016)
Certification	3	(Gallemore and Jespersen 2019; Grabs 2020; Roberts 2011)
Market-based policy instruments	3	(Marazi et al. 2022; van Grieken et al. 2019; Browne et al. 2013)
Recycling and waste reduction	2	(Aramyan et al. 2020; Johnstone and De Tilly 2006)
Carbon Markets	2	(Lecocq and Shalizi 2014; Miltenberger, Jospe, and Pittman 2021)
Corporate sustainability	2	(Cho and Voss 2011; Walkiewicz, Lay-Kumar, and Herzig 2020)
Voluntary regulations	1	(Lim and Prakash 2014)

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4.1.2 Case studies

The primary data collection, based on the FOODCoST case studies, consisted of three subsequent phases (Figure 4). It started with the establishment of a preliminary overview of barriers affecting the internalization of externalities within the case studies. This overview is based on the collection of information through an online questionnaire, sent to all case study leaders in February 2023, to gauge their comprehension and awareness of the barriers impacting their system (Appendix 1). Together with results from the literature review, this step provided a big picture of the type of barriers that might affect the internalization of externalities and ways of grouping them. This preliminary investigation was then complemented by an in-depth online survey in November 2023, tailored specifically for each case study and designed to pinpoint their specific characteristics and clarify the main barriers they are facing (Appendix 2). Responses were used to prepare the subsequent round of interviews with case studies' leaders according to the distinct context of each case study. These final interviews, held in January 2024, were used to validate and further detail the identification of barriers.

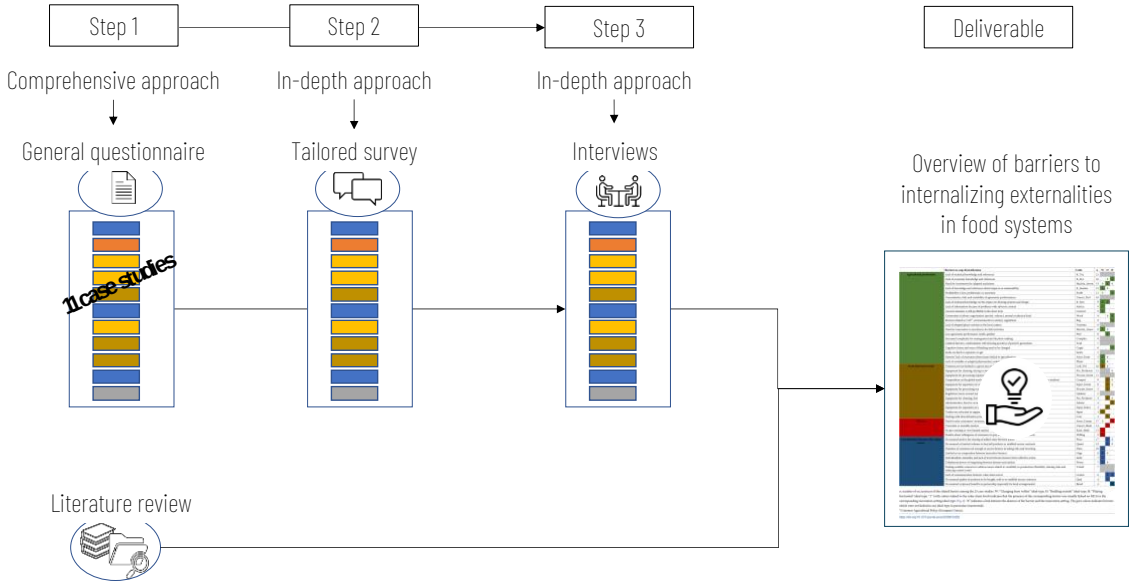

Figure 4. Overview of the data collection steps

Box A. Scope of the FOODCoST case studies

Following the first prerequisite outlined in the guidebook to mapping lock-ins, we assessed the boundaries of the system considered in each case study. The aim, in our case, was to try and uncover similarities to allow for group comparison and classification of barriers according to specific characteristics. Figure 5 summarizes the boundaries of the project's case studies, in terms of principal level of impact within the project and level of action within the value chain.

There appears to be a large heterogeneity in the scope of the case studies, both on the level of impact and the level of action. Some case studies plan to impact the FOODCoST project through methodological lenses, testing alternative valuation methods that are developed to account for externalities (ex. case study 6 that is dedicated to quantifying health and environmental externalities of fish production and consumption). Others are focusing on business aspects, testing concrete actions to improve the impact of their business activities (ex. case study 5 that assesses the feasibility for companies to adopt an integrated framework enabling them to communicate on their extra-financial performances). Finally, some case studies are mostly interested in studying the political constraints and proposing alternative policy measures to allow for a better internalization of externalities (ex. case study 11 that investigates relevant policy interventions for fostering the protein transition at the farm and value chain level in Belgium). Then, certain case studies are positioned at the convergence of these impact pathways, engaging in activities that span across multiple (or all) of these facets (ex. case study 1 that primarily focuses on examining value redistribution within coffee value chains through the application of a TCA methodology, while seeking to raise awareness among business operators and policymakers on the importance of considering externalities). On the level of action, it appears that the FOODCoST case studies successfully cover the different levels of the value chain, from production and transformation to retail and consumption. While this is positive to allow for a systemic analysis of internalization potential, it brings a lot of complexity as many actors and expertise must be considered.

Looking at the commodities covered by the case studies, no similarities could be uncovered neither, as it ranges from very different and specific commodities (such as coffee, meat and alternative proteins, or fish) to a whole companies' portfolio (such as case study 5 focusing on Danone's portfolio), or to no commodity at all (for instance, in case study 8 that is broadly interested in communicating about externalities in food products).

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Case studies	Impact			Value chain level			
	Methodo-logy	Business model	Policy	Production	Transfor-mation	Retail	Consum-ption
1. Alternative Pricing within coffee value chain	X	X	X	X	X	X	X
2. Locally grown high protein non-GM soybeans for feed		X		X			
3. Optimised food-water-energy-carbon nexus in vegetable greenhouse	X	X		X (+marketing)			
5. Financial instruments to shift investments towards sustainable production		X			X		
6. Quantify the externalities of fish consumption and production	X			X			X
7. Scaling the transition to plant-based meat alternatives and biodiverse beef			X	X			X
8. Validating approaches to communicating externalities using true price labels		X	X			X	X
9. Shifting investments to healthy food by disclosing Health-Adjusted Earnings	X	X			X		
10. Decision-Making for Public Out of Home Catering based on External Costs		X	X	X	X	X	X
11. Policy interventions for fostering the protein transition			X	X	X	X	X

Figure 5. Boundaries of the studied case studies, in terms of level of impact within the project and level of action within the value chain

The extensive variability in scope among the systems covered in the case studies influences the scope of the analysis that can be performed. Given the diversity of contexts and the inability to find common grounds, achieving a finely-tuned assessment of barriers within each system is not feasible within the confines of the FOODCoST project. Consequently, the current assessment is limited to a broader scale. To delve into a more nuanced depiction of barriers, experts from each system can utilize the established guidelines to conduct a systemic assessment of barriers hindering the internalization of externalities within their unique context.

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4.2 Analyzing data

The data collected from both literature review and case study interactions were analyzed to extract information that is relevant for the identification of barriers. We provide, first, a comprehensive overview of all barriers to the internalization of externalities in food systems, as identified through this process (sub-section 4.2.1). Barriers were categorized according to the taxonomy outlined in the guidebook. We then present specific implications for the FOODCoST case studies by highlighting the barriers that affect each of them (sub-section 4.2.2). General observations about barriers' occurrence across contexts are finally synthetized in section 4.3 (Figure 6).

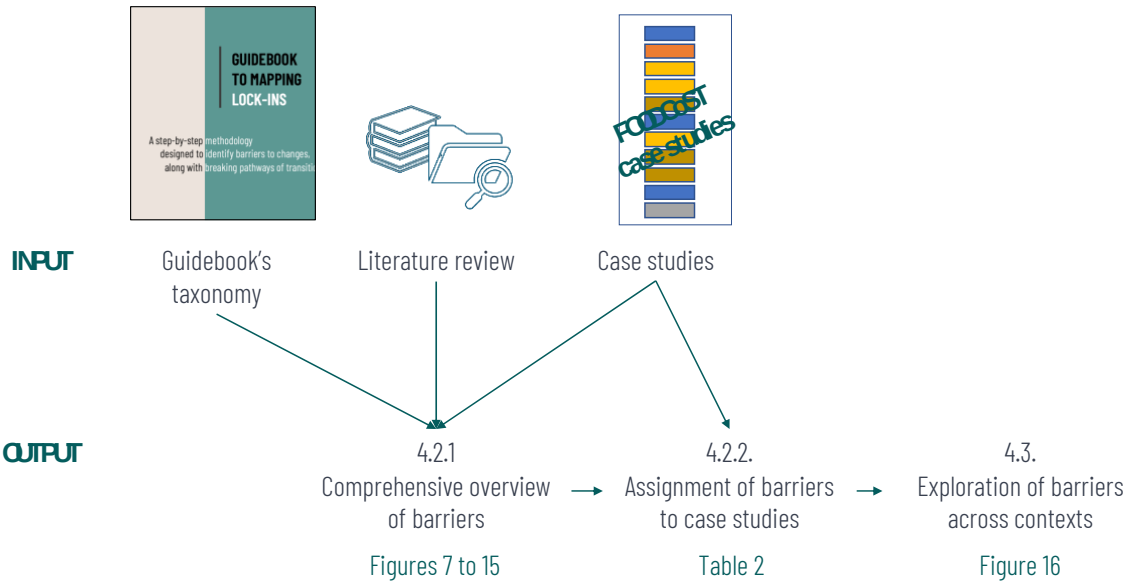

Figure 6. Overview of the main input and output of the analysis process

Besides providing insights into barriers to the internalization of externalities in food systems, the case studies' data collected via the preliminary online questionnaire offered additional insight into the experience and knowledge of case studies' participants regarding barriers. These additional results can be found in Appendix 1.

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4.2.1 Comprehensive overview of barriers to internalizing externalities in food systems

Through both literature review and case studies' exploration, we identified a total set of 58 distinct barriers contributing to locking out internalization strategies in food systems. Among these, eight barriers were exclusively identified within the literature, absent in any case study references; five barriers emerged solely through case study discussions, lacking specific mention in existing literature; while the remaining 45 barriers were identified through a convergence of both literature and case study analyses (details available in Table 2). These barriers were classified into categories following the taxonomy outlined in the guidebook, spanning across technical, organizational, financial, market-related, knowledge-related, governance-related, socio-cultural, relational, and external dimensions (Figure 7). The following sub-sections examine each category separately. The aggregate list of barriers to the internalization of externalities is provided in Appendix 3.

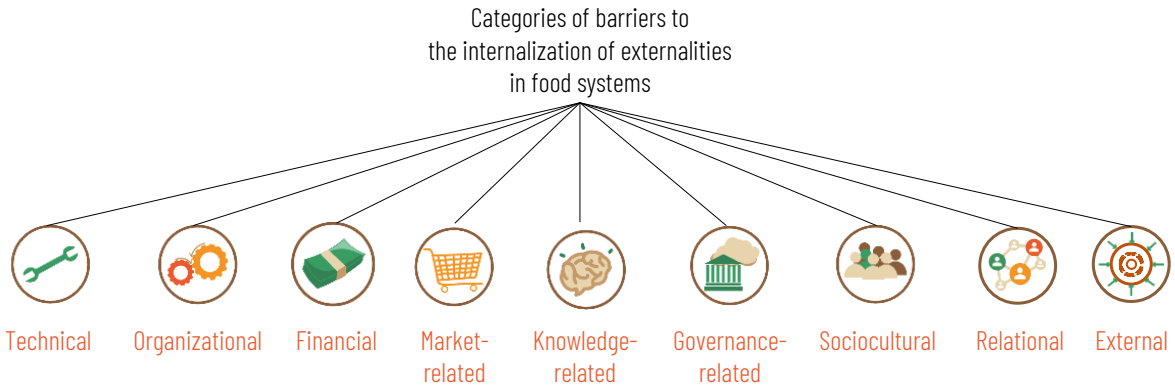

Figure 7. Main categories of barriers to the internalization of externalities.

4.2.1.1 Technical barriers

Technical barriers refer to factors impeding the practical implementation of an innovation. In the context of internalizing externalities, eight technical barriers were identified in relation to three main themes (Figure 8): (1) the limited availability of resources (excluding financial resources, which are further considered in the 'financial' category), (2) limitations in the scale-up process for internalization strategies, and (3) the absence of adequate procedures to assess the level of internalization required and the strategy to adopt.

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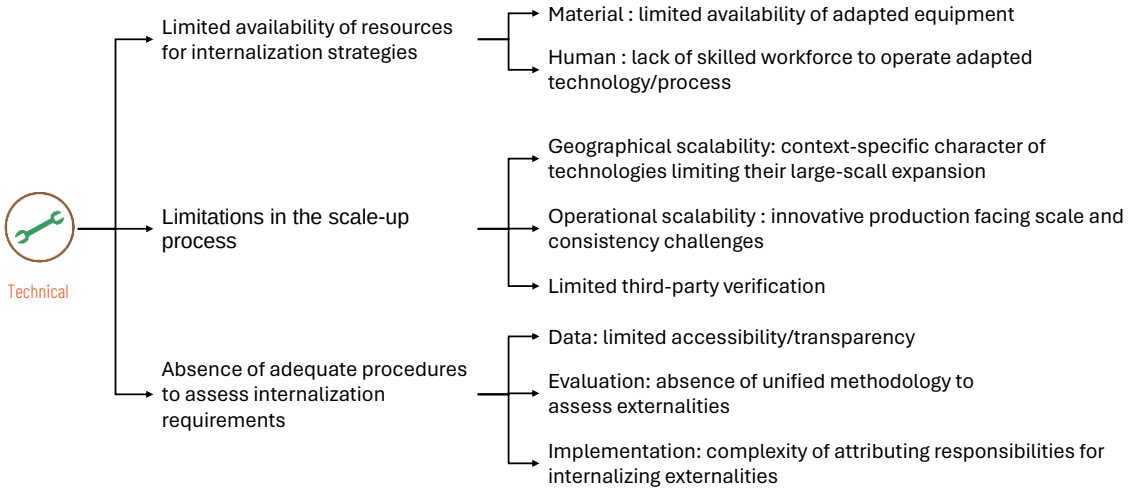

Figure 8. Overview of technical barriers to the internalization of externalities

The first two themes, i.e. the unavailability of resources and inability of internalization technologies and processes to expand, directly impact the capacity of actors to implement internalization strategies. Resources scarcity can be associated to both material and human capital, including, for instance, a lack of adapted equipment allowing for internalization practices, such as the absence of appropriate pastry studio in school canteens to provide locally produced pastries, or a shortage of workforce with required skills to engage in internalization technologies or processes. The ability to scale up an internalization strategy from one initiative to a large-scale adoption is often constricted by the limited third-party verification giving credibility to the process (Grabs 2020). It can also be associated with limited geographical scalability, attributed to significant territorial specificities of innovations (Aramyan et al. 2020), or operational challenges in achieving scalability, such as lower production levels of innovative practices, resulting in difficulties meeting industry-required production scale and consistency. While such barriers do not directly pertain to internalization of externalities within market price, it influences the change of practices towards activities generating fewer externalities.

The third factor, the lack of adequate procedures, relates to complexities involved in quantifying externalities and determining internalization levels. It is closely intertwined with knowledge-related barriers. At technical levels, barriers impeding an accurate assessment of internalization included the inability to access data, as well as the absence of a robust and unified calculation methodology and the complexity of attributing responsibilities for internalizing externalities. The absence of a robust methodology was, for instance, linked to issues such as double counting when two or more entities claim the same offset in a carbon market strategy (Miltenberger, Jospe, and Pittman 2021), the difficulty in defining exact goals for internalization and measures of externalities, the complexity of ensuring permanence (i.e. the assurance that carbon will remain in a stock for a long period of time) in carbon markets, or the complexity of integrating all externalities in an assessment, leading to the development of inadequate pricing strategies (Lecocq and Shalizi 2014). Once monetary values have been calculated to reflect external costs, the next step is to devise a mechanism for internalizing them into market prices. However, this step is hindered by the complexity of attributing clear

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responsibilities for the generation of externalities. For instance, it is technically challenging to establish an internalization strategy that insures a fair impact among all socio-economic groups. In the case of market-based instruments, Browne et al. (2013) and Owen (2006) criticize the idea of implementing a tax through full internalization of external costs, as it could result, among others, in an unfair impact on poorer sections of society. Owen (2006) further argues that the internalization mechanism should prioritize equity by imposing comparable impacts on various stakeholders responsible for generating externalities. As such, the internalization mechanisms may need to account for various impacts on both small and medium-sized enterprises or large corporations.

4.2.1.2 Organizational barriers

Organizational barriers are linked to the management of both time and tasks by individual actors of the system (Figure 9). We identified five organizational barriers among these two themes in the context of internalizing externalities.

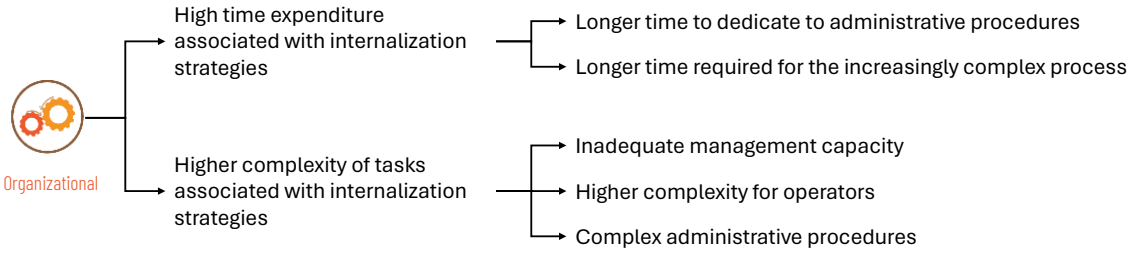

Figure 9. Overview of organizational barriers to the internalization of externalities

Innovating, whether in the social or technical sphere, is highly susceptible to cause a need to reorganize ongoing activities. For instance, Yaqoot et al. (2016) and Briguglio et al. (2021) both identified tedious administrative procedures and bureaucracy as barriers to the adoption of internalization strategies, in particular in decentralized renewable energy systems and circular economy in their cases. Addressing these administrative demands not only consumes time but may also necessitate the acquisition of new skills and the restructuring of the tasks performed. Also, internalization strategies typically demand additional time due to their increased complexity and the necessity for ingraining them as habitual practices. Since these strategies often involve novel approaches, there's a learning curve involved in adopting and internalizing them into routine operations. Beside these time issues, an internalization strategy will probably affect the management and implementation of tasks and activities within an organization. For instance, in their evaluation of voluntary carbon markets as tools to support climate action, Miltenberger et al. (2021) highlight the higher complexity of monitoring and reporting, as a significant hurdle that requires substantial capacity. Meeting these capacity requirements may necessitate a reorganization of tasks and competences within the organizations that implement internalization. Furthermore, insufficient management capacity has been identified as an important barrier to the adoption of circular economy practices in food supply chain management (Farooque, Zhang, and Liu 2019). This obstacle is closely tied to a limited organizational vision and managerial approach (see also socio-cultural barrier), thereby impeding a company's ability to

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reorganize its operations in response to changing circumstances and effectively embrace innovation.

4.2.1.3 Financial barriers

Five financial barriers, i.e. related to the allocation, acquisition, and utilization of financial resources, were identified in relation to two main themes: (1) the higher costs associated with internalization strategies, and (2) the limited financial accessibility for internalization processes (Figure 10).

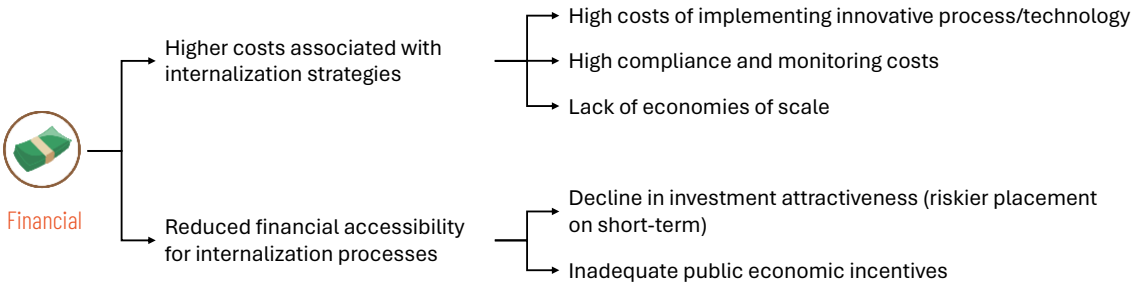

Figure 10. Overview of financial barriers to the internalization of externalities

The adoption of internalization strategies frequently encounters a significant hurdle in the form of additional costs. These costs are associated with either substantial upfront investment and compliance costs (Azcarate-Aguerre et al. 2022; Miltenberger, Jospe, and Pittman 2021; Aramyan et al. 2020; Farooque, Zhang, and Liu 2019; Yaqoot, Diwan, and Kandpal 2016; Roberts 2011; Anthony D. Owen 2006; Del Rio 2004), or monitoring expenses necessary to valuate, register, validate, monitor, report, and verify outcomes (Miltenberger, Jospe, and Pittman 2021). The higher costs are further exacerbated by the absence of economies of scale for internalization processes within the current regime (Farooque, Zhang, and Liu 2019).

Compounding this barrier created by the need for substantial capital is the scarcity of financial resources available to support internalization efforts. The waning attractiveness of investments contributes to this limited financial resource pool for internalization (Kurdyukov and Kanurny 2021; Yaqoot, Diwan, and Kandpal 2016). This phenomenon may, in part, be linked to the misalignment of interests between stakeholders, especially capital providers, and the predominance of short-term vision whereas internalization might require longer return time (Barquet et al. 2020); those are also manifestations of socio-cultural barriers. This can generate lower predictability regarding economic returns, which increases investment risk (Del Rio 2004; Briguglio et al. 2021) and thus lower attractiveness for investors. The insufficiency of financial resources can also be attributed to the inadequacy of economic incentives, which tend to predominantly favor productivity and competitiveness over other interests (Aramyan et al. 2020).

4.2.1.4 Market-related barriers

Market-related barriers are obstacles linked to external market conditions, which can significantly affect the feasibility and effectiveness of internalization efforts. Three main market-related themes hindering the deployment of internalization strategies were identified (Figure 11): (1) the lack of demand-side interest for internalized products, (2)

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the inadequate supply-side structure for internalization strategies, and (3) obstructing marketing practices. In total, six market-related barriers were identified in relation to these themes.

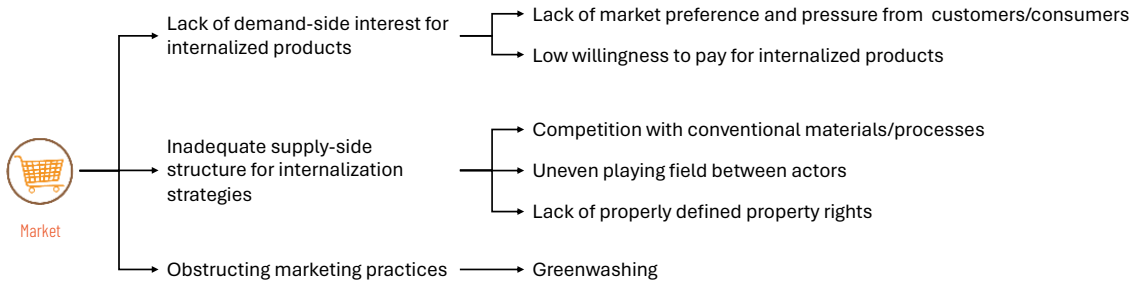

Figure 11. Overview of market-related barriers to the internalization of externalities

The first theme – the lack of demand-side interest – was attributed to two interconnected barriers. Firstly, there may be a lack of market preference and insufficient pressure from consumers and customers to embrace internalized products (Farooque, Zhang, and Liu 2019). If people do not actively seek out or demand environmentally and socially responsible goods or services, it becomes challenging to create a viable market for them. Secondly, it can be associated with a low willingness among consumers to pay a premium for internalized products (Aramyan et al. 2020). When consumers are not willing to invest more in sustainable alternatives, the market for these products tends to remain underdeveloped.

The second theme – inadequate supply-side structure – was associated to two main barriers as well. It includes the high competition of internalized products with more conventional materials and processes that may be cheaper or more readily available (Azcarate-Aguerre et al. 2022; Briguglio et al. 2021; Grabs 2020; Yaqoot, Diwan, and Kandpal 2016; Roberts 2011). This competitive disadvantage can hinder the growth of internalized product markets. Moreover, there may exist uneven playing fields between various actors in the market, where some have advantages in terms of resources or market presence, making it difficult for newcomers offering internalized products to gain a foothold (Barquet et al. 2020).

The third theme – greenwashing – refers to a deceptive market practice where an organization only pretends to internalize. This is dangerous as it can divert internalization efforts away from meaningful and effective strategies. This practice creates unfair competition from organizations that purport to adhere to social and environmental standards but do not actually take any real action to address these concerns (Roberts 2011).

4.2.1.5 Knowledge-related barriers

Knowledge-related barriers are linked to the gap of knowledge, awareness, and experience of actors regarding an innovation and its implementation. We identified three main themes, encompassing a total of eight knowledge-related barriers (Figure 12): (1) the overall insufficiency of existing knowledge about internalization strategies, (2) the

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imbalance in information distribution within the value chains, and (3) the remaining uncertainty about the benefits of internalization.

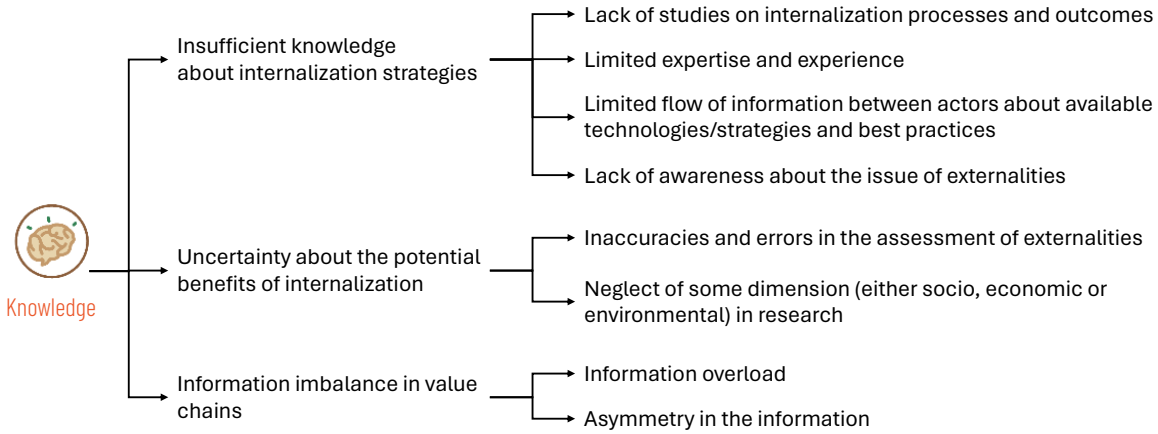

Figure 12. Overview of knowledge-related barriers to the internalization of externalities

This knowledge gap surrounding internalization products and processes was highlighted through various barriers, including the presence of understudied topics, such as economic, agricultural and environmental performances of circular economy practices as illustrated by Barquet et al. (2020) for the phosphorus reuse, as well as the scarcity of expertise and experience (Cho and Voss 2011; Yaqoot, Diwan, and Kandpal 2016; Farooque, Zhang, and Liu 2019). Knowledge gaps also manifest themselves through the limited dissemination of information (Yaqoot, Diwan, and Kandpal 2016; Farooque, Zhang, and Liu 2019), including, for instance, the absence of community of practice and forums for the exchange of experiences and best practice (Grabs 2020). Insufficient knowledge further arises from a general lack of awareness about the issue of externalities at all levels of the value chains.

Beyond the fundamental knowledge gap surrounding internalization, persistent uncertainties can present additional barriers to the successful internalization process (Farooque, Zhang, and Liu 2019). These uncertainties might emerge from inaccuracies and errors in the assessment of externalities (Kurdyukov and Kanurny 2021; Anthony D. Owen 2006), which may hamper the optimal allocation of costs and undermine the recognition of internalization as a valuable strategy for mitigating externalities. This failure can be attributed to technical barriers, particularly the absence of adequate procedures for assessing internalization needs. Moreover, uncertainties may arise from neglected aspects of externalities (Lecocq and Shalizi 2014; Walkiewicz, Lay-Kumar, and Herzig 2020), including socio-economic dimensions in environmental studies, introducing a bias in the evaluation of externalities.

Finally, knowledge-related barriers included aspects of information imbalance within the value chain. In contrast to the lack of information, an overload can create confusion. Roberts (2011) identified the profusion of labeling as a source of label fatigue, which desensitizes consumers and dampens demand for labeled products. Also, asymmetric information can create uneven market forces. Asymmetry refers to a situation where

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some actors of the value chain, often situated upstream, have more information on a product's quality than their counterparts, usually downstream. This imbalance in knowledge can, for instance, hamper the ability of customers/consumers to make informed decisions. As illustrated by Gallemore & Jespersen (2019), in such instances, buyers find it challenging to differentiate between high-quality and inferior products, resulting in the payment of identical prices for both. This can lead to a problematic situation where superior products are undervalued. Consequently, owners of these high-quality products are compelled to retain them rather than sell, as they are unable to secure a fair price in the market. Altogether, these factors can jeopardize the acceptation of internalized food products on the market.

4.2.1.6 Governance-related barriers

Governance-related barriers refer to obstacles linked to the decision-making process, as well as the legal and regulatory frameworks and their implementation (Figure 13). We identified nine barriers across these two themes.

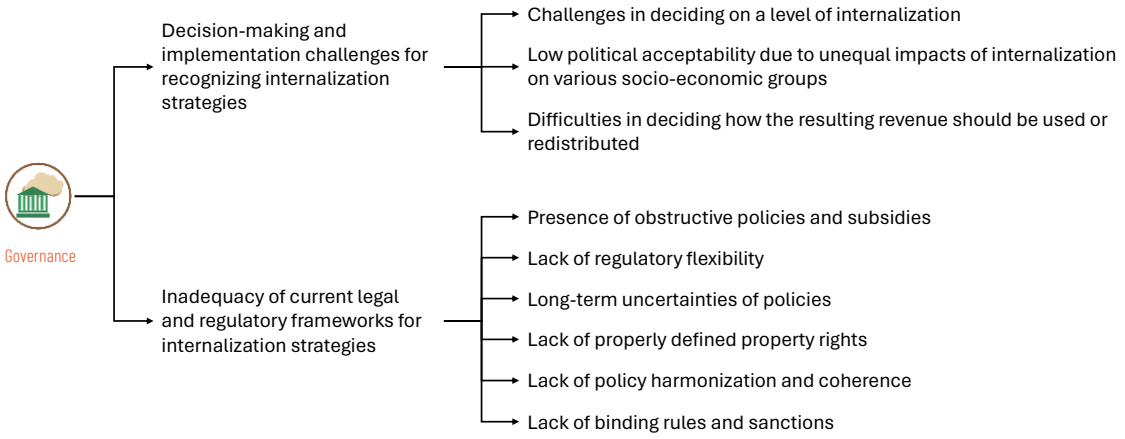

Figure 13. Overview of institutional barriers to the internalization of externalities

The first theme refers to challenges associated with the public and private decision-making process for internalization strategies. In particular, challenges in determining how the costs and benefits of internalization should be allocated among different actors, respecting fair and equitable repartition, seem at the core of the struggle (Del Rio 2004; Anthony D. Owen 2006; Browne et al. 2013). Such challenge often arises when considering the tax as internalization strategy, such as the implementation of a sugar tax to address health externalities associated with high-sugar-content food products. While such a tax could potentially mitigate health risks by reducing consumption, determining the appropriate tax rate and allocation of resulting revenues poses significant dilemmas. Striking a balance between discouraging unhealthy behaviors and ensuring socio-economic equity remains a very complex issue in the decision-making process surrounding internalization strategies.

The second theme refers to inadequacies of current legal and regulatory frameworks for internalization strategies. An overall lack of policy support for the internalization of externalities has often been highlighted (Johnstone and De Tilly 2006; Cho and Voss 2011; Yaqoot, Diwan, and Kandpal 2016; Walkiewicz, Lay-Kumar, and Herzig 2020;

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Briguglio et al. 2021). Unfavorable regulations partly stem from the obstructive nature of some current policies and subsidies. For instance, according to Briguglio et al. (2021), existing public policies might impose penalties on circular entrepreneurs and businesses aiming to transition to circular practices, either through their implicit bias in favor of traditional linear business models or by imposing excessively burdensome regulatory barriers. In a similar vein, Johnstone & De Tilly (2006) highlighted the existence of subsidies that favor the use of virgin materials, creating competition with recyclable alternatives.

The lack of regulatory flexibility in command-and-control regulations, recognized as a hindrance to innovation (Lim and Prakash 2014), and the long-term uncertainties of policies, which may push actors of the systems to opt for short-term, incremental innovations offering modest improvement (Del Rio 2004; Levidow et al. 2016), have also been recognized as governance-related barriers to the adoption of internalization strategies. Additionally, the absence of properly defined property rights can introduce ambiguity regarding the responsible stewardship of commonly held resources, potentially rendering them more susceptible to overuse and depletion (Roberts 2011).

Furthermore, current institutional frameworks lack binding requirements and clear governmental sanctions (Roberts 2011), which can lead to less impactful outcomes. Indeed, when regulations are formulated to encourage companies or individuals to voluntarily adopt specific practices or adhere to particular criteria for addressing externalities, these systems inherently lack the legal authority or governmental power to enforce participation and ensure compliance. Such a lack of binding rules and sanctions was highlighted in the case studies through, for instance, the use of voluntary systems for communicating externalities, whereas mandatory labelling was considered more effective. Additionally, the absence of laws mandating companies to report against sustainable criteria, such as nutritional profiling, was noted. A lack of government sanctions was evidenced through the example of the French Agriculture and Food Law (“loi Egalim”), reflecting a current approach where governments tend to incentivize positive behaviors through subsidies but falls short in penalizing detrimental actions.

Finally, Briguglio et al. (2021) identified a notable barrier to the adoption of internalization strategies in the form of insufficient policy harmonization and coherence at the EU level, particularly in the context of circular practices. Within the case studies, this barrier manifested itself in relation to global perspective on sustainability, with strong concerns about the adoption of practices in Europe leading to the outsourcing of environmental and social responsibilities to regions with less stringent regulations. In that regard, actors recognized the need to harmonize rules and regulations in Europe to mitigate adverse impacts elsewhere. Coherence issues mainly pertained to international trade, underscoring the necessity for policies and regulations to better balance competition between local and imported goods in order to support internalization efforts in Europe.

All in all, these barriers collectively contribute to the creation of an unfavorable regulatory environment, discouraging organizations from embracing more sustainable and responsible practices.

4.2.1.7 Socio-cultural barriers

We classify socio-cultural barriers as obstacles that originate from the attitudes, beliefs, norms and value of actors within a value chain. We identified three distinct themes,

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encompassing a total of eleven socio-cultural barriers (Figure 14): (1) a resistance to change towards internalization strategies, (2), a weak commitment for internalization strategies, particularly at corporate managerial level, and (3) a lack of alignment between actor's visions and objectives.

Figure 14. Overview of socio-cultural barriers to the internalization of externalities

Resistance to change is a common concept encountered when addressing lock-in phenomena. Several socio-cultural barriers can be the source of such resistance, including an aversion to any risk (Takacs, Brunner, and Frankenberger 2022). We view risk aversion as a psychological and behavioral trait influenced by our socio-cultural settings. This trait often hinders willingness to embrace change, primarily because change introduces uncertainty and diverts from established norms and practices. Resistance may also stem from the prevailing short-term perspective in which a society is rooted (A.D. Owen 2004; Takacs, Brunner, and Frankenberger 2022), where immediate outcomes and benefits often take precedence, obscuring any long-term benefit from the picture. This characteristic is a strong barrier, which can be linked to a decline in the availability of financial resources (see financial barriers). The short-term perspective is partly linked to the economically dominated thinking within society (Gallemore and Jespersen 2019; Briguglio et al. 2021; Takacs, Brunner, and Frankenberger 2022). Resistance to change is exacerbated by unwillingness to engage in trade-offs (Takacs, Brunner, and Frankenberger 2022), as well as norms of social acceptability (Barquet et al. 2020). Barquet et al. (2020) illustrate the concept of social acceptability using the case of sewage sludge-derived products within a circular phosphorus economy. In that example, the author traced back the issue of social acceptability to a general cognitive barrier of using human excreta for agricultural production. Finally, traditions and generational effects are elements potentially blocking the emergence of innovative processes or practices. Traditions often drive daily activities, restraining the adoption of larger perspectives; this can be witnessed in the operational choices at farm-level, as well as consuming practices (for instance, cultural traditions favoring meat consumption impeding the acceptance of alternative-protein diets). Generational effects translate in a slow change of attitude, as older individuals,

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who tend to conservatively adhere to established practices, often hold decision-making/leadership positions.

Socio-cultural barriers to the adoption of internalization strategies further include the lack of management commitment towards sustainability (Farooque, Zhang, and Liu 2019). This lack of commitment can be evidenced through the absence of distinct sustainability goals and measures within organizations (Walkiewicz, Lay-Kumar, and Herzig 2020) and the lack – or limited – perception of socio-environmental issues, which was perceived by Cho & Voss (2011) as a barrier for international and corporate environmental strategies.

Finally, socio-cultural barriers were identified in relation to a lack of alignment between stakeholders' visions and objectives. The historical legacy of conflict between actors (Grabs 2020) can lead to significant discrepancies between their perspectives, which in turn presents a challenge to effective collaboration (see relational barrier) and decision-making, as opposing lobbying forces come into play (Del Rio 2004). The existence of a large heterogeneity and multiplicity of consumers' expectations can further complicate internalization by creating widely different markets (Grabs 2020).

4.2.1.8 Relational barriers

We categorize relational barriers as obstacles linked to the relations and interactions between actors of a value chain. Four main relational barriers were identified in the context of internalizing externalities (Figure 15): (1) a lack of coordination among actors of the value chains (Yaqoot, Diwan, and Kandpal 2016; Barquet et al. 2020), (2) the existence of opposed visions and preferences among actors at various levels of the value chains (Grabs 2020), which creates tensions and competition, (3) an imbalance in power between actors in decision-making process (Lecocq and Shalizi 2014), and (4) a lack of transparency, in particular with respect to the price premiums paid by consumers (Roberts 2011).

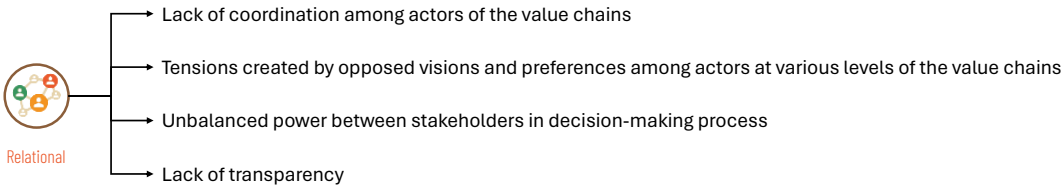

Figure 15. Overview of relational barriers to the internalization of externalities

4.2.1.9 External barriers

We introduced a final category of barriers, referred to as "external barriers," to encompass all other barriers that are currently beyond the influence or control of the system's actors. In the context of internalizing externalities, we identified two external barriers (Figure 14): the risk of reversal in the context of carbon markets (Miltenberger, Jospe, and Pittman 2021) and climate change. Reversal can happen following events such as disturbance, change of ownership or policy, or altered market dynamics. The risk of reversal is a significant concern in carbon markets because the fundamental idea behind carbon offset projects is to deliver real and permanent emissions reductions. If

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these reductions are later reversed, it undermines the effectiveness and integrity of carbon markets as a tool for mitigating climate change. Climate change was also acknowledged as a tangible threat to the effective implementation of strategies tackling food externalities. For agricultural producers specifically, more extreme climate conditions leading to unpredictable production levels might discourage the transition towards new practices, including those addressing externalities. This is closely linked to the risk aversion nature of actors (socio-cultural barrier).

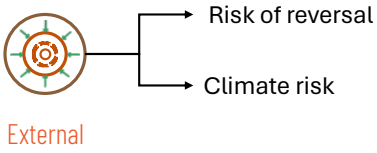

Figure 16. Overview of external barriers to the internalization of externalities

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4.2.2 Assignment of barriers to the FOODCoST case studies

The previous section provided a global mapping of barriers that contribute to locking out any internalization effort. Each internalization strategy will however be impacted by its own specific set of barriers. Using the FOODCoST case studies, we illustrate this context-specific nature by assigning to each case study the exact barriers that impede its implementation.

Overall, the barriers identified through case study interviews largely align with those identified in the literature review (Table 2). Among the 58 barriers to internalization, 47 were identified in both literature and case studies; seven were identified in the literature only, and four came from case studies' interviews. These additional insights from case studies addressed the operational scalability of internalization efforts, with interviews emphasizing technical challenges in meeting industry demand when implementing innovative practices. Moreover, interviews highlighted a common lack of awareness about externalities across value chains, contributing to insufficient knowledge about internalization strategies. Furthermore, they provided deeper insights into socio-cultural barriers, highlighting the significance of traditions and generational effects as resistance to adopting internalization strategies. The categories of barriers with the highest occurrence are technical and socio-cultural categories, with 31 and 25 mentions in the case studies respectively (Table 2), suggesting that these areas may require particular attention by case studies' participants in addressing barriers to innovation expansion. A comprehensive breakdown of barrier-related elements gathered throughout our interactions with case studies is provided in Appendix 4.

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Table 2 Overview of barriers to the internalization of externalities across various categories and themes. Each barrier is marked with an 'X' for case studies (CS) where it applies (CS4 did not take part in the study). Most barriers were initially identified in the literature, those stemming from CSs interview solely are marked with an asterisk (*).

Category	Theme	Barrier	CS1	CS2	CS3	CS5	CS6	CS7	CS8	CS9	CS10	CS11	Total
Technical	Limited availability of resources for internalization strategies	Material: limited availability of adapted equipment		X	X			X			X	X	5
		Human: lack of skilled workforce to operate adapted technology/process		X	X			X					3
	Limitations in the scale-up process	Geographical scalability: context-specific character of technologies limiting their large-scall expansion				X	X						2
		Operational scalability: innovative production facing scale and consistency challenges *		X								X	2
		Limited third-party verification			X			X					2
	Absence of adequate procedures to assess internalization requirements	Data: limited accessibility/transparency	X	X	X	X	X	X		X			7
		Evaluation: absence of unified methodology to assess externalities	X	X		X	X	X		X	X		7
		Implementation: complexity of attributing responsibilities and level of actions for internalizing externalities				X		X		X			3
Organizational	High time expenditure associated with internalization strategies	Longer time to dedicate to administrative procedures		X				X			X		3
		Longer time required for the increasingly complex process											0
	Higher complexity of tasks associated with internalization strategies	Inadequate management capacity										X	1
		Higher complexity for operators				X					X	X	3
		Complex administrative procedures		X				X			X		3
Financial	Higher costs associated with internalization strategies	High costs of implementing innovative process/technology	X		X			X			X	X	5
		High compliance and monitoring costs	X	X	X			X					4
		Lack of economies of scale	X									X	2
		Decline in investment attractiveness	X			X		X		X			4

Category	Theme	Barrier	CS1	CS2	CS3	CS5	CS6	CS7	CS8	CS9	CS10	CS11	Total
	Reduced financial accessibility for internalization processes	Inadequate economic incentives	X					X			X		3
Market-related	Lack of demand-side interest for internalized products	Lack of market preference and pressure from customers/consumers	X	X								X	3
		Low willingness to pay for internalized products	X	X	X								3
	Inadequate supply-side structure for internalization strategies	Competition with conventional materials/processes		X	X			X			X		4
		Uneven playing field between actors		X				X				X	3
		Lack of properly defined property rights			X								1
	Obstructing marketing practices	Greenwashing	X					X					2
Knowledge-related	Insufficient knowledge about internalization strategies	Lack of studies on relevant technologies/processes	X		X			X					3
		Limited expertise and experience	X	X	X							X	4
		Limited flow of information between actors about available technologies and best practices	X	X	X			X				X	5
		Lack of awareness about the issue of externalities *	X					X					2
	Uncertainty about the potential benefits of internalization	Inaccuracies and errors in the assessment of externalities											0
		Neglect of some dimension (either socio, economic or environmental) in research						X					1
	Information imbalance in value chains	Information overload											0
		Asymmetry in the information	X										1
Governance-related	Decision-making and implementation challenges for recognizing internalization strategies	Challenges in deciding on a level of internalization	X					X			X		3
		Low political acceptability due to unequal impacts of internalization on various socio-economic groups											0
		Difficulties in deciding how the resulting revenue should be used or redistributed						X					1
		Presence of obstructive policies and subsidies		X				X					2

Category	Theme	Barrier	CS1	CS2	CS3	CS5	CS6	CS7	CS8	CS9	CS10	CS11	Total
	Inadequacy of current legal and regulatory frameworks for internalization strategies	Lack of regulatory flexibility		X				X					2
		Long-term uncertainties of policies				X		X					2
		Lack of properly defined property rights											0
		Lack of policy harmonization and coherence			X			X				X	3
		Lack of binding rules and sanctions						X	X	X	X		4
Socio-cultural	Resistance to change towards internalization strategies	Risk aversion		X	X	X		X		X			5
		Absence of long-term consideration			X	X		X		X			4
		Economically dominated thinking	X	X	X	X		X					5
		Low social acceptability of internalized products/processes								X			1
		Unwillingness to engage in trade-offs											0
		Importance of traditions blocking innovative processes/practices *		X				X			X	X	4
		Generational effect blocking innovative processes/practices *		X									1
	Weak commitment (particularly at corporate managerial level) for internalization strategies	Lack of distinct goals and measures to address sustainability		X				X					2
		Low recognition of socio-environmental issues	X					X					2
	Lack of alignment between actors' visions and objectives	Historical legacy of conflict between actors											0
		Heterogeneity and multiplicity of consumers' expectations						X					1
Relational		Lack of coordination among actors of the value chains		X	X						X		3
		Tensions created by opposed visions and preferences among actors at various levels of the value chains	X	X	X			X	X		X		6
		Unbalanced power between actors in decision-making process	X	X	X			X			X		5
		Lack of transparency			X			X			X		3

Category	Theme	Barrier	CS1	CS2	CS3	CS5	CS6	CS7	CS8	CS9	CS10	CS11	Total
External		Risk of reversal											0
		Climate risk *	X	X				X					3

4.3 Exploring barriers across contexts

While each case study context presents its own unique set of barriers, certain categories tend to reappear consistently across most contexts. These cross-sectional topics are governance-related barriers, as well as technical, financial, and socio-cultural barriers (Figure 17). Any endeavor to internalize externalities in food systems will thus likely be affected by such categories of barriers. There's an exception for strategies concentrating on developing methodological approaches to internalize externalities, such as with case study 6, which are affected by specific issues. This is further detailed in Box B.

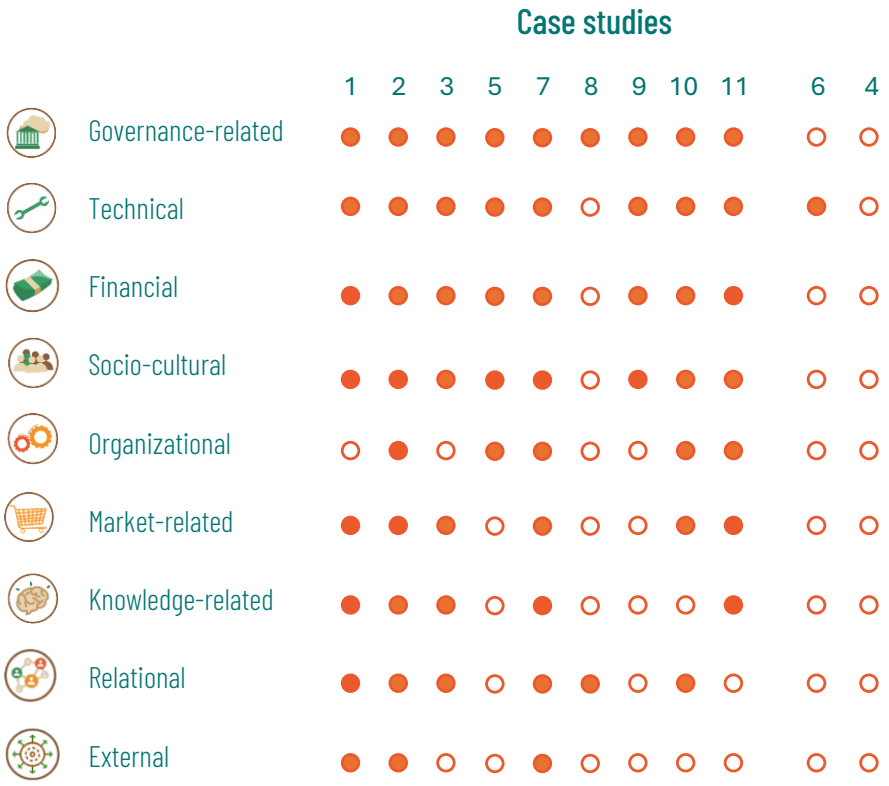

Figure 17. Overview of the categories of barriers affecting each FOODCoST case study.
Notes: CS6 focuses on methodological aspects (see Box B) ; CS4 did not take part in the study.

From the optimization of water-energy-carbon nexus in greenhouse production (CS3) to innovative financial reporting in big corporations (CS5 and 9), or communication strategies through labeling (CS8), each approach to internalizing externalities in food systems seems intricately tied to a supportive governance framework. In particular, the interviews conducted with the case studies' leaders confirmed a widespread feeling about the impact of unfavorable legal and regulatory frameworks for internalization strategies.

As a general observation, the current institutional framework seems to lack the capacity to provide a coherent vision with clear objectives and trajectory. As a results, actors of food systems find themselves without a clear roadmap when faced with trade-offs, such as balancing economic gains and environmental constraints (example in CS1: generating more value for small coffee farmers by locally roasting and processing the

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beans, which generates more emissions) or balancing sustainability and consumer affordability (CS3). Additionally, discussions underscored a noticeable gap between policymakers and their understanding of the ground-level realities, emphasizing the imperative for policymakers to be well-informed about the true state of affairs in agriculture. Finally, greenwashing waves were recognized as a failure within the political sphere, pointing to a lack of robust regulatory frameworks, enforcement mechanisms, and oversight to ensure transparency and accuracy in sustainability-related communications.

Other cross-sectional barriers, i.e. technical, financial, and socio-cultural barriers, are interesting to reflect the current feasibility and acceptability of internalization strategies. The technical challenges inherent in internalization strategies are not surprising. They largely stem from the inadequacy of existing procedures to assess internalization needs, which can be attributed to limited data availability and accuracy, the difficulty in devising a unified methodology, and the complexity of attributing clear responsibilities and level of actions for internalizing externalities. The technical implementation of internalization efforts is further complicated across all contexts by the reduced availability of adapted technologies and skilled human resources, which are needed to execute internalization process and practices. Additionally, the very context-specific nature of the innovative strategies identified to internalize externalities limits their potential for large-scale expansion. All in all, these technical barriers are reinforced by financial barriers, particularly the higher costs associated with internalization strategies and the limited financial accessibility for internalization processes, which strongly reduce the practical feasibility of internalization efforts. Socio-cultural barriers, on the other hand, reflect the existing challenges surrounding the acceptance of internalization strategies. A strong resistance to change towards internalization strategies persists across case studies. This resistance can manifest in various forms, such as a preference for short-term gains over long-term benefits and the associated reluctance to accept greater risks on the short-term. Additionally, there exists skepticism towards innovative approaches that disrupt established traditions. These entrenched norms and attitudes pose significant challenges for proponents of internalization, as they hinder efforts to garner widespread support.

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Box B. Specific issue related to methodological approach to internalizing externalities

Distinct types of barriers affecting the internalization of externalities were observed according to the expected level of impact of the case studies, either methodological valuation of externalities, or policy and business implementation of internalization strategies.

Applying a methodology to assess the externalities generated within a system is a strategy that demands significant expertise and resources, encompassing both time and financial investment. Barriers to adopting such a methodological approach are thus primarily centered around technical, organizational, and financial considerations (Figure 18). Going through a phase of valuation as a first step toward enhanced internalization of externalities appears to be a strategy primarily accessible to large companies that can allocate the requisite resources for this purpose. In contrast, smaller actors may encounter significant challenges in precisely valuing the externalities they generate. Nevertheless, this does not diminish their capacity for effective action. Interviews conducted with leaders of the case studies underscored instances where actors acknowledged that sophisticated methodologies and calculations are not always essential; rather, one can still act to internalize the externalities they generate by simply being aware of them and taking appropriate actions.

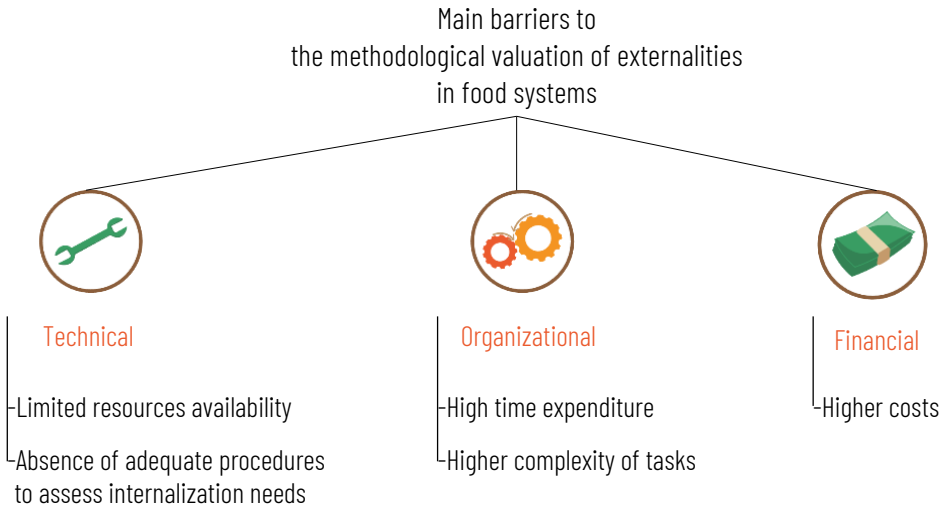

Figure 18. Specific barriers to the methodological valuation of externalities in food systems

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4.4 Validating findings

The findings regarding barrier identification and interconnections, as presented in this report within the framework of internalizing externalities in food systems, will be shared with FOODCoST partners and participants involved in the case studies. Over the next two years of the project, these actors will have the opportunity to provide feedback and validate the conclusions drawn from the research. Additionally, we will reflect on levers and operational measures that could be developed in order to break free of the inertia caused by lock-in situation and facilitate the transition towards effective internalization.

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5 Conclusions

The analysis of barriers locking a system into a given trajectory is a complex endeavor that, until now, lacked support from a unified methodology. Therefore, our first achievement lies in proposing such a methodology.

The study then offers a comprehensive examination of the barriers to internalizing externalities within food systems, drawing insights from both literature review and case studies conducted within the FOODCoST project. Through a systemic analysis, the study identified 58 barriers, spanning across technical, organizational, financial, market-related, governance-related, knowledge-related, relational, socio-cultural and external dimensions, that hinder the successful implementation of internalization strategies across various contexts within the food supply chain. The study underscores the diverse array of barriers that must be navigated to promote sustainable practices and mitigate the negative externalities associated with food production, processing and consumption. The context-specific nature of these barriers, as evidenced through the analysis of the case studies, stresses however the necessity to address each case of internalization individually. In light of this, our mapping of barriers can serve as a helpful checklist, facilitating the targeted identification of barriers impacting cases of internalization. Furthermore, the study identified certain categories of barriers that tend to reappear consistently across the case studied. These are governance-related, technical, financial, and socio-cultural barriers. By identifying cross-sectional barriers that cut across different contexts and impact pathways, the study provides valuable insights into common challenges that must be addressed at both policy and implementation levels.

Overall, the study provides a valuable tool for actors seeking to internalize externalities within food systems by shedding light on the holistic nature of the lock-in situation that may impede their progress. By delving deeper into the interconnections among barriers, actors can identify key leverage points where efforts should be concentrated to overcome the lock-in. Armed with this understanding, stakeholders will be better equipped to drive the transition towards more sustainable and resilient food systems.

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7 Appendixes

7.1 Appendix 1. Analysis of results from the preliminary online questionnaire

A preliminary overview of barriers affecting the internalization of externalities in the FOODCoST case studies was gathered through responses of case studies' leaders to an online questionnaire sent in February 2023. Two specific questions were asked to assess:

1. Whether the structure of the value chains, i.e., contracts/arrangements between actors, is favorable for the internalization of externalities,
2. The experience and knowledge of case studies about barriers linked to the internalization of externalities.

Responses' rate

Out of the eleven case studies, four did not respond to the first question about value chain structure and five did not respond to the second question about barriers (Figure 19).

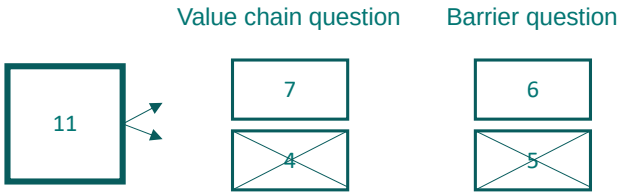

Figure 19. Number of case studies that answered each question.

In our analysis, we found that among the five case studies that did not address the issue of barriers, one was solely focused on communicating externalities to consumers, with no considerations regarding mitigating negative externalities or fostering positive ones. Consequently, most questions in the questionnaire were left unanswered in that particular context, as they were deemed irrelevant by the respondent. For the remaining four case studies, while they provided responses to most questions in the questionnaire, they omitted those related to barriers. This observation might suggest a general lack of awareness or comprehension concerning the barriers that impact the implementation of internalization strategies. Alternatively, it is possible that respondent fatigue played a role in neglecting these questions, given their placement at the end of the questionnaire. A notable exception was found in one case study (9%), which stood out for its comprehensive identification of barriers across every stage of its value chain. This performance can be attributed to the experience and familiarity of the case study's team in dealing with such topic.

Value chains organization and internalization opportunities

Among the seven case studies that provided responses, a majority of five (71%) recognized the presence of suitable value chain structures for internalization, while the remaining two indicated inadequate structures. The favorable characteristics associated

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with these current value chain structures for successful externalities internalization include:

- Short value chains, facilitating direct marketing and traceability.
- Investors compliance with Environmental, Social, and Governance (ESG) standards.
- Strong and sustainable relationships with other value chain actors.

Additionally, the presence of a well-functioning market for the produced commodity and a commitment among actors to reduce externalities from their activities were identified as further favorable elements conducive to the successful internalization of externalities.

In contrast, certain aspects of the existing value chain structures were deemed unfavorable for the internalization of externalities. These include:

- Weak coordination along the value chain,
- Absence of long-term contracts,
- An imbalance in the influence yielded by specific actors within the value chain,
- The indirect effects of 1-to-1 relationships complicating a holistic value chain approach.

Other challenges that were reported regarding the internalization of externalities included:

- Inadequate governmental support,
- Poor agronomic discipline at production level,
- Pricing strategies of processors disconnected from product quality characteristics,
- Willingness to pay of consumers,
- The cultural and social paradigm shift needed for the adoption of a fairness approach in value chains.

Knowledge and experience about barriers

To evaluate the experience and knowledge of barriers, the case studies were requested to identify known barriers at various levels within their value chain, encompassing input provision/supply, production, transportation/logistics, packaging, processing, retail/sales, consumption, and disposal. The reported barriers primarily affected the production level of the value chain (Table 1). Following closely were barriers encountered at the processing and consumption levels. Notably, no barriers were mentioned for the disposal level.

Respondents were also prompted to specify the nature of barriers impacting the internalization of externalities within their value chain, while considering the various categories[1] of potential barriers:

- Technical (e.g., insufficiency of suitable technologies, lack of instruments for internalization and compensation).

[1] These initial categories were not yet fully aligned with those employed in the final analysis of barriers, as the ultimate taxonomy resulted from an iterative process of refinement and learning from practical experience.

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- Financial (e.g., high investment costs, reduced profitability, unequal distribution of externalities' costs across the value chain).
- Market-related (e.g., reduced competitiveness, limited demand for products integrating externalities).
- Organizational (e.g., regulatory gaps, inadequate taxation, communication gaps among value chain actors, lack of adapted contracts, difficulties in implementing internalization of externalities over large geographical and temporal spans).
- Knowledge-related (e.g., absence of reference points regarding the costs and benefits of internalization of externalities).
- Cultural/social (e.g., resistance to altering practices and behaviors, misperceptions of the externalities linked to an activity, apprehension of risks and uncertainties).

Technical barriers were the most frequently cited, as illustrated in Table 1, with a total of nine mentions by case studies across all levels of the value chain. The production stage appeared notably affected by technical barriers, as evidenced by the three case studies highlighting such obstacles. Market-related, cultural/social, and financial barriers followed in the ranking. It is notable that production and processing were the only value chain levels where all types of barriers were reported across the case studies. Insights into specific barriers' elements mentioned in the FOODCoST case studies can be found in Appendix 4.

Table 1. Number of cases studies reporting barriers and type of barriers reported, by level of the value chain.

Level of the value chain	Number of case studies	Type of barriers reported							
		Technical	Financial	Market-related	Organizational	Knowledge-related	Cultural/social	Other	Total
Input provision/supply level	2	2							2
Production level	4	3	2	2	1	2	1		11
Transportation/logistics level	2	1	1						2
Packaging level	1		1						1
Processing level	3	2	1	2	2	1	1		9
Retail/sale level	1			1			1		2
Consumption level	3	1		1			3		5
Disposal level	0								0
	Total	9	5	6	3	3	6	0	

An evaluation of the case studies' experiences in dealing with barriers exposed a significant trend: the majority had not formulated any strategies to address these challenges. Among the eleven case studies, only one indicated taking action to tackle specific barriers. This action included activities such as engaging in discussions with value chain partners, participating in collaborative research projects, and exploring innovative processing techniques. In contrast, the remaining ten case studies appeared to have never proactively dealt with these issues.

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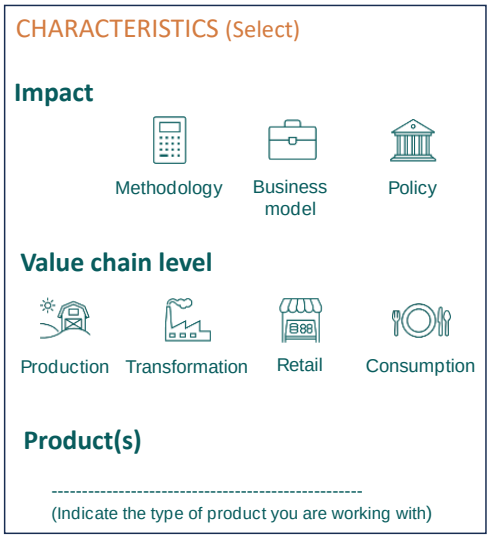
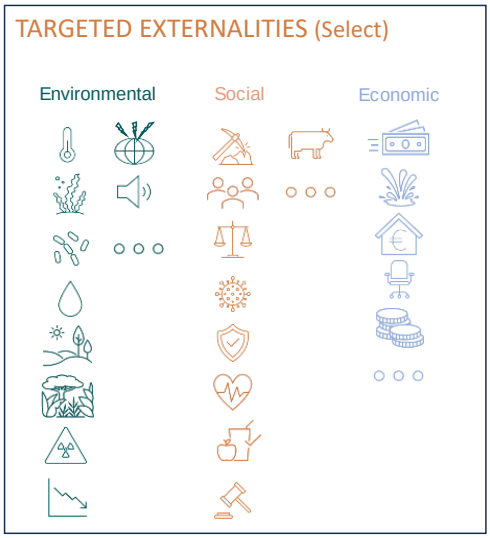
7.2 Appendix 2. Structure of the FOODCoST case studies' in-depth online survey

Each FOODCoST case study leader was asked, in November 2023, to complete and send back two documents designed to pinpoint the specific characteristics of their case study and clarify the main barriers they are facing.

In the first document, the case study leaders had to select characteristics fitting their context, including the expected level of impact for the project (i.e. methodological contribution, and/or business or policy suggestions for internalization), as well as the value chain level where their actions were targeted at and the externalities they aimed to address (to be selected from the FOODCoST list of externalities).





FOODCoST list of externalities:

Environmental	Social	Economic
Climate Change	Labour right and conditions	Income transfers
Acidification and eutrophication	Local community rights and wellbeing	Spillovers
Particulate matter	Equity	Effects on market and institutional structure
Water stress (use, management, etc.)	Infectuous diseases	Effects on employment
Land use and land transformation	Food safety	Effects on transaction costs
Direct effects on biodiversity and ecosystems	Health effects of diets	Others
Toxicity	Food security	
Non- renewable resource depletion	Consumer rights	
Ozone and radiation	Animal welfare	
Noise, smell and visual disturbance	Others	
Others		

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The second document introduced them with an initial list of barriers to internalization, from which they add to identify those relevant to their context and provide details on the causes and consequences of these barriers.

Barriers to the internalization of externalities in food systems				Check those relevant to your CS	Describe how the barriers apply in your CS
Technical					
1	Limited resources availability				
1a		Limited availability of adapted technology			
1b		Lack of skilled workforce to operate new equipment			
2	Lack of effectiveness of new technology/ process				
2a		Limited large-scale expansion of context-specific technologies			
2b		Limited third-party verification			
3	Lack of adequate procedures to assess internalization needs				
3a		Limited data accessibility			
3b		Absence of robust methodologies to assess externalities			
3a1			Double counting issues		
3a2			Difficulties in defining goals and measures		
3a3			Complexity of ensuring permanence in carbon markets		
3a4			Unaddressed externalities leading to inadequate pricing		
4		Complexity of devising a mechanism for internalization			
4a			Difficulties in establishing fair impact of internalization strategies among various socio-economic groups		
4b			Difficulties in establishing equitable rates of internalization (differentiated taxes)		
Organizational					
1	Challenges in managing time				
1a		Tedious administrative procedures			
2	Challenges in managing tasks				
2a		Inadequate management capacity			
2b		Higher complexity for operators			
2c		Tedious administrative procedures and bureaucracy			
Financial					
1	High investments needs				
1a		High investment/compliance costs (esp. for small & medium producers/companies			
1b		High monitoring costs			
2	Lack of financial resources available				
2a		Decline in investment attractiveness			
2b		Inadequate economic incentives			
3	Lack of predictability about economic returns				
3a		Risky investments			
3b		Long-term investments horizons			
3c		Lack of economies of scale			
Market-related					
1	Absence of market for internalized products				
1a		Lack of market preference and pressure from customers/consumers			
1b		Low willingness to pay for internalized products			
2	Insufficient market performance for internalized products				
2a		Competition with conventional materials/processes			
2b		Uneven playing field between actors			
2c		Lack of properly defined property rights			
3	Greenwashing				
Institutional					
1	Long-term policy uncertainties				
2	Lack of government sanctions				
3	Lack of EU policy harmonization				
4	Unfavorable regulations				
4a		Lack of policy support			
4a1			Difficulties in deciding on a level of internalization		
4a2			Low acceptability due to unequal impacts of internalization on lower socio-economic groups and rural communities		
4a3			Difficulties in deciding how the resulting revenue should be used or redistributed		
4a4			Opposing lobbying forces		
5		Obstructive policies and subsidies			
6		Lack of regulatory flexibility (Command & Control)			
7		Lack of legal recognition of internalization products and processes			
Knowledge-related					
1	Insufficient knowledge about new innovations				
1a		Lack of studies on relevant technologies/processes			
1b		Limited expertise and experience			
1c		Limited flow of information about available technologies and best practices			
2	Uncertainty about the potential environmental and economic benefits of innovations				
2a		Inaccuracies and errors in the assessment of externalities			
2b		Neglect of socio-economic dimension in research			
3	Information overload				
4	Asymmetric information				
Relational					
1	Lack of coordination among actors of the value chains				
2	Opposed visions and preferences among actors at various levels of the value chains				
3	Unbalanced power between stakeholders in decision- making process				
4	Lack of transparency				

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Barriers to the internalization of externalities in food systems						Check those relevant to your CS	Describe how the barriers apply in your CS
Socio-cultural							
1	Resistance to change						
1a		Risk aversion					
1b		Short-term perspective					
1c		Economically dominated thinking					
1d		Unwillingness to engage in trade-offs					
1e		Social acceptability of internalized products/processes					
2	Lack of management commitment						
2a		Lack of distinct goals and measures					
2b		Lack of perception of socio- environmental issues					
3	Lack of alignment between stakeholders' visions and objectives						
3a		Historical legacy of conflict between actors					
3b		Heterogeneity and multiplicity of consumers' expectations					
External							
1	Risk of reversal						

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7.3 Appendix 3. Comprehensive list of barriers to the internalization of externalities

Category	Theme	Barrier
Technical	Limited availability of resources for internalization strategies	Material: limited availability of adapted equipment
		Human: lack of skilled workforce to operate adapted technology/process
	Limitations in the scale-up process	Geographical scalability: context-specific character of technologies limiting their large-scall expansion
		Operational scalability: innovative production facing scale and consistency challenges
		Limited third-party verification
	Absence of adequate procedures to assess internalization requirements	Data: limited accessibility/transparency
		Evaluation: absence of unified methodology to assess externalities
		Implementation: complexity of attributing responsibilities and level of actions for internalizing externalities
Organizational	High time expenditure associated with internalization strategies	Longer time to dedicate to administrative procedures
		Longer time required for the increasingly complex process
	Higher complexity of tasks associated with internalization strategies	Inadequate management capacity
		Higher complexity for operators
		Complex administrative procedures
Financial	Higher costs associated with internalization strategies	High costs of implementing innovative process/technology
		High compliance and monitoring costs
		Lack of economies of scale
	Reduced financial accessibility for internalization processes	Decline in investment attractiveness
		Inadequate economic incentives
Market-related	Lack of demand-side interest for internalized products	Lack of market preference and pressure from customers/consumers
		Low willingness to pay for internalized products
	Inadequate supply-side structure for internalization strategies	Competition with conventional materials/processes
		Uneven playing field between actors
		Lack of properly defined property rights
	Obstructing marketing practices	Greenwashing
Governance-related	Decision-making and implementation challenges for recognizing internalization strategies	Challenges in deciding on a level of internalization
		Low political acceptability due to unequal impacts of internalization on various socio-economic groups
		Difficulties in deciding how the resulting revenue should be used or redistributed
	Inadequacy of current legal and regulatory frameworks for internalization strategies	Presence of obstructive policies and subsidies
		Lack of regulatory flexibility (Command & Control)
		Long-term uncertainties of policies
		Lack of properly defined property rights

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		Lack of policy harmonization and coherence
		Lack of binding rules and sanctions
Knowledge-related	Insufficient knowledge about internalization strategies	Lack of studies on relevant technologies/processes
		Limited expertise and experience
		Limited flow of information between actors about available technologies and best practices
		Lack of awareness about the issue of externalities
	Uncertainty about the potential benefits of internalization	Inaccuracies and errors in the assessment of externalities
		Neglect of some dimension (either socio, economic or environmental) in research
	Information imbalance in value chains	Information overload
		Asymmetry in the information
Relational		Lack of coordination among actors of the value chains
		Tensions created by opposed visions and preferences among actors at various levels of the value chains
		Unbalanced power between actors in decision-making process
		Lack of transparency
Socio-cultural	Resistance to change towards internalization strategies	Risk aversion
		Absence of long-term consideration
		Economically dominated thinking
		Low social acceptability of internalized products/processes
		Unwillingness to engage in trade-offs
		Importance of traditions blocking innovative processes/practices
		Generational effect blocking innovative processes/practices
	Weak commitment (particularly at corporate managerial level) for internalization strategies	Lack of distinct goals and measures to address sustainability
		Low recognition of socio-environmental issues
	Lack of alignment between actors' visions and objectives	Historical legacy of conflict between actors
		Heterogeneity and multiplicity of consumers' expectations
External		Risk of reversal
		Climate risk

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7.4 Appendix 4. Specific barriers' elements mentioned in the FOODCoST case studies (through preliminary questionnaire, online survey and interview), by main categories of barriers

	 Technical	 Organizational	 Financial	 Market	 Knowledge	 Governance	 Socio-cultural	 Relational	 External
CS1	- Data access and reliability - Methods availability and coherence		- Cost of calculation - Access to finance	- Priority on cheap coffee (limited demand for 'internalized' coffee) - Consumers resistance to price increase -Managing volumes to avoid TCA-certified coffee becoming surplus - Greenwashing wave	- Lack of education in companies about fair distribution of value - Unknown cost of their farming by farmers - Lack of knowledge about sustainable farming practices	- Trade-off (leading to internal difficulties on deciding a level of internalization): local value generation vs emissions	- Lack of awareness and resistance to change in corporate practices	- Unbalanced power dynamics - Opposed interests between producers and consumers	- Climate risks for producers
CS2	- Lack of equipment for mechanical weeding, lack of separate storage capacity for non-GM soybean- Lack of educated expertise in	- Administrative burden on farmers (up-to-date farm logbook, spraying	- high cost of cleaning the processing machinery after imported soy	- Lack of solvent uptake market for the end product (meat) produced from non-GM, locally	- Lack of practice-related education for students; large number of non-educated farmers	- Regulatory delays impacting production	- Slow change of perspective towards sustainability due to slow generational	- Lack of collaboration and coordination in the soybean value (partly due	- Climate, environment

	Technical	Organizational	Financial	Market	Knowledge	Governance	Socio-cultural	Relational	External
	formulating feeds by taking into account air-emission- Challenge in achieving high yield and quality- Difficulty meeting production scale and consistency required by the industry- Lack of data for precise farm level air-emission calculation and limited number of air-emission calculators applicable for agricultural production + no price recognition for positive externalities of soybean production	logbook, reports, specific data need for emission-calculator)		grown, high quality soybean (no consumer recognition of these features yet, no label yet)- Competition with conventional products (Hungarian soymeal is not better than the South American origin's (not taking into account LUC effect))- Lot of soybean export because of higher market prices on external markets	+ low amount of the produced crop (limited experience)- Weak knowledge-transfer; language barrier		turnover- Farmers' ageing + old non-innovative farmers are in decision-main/leading positions who are avoiding or not accepting new thinking methods- Farming driven by tradition and instinct rather than perspective and purpose	to uneven geographic distribution)- Weak bargaining position and advocacy skills of the individual soybean farmers because of low amount of the produce and the absence of collaboration; - Opposed interests between producers (volume+yield) and processors (quality)- Lack of value chain perspective	

	Technical	Organizational	Financial	Market	Knowledge	Governance	Socio-cultural	Relational	External
				(Germany, Italy, Austria,...)					
CS3	- Data ownership and sharing (producers having to invest in data collection but not always reaping the benefits from their contributions)		- Increased investments in greenhouse infrastructure and adopting practices like using fewer pesticides and fertilizers	- Consumers resistance to price increase despite informative labels - Same market price for premium and conventional products	- Lack of studies on relevant technologies/processes- Limited expertise and experience- Limited flow of information about available technologies and best practices	- Need for regulations promoting sustainability- Need properly defined property rights (water, carbon, and sun)- Importance of policymakers being aware of the actual situation in agriculture- Outsourcing environmental and social responsibilities to other regions	- Risk aversion- Short-term perspective- Economically dominated thinking	- Lack of coordination - Opposed visions and preferences- Unbalanced power- Lack of transparency	
CS4									

	Technical	Organizational	Financial	Market	Knowledge	Governance	Socio-cultural	Relational	External
CS5 (+ see CS9)	- Data disclosure - Local relevance - Need for sector-specific guidance, as different industries may have unique challenges in assessing and reporting their impact on consumer health	- Due to complexity of procedure, t's mostly for big companies, not SME	- Potential decline in investment attractiveness if investors see this reporting as short-term risk generator			- Need data transparency/availability - Need policies for shaping reporting practices, but hard to anticipate potential future regulations	- Including the cost of externalities in the financial performance of the company could be a huge change in the strategy of companies. The financial community can be reluctant to implement such a strategy (resistance to change)		

	Technical	Organizational	Financial	Market	Knowledge	Governance	Socio-cultural	Relational	External
CS6	- Establishing clear causality chains (ex. Linking food exposure to health/envi effects)- Data availability and uncertainty- Differentiating between incidence and prevalence of diseases - Establishing a harmonized methodology (ideal but unfeasible)								
CS7	- Limited availability of adapted technology & lack of skilled workforce- Limited data accessibility, methodo issues (unaddressed externalities leading to inadequate pricing + difficulties in establishing equitable rates of internalization)	- Tedious administrative procedures and bureaucracy	- Need for investment, especially for larger-scale sustainable beef production, with a suggestion that public authorities should bear initial costs.	- Power dynamics between conventional and sustainable producers, and their negotiation power with retailers, influence the market and consumer	- Resistance to change in consumer behavior is linked to a lack of education, particularly in terms of nutrition and a healthy diet - While there is a growing amount of studies	- Allocation of taxed money (necessity for transparency to prevent undue influence from big actors)- Financial support for investments like for larger-scale sustainable beef production	- Tradition to eat meat and Cooking traditions as obstacles to the uptake of plant-based meat alternatives	- Power dynamics- Conflicting visions of sustainability and economic profitability- Lack of transparency (influences of big actors behind policies)	- Unfavorable environmental conditions for sustainable beef production

	Technical	Organizational	Financial	Market	Knowledge	Governance	Socio-cultural	Relational	External
				choices.- Greenwashing	regarding the plant-based meat alternatives and its potential benefits, there is yet to be a scientific consensus on this matter - There is the need to expand and share the information on what sustainable beef entails.				
CS8						- Mandatory labeling probably more effective than voluntary schemes		- Reservations from retailers about communicating negative externalities & preference for focusing on positive externalities	

	Technical	Organizational	Financial	Market	Knowledge	Governance	Socio-cultural	Relational	External
CS9	- Data accessibility and uncertainty (companies do not have sufficient data of their own portfolios (age, sex, health status of product purchaser)- Complexity of the methodologies (including factors like disease burden, consumption patterns, and individual vulnerabilities in financial reporting)- Difficulty in attributing productivity loss to specific food product portfolios - Limited user-friendly character of proposed financial tools		- Potential decline in investment attractiveness if investors see this reporting as short-term risk generator			- Need policies for shaping reporting practices. There is currently no law is forcing companies to report against nutritional profiling model, such as NUTRI score or Healthy star rating. And if Member State were to do it, it will be against the EU law since it hasn't been settled yet.	- Need for shifting investor perspectives towards a long-term view - Social acceptability: Consumers want healthier products e.g. less sugar, but they want it to taste the same.		

	Technical	Organizational	Financial	Market	Knowledge	Governance	Socio-cultural	Relational	External
CS10	- Limited availability of locally produced food, which can't respond to the growing policy demand- Lack of facilities (ex. pastry studios) - Challenge in assessing external costs of menus	- Complex procedures requiring time and expertise (ex. more homemade and raw products to prepare, which take longer to cook + staff needs to be formed)	- Additional costs (staff, equipment, trainings)- In France, there are existing financial support and incentives for some kind of products (dairy, meat, vegetable & fruits). They are adequate, but not sufficient (more money needed).	- Need for competitive prices in order to be able to provide affordable menus		- Lack of government sanctions (// law Egalim; stimulating good behaviors through subventions, but not sanctioning bad behaviors) - Trade-offs between maintaining the cold chain and reducing negative externalities	- Cultural habits and the challenge of sensitizing parents and children to alternative dishes/menu (especially those with less meat)	- Lack of coordination - Tensions created by opposed visions and preferences in the value chains - Unbalanced power between actors (Power dynamics with retailer pushing for lower prices) - Lack of transparency	

	Technical	Organizational	Financial	Market	Knowledge	Governance	Socio-cultural	Relational	External
CS11	- Availability of genetic diversity	- Limited infrastructures (leading to difficulties in managing dehulling and drying after harvest)	- Costly investments at the production and processing stages. - Extra transportation costs for storage and drying (for farmers not having such infrastructures) - Lack of economies of scale (higher costs associated with lower volumes, especially during the exploratory phase of the project)	- Lack of demand for locally produced soy. - Higher costs of local soy production compared to imports	- Lack of experience and expertise for locally grown soy - Lack of clarity on quality criteria for the new crop - Lack of knowledge about benefits of plant-based eating	- Need for policies or regulations to level the competition between local and imported goods.	- Lack of plant-based eating culture (lack of knowledge about benefits)		

7.5 Appendix 5. Guidebook to mapping lock-ins

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GUIDEBOOK TO MAPPING LOCK-INS

A step-by-step methodology
designed to identify barriers to changes,
along with breaking pathways of transition

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2024

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transition of food systems

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Table of contents

GLOSSARY **4**

PREAMBLE **6**

WHY A GUIDEBOOK ON LOCK-INS IDENTIFICATION? 7
PROPOSITION OF AN APPROACH TO IDENTIFYING LOCK-INS 9

THE STEP-BY-STEP PROCEDURE **11**

A. SCOPING THE RESEARCH 12
1. Defining the system boundaries 12
2. Mapping actors of the system 16
B. IMPLEMENTING THE RESEARCH 22
B.1. IDENTIFYING BARRIERS 23
3. Collecting data 23
4. Analyzing data 26
5. Connecting barriers 30
6. Validating data 32
B.2. IDENTIFYING LEVERS 33
7. Identify levers 34
8. Linking levers to operational measures 36
9. Linking operational measures to actors 36
C. FINALIZING THE RESEARCH 39
10. Reporting results 39

CONCLUSION **41**

ANNEXES **42**

ANNEX 1. ANALYSIS PERFORMED TO VALIDATE THE GUIDEBOOK'S METHODOLOGY 43
Annex 1.a. Defining the system's boundaries 43
Annex 1.b. Mapping actors 44
ANNEX 2. EXAMPLE OF INTERVIEW FOCUS FROM THE DIVERIMPACTS PROJECT 46

REFERENCES **47**

Glossary

Agri-food systems
Web of actors, processes, and interactions involved in growing, processing, distributing, consuming, and disposing of foods, from the provision of inputs and farmer training to product packaging and marketing, to waste recycling (IPES 2015).

Barrier
A specific factor of a system that hinders a change of practices or strategies (proposed definition).
When barriers are stronger than drivers promoting change, the current production system is strengthened and self-perpetuated, creating a lock-in (Weituschat et al. 2022).

Innovation
Something new or improved, which differs substantially from what is commonly accepted in the established regime (proposed definition). Innovations span from technological breakthroughs to novelties in social, institutional or business models.

Lever
An influential factor or mechanism that can be strategically utilized to exert influence on a system in order to break free from an existing lock-in situation and enable a transition to a more desirable state (proposed definition).
These are often broad and high-level strategies that have the potential to disrupt the current lock-in dynamics. For practical implementation, levers are further disaggregated into operational measures, translating broad strategies into tangible, actionable steps to drive change.

Lock-in
A phenomenon occurring due to the tendency for policies, technologies, cognitive frames, infrastructure, and social systems to co-evolve and reach a state of stability and self-perpetuation. Lock-ins occur when links or feedback between these factors combine to lock a system or set of actors onto a particular pathway or behaviors, thereby hampering any change towards a potentially superior system (adapted from Truong, Trencher, and Matsubae 2022).

Operational measures
Specific, tangible actions or interventions taken at a practical level to bring about change and navigate out of a lock-in situation (proposed definition).

Path-dependency
A concept used to explain how historical events orient a certain process onto one or another path (Cowan and Gunby 1996).

Regime
The locus of established practices and associated rules that stabilize existing systems (Geels 2011).

Sustainability transitions
We address transitions towards sustainability through the Multi-Level Perspective (MLP) framework developed by Geels and Schot (2007) to describe and analyze the complex, long-term processes of configurations of technologies, infrastructures, social practices, markets,

institutions. The MLP framework encapsulates a dynamic process where niche innovations gradually build up internal momentum, while changes at the landscape level create pressure on the system and regime. Consequently, destabilization of the regime creates windows of opportunity for niche innovations, which then diffuse and disrupt (parts of) the existing system (Geels 2020), thereby catalyzing a transition.

Systemic approach

An analysis method that considers all constituent parts of a system rather than its individual elements. Rooted in the concept that "the whole is more than the sum of its parts", a systemic approach acknowledges and explores the interactions and interdependencies among the different elements within the system (proposed definition). This method inherently embraces interdisciplinarity, encouraging the integration of insights and methodologies from diverse disciplines to foster a more comprehensive understanding of complex systems.

Preamble

The why and how of this guidebook

Why a guidebook on lock-ins identification?

The reconfiguration of unsustainable agri-food practices requires overcoming lock-ins in the systems

It is glaringly apparent that modern food systems have veered towards unsustainable trajectories in the last half-century (De Schutter 2017). The reliance on environmentally impactful inputs and practices in contemporary agricultural systems has resulted in adverse effects with numerous negative externalities spawning on the environment and society. Despite these alarming realities, the transition of agri-food systems towards sustainable modes of production and consumption encounters strong resistance, as outlined by Conti, Zanello, et Hall (2021). This resistance of agri-food systems to change in new directions is increasingly studied under the lenses of *path-dependency* and *lock-in* concepts.

We define a lock-in as a phenomenon stemming from the co-evolution of policies, technologies, cognitive frames, infrastructure, and social systems, culminating in a state of stability and self-perpetuation. Lock-ins emerge when these individual factors, referred to as 'barriers', interconnect to lock a system or set of actors onto a specific pathway or behavior, hindering any change towards a potentially superior system. The lock-in mechanism thus solidifies the status quo, obstructing the exploration of alternative developmental pathways. This perpetuation is notably evident in agri-food systems, which globally remain entrenched in their current unsustainable states (De Herde, Maréchal, and Baret 2019; Weituschat et al. 2022). For instance, despite growing advocacy for agroecology, this agricultural narrative is kept at bay by numerous factors. These factors can include dominant research priorities favoring industrial agriculture, historical production preferences, infrastructures supporting lucrative crops, institutional policies, and influential entities dismissing agroecology collectively (Vanloqueren and Baret 2009; Conti, Zanello, and Hall 2021). In the illustrated example (Figure 20), the Belgian cereal sector is locked into a conventional agricultural production system reliant on intensive chemical inputs, perpetuated by various barriers (seven barriers identified). Interactions among these barriers, as depicted by dashed arrows, further fortify the locked state of the system.

Lock-ins frequently emerge from path-dependent processes, where historical events shape technological development trajectories (Cowan and Gunby 1996). Once historic circumstances and preliminary strategic choices have led to the establishment of a certain trajectory, a set of coevolving factors builds around and reinforces these choices (Conti, Zanello, and Hall 2021). Thus, the trajectory initially set becomes extremely difficult to dislodge.

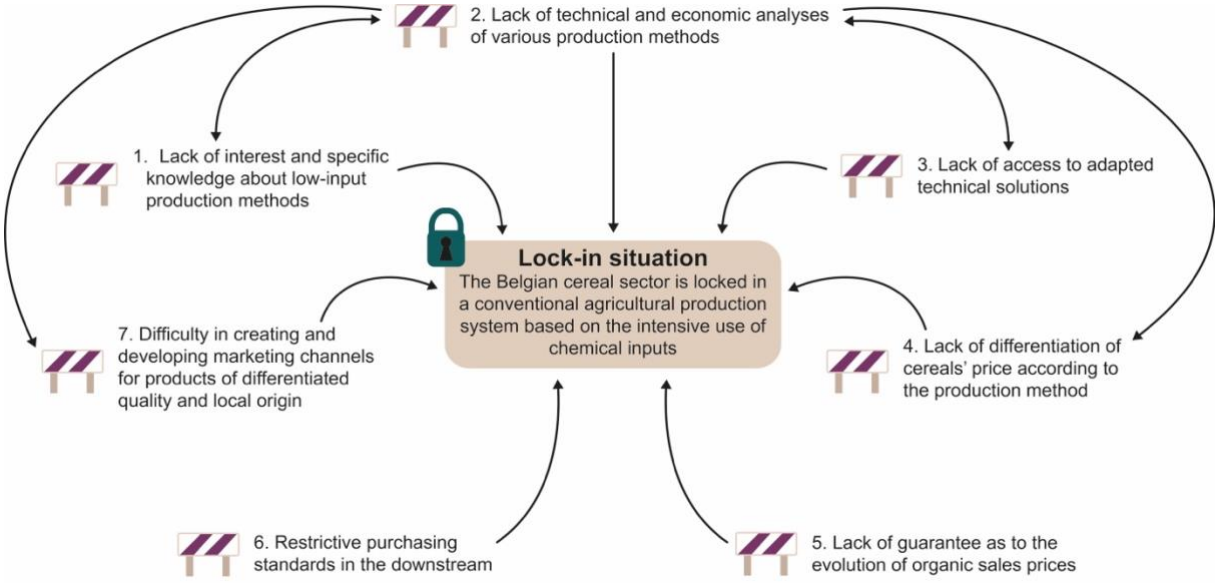

Figure 20. Illustration of a lock-in situation created by seven barriers within the Belgian cereal sector. Source: (Petel, Antier, and Baret 2019)

To move beyond current unsustainable food production and consumption patterns, a systemic understanding of how agri-food systems can be unlocked is crucial (Conti, Zanello, and Hall 2021). This involves comprehending the interconnected and self-reinforcing nature of factors creating resistance to change. This guidebook on lock-ins identification bridges the gap between theory and practice, offering a structured methodology to identify components of a system that resist change and perpetuate unsustainable regimes—the barriers. It primarily serves researchers as a methodological tool aimed at enhancing comprehension of the present circumstances of a locked system, serving as a prerequisite for sparking discussions on future pathways. Employing a systemic approach, the guidebook guides readers through an analysis of all constituent parts of a system and their relationships, providing a comprehensive assessment of potential blockages. Moreover, it introduces a methodology to identify levers and operational measures to overcome these barriers, thereby facilitating the required changes. Indeed, recognizing and characterizing lock-in phenomena is impactful only when followed by effective action. The guidebook's ultimate objective is to catalyze action-oriented research on agri-food systems transition, empowering decision-makers to drive fundamental changes towards increased sustainability.

Proposition of an approach to identifying lock-ins

There is a growing scholarly focus on uncovering lock-ins within agri-food systems, with various studies shedding light on this phenomenon (Revoyron et al. 2022; Weituschat et al. 2022; Messner, Johnson, and Richards 2021; Conti, Zanello, and Hall 2021; Sopjani et al. 2020; De Herde, Maréchal, and Baret 2019; Meynard et al. 2018; Magrini et al. 2016; Fares, Magrini, and Triboulet 2012; Stassart and Jamar 2009; Vanloqueren and Baret 2008). However, we identified a gap as there was a notable absence of a unified methodology for conducting a systemic analysis of the mechanisms in play. This guidebook aimed to fill this void by presenting a comprehensive, step-by-step approach.

In this guidebook, we introduce a ten-step methodology to facilitate the identification of barriers and levers. These steps draw on the extensive research conducted by Sytra, a research team from the Université catholique de Louvain (Belgium), informed by studies spanning various contexts (Vanloqueren and Baret 2008; 2009; Baret et al. 2013; De Herde, Maréchal, and Baret 2019; De Herde, Baret, and Maréchal 2020; Morel et al. 2020; Amrom et al. 2021). The methodology's implementation is further refined through a thorough review of existing literature, consultations with experts, and insights gained from our practical experience. This guidebook, designed as a working paper, serves as a supportive tool for identifying lock-ins hindering the transition of any agri-food system. It will be subject to continuous improvement as feedback comes in.

The ten-step methodology unfolds across three levels: scoping, implementing, and finalizing the lock-in research (Figure 21). The scoping phase aims to precisely define the boundaries of the system under consideration (step 1) and map the involved actors (step 2). Recognizing that barriers creating a lock-in can vary based on the system's limits and its actors, these initial steps serve as the indispensable foundation for a rigorous investigation of lock-ins. Once the system and its actors are clarified, the methodology progresses to the second level: identifying individual barriers and levers. This implementation phase emphasizes close collaboration with key informants representing actors of the system to ground the identification process in collective intelligence (steps 3 to 9). Lastly, at the finalization level, we underscore key considerations for synthesizing and reporting results, ensuring objectives are met, targeting the right audience, and aligning the report with action-oriented research. We advocate for systems mapping as a comprehensive methodological approach to lock-ins identification, involving visual depictions such as diagrams, maps, or sketched models that capture the intricate relationships and feedback loops among actors and trends (Sedlacko et al. 2014; Waddell 2016).

Grounding the lock-in identification in a scientific approach enhances its recognition and validity among all actors, laying a solid foundation for subsequent discussion and action. Moving beyond locked-in situations requires engaging multiple actors in concerted action, a feat achievable only with a shared understanding of the initial situation. Thus, a lock-in mapping is relevant when it is perceived and can be defended as reliable. The scientific approach must thus allow for transparency (of the process, data quality and sources), reproducibility (of the results with a given data collection and analysis method) and consistency (with other sources, previous publications, etc.). This scientific approach also serves to embed the mapping and analysis within the broader realm of research in sustainability and transition management.

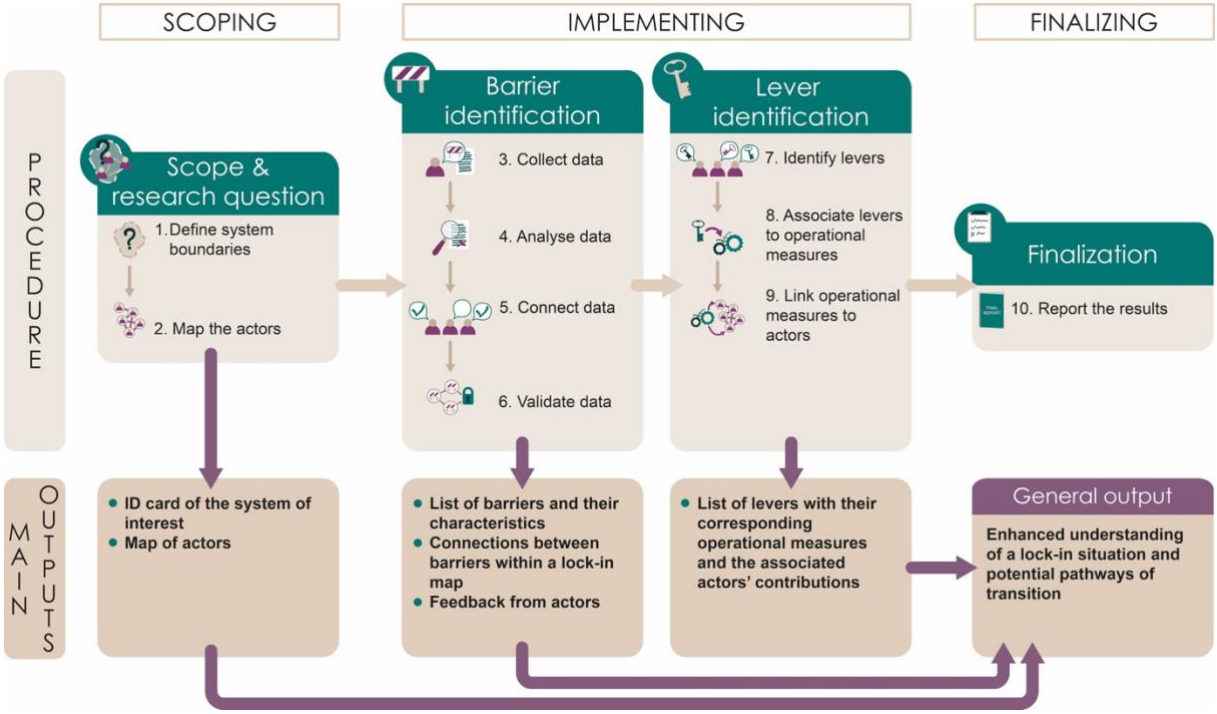

Figure 21. Overview of the ten-step methodology and its main outputs for mapping lock-ins

The step-by-step procedure

A practical ten step methodology to identify barriers that perpetuate unsustainable systems and to facilitate a disruption towards transition

A. SCOPING THE RESEARCH

1. Defining the system boundaries

A. Purpose and rationale

As a first step in identifying lock-ins phenomena in a specific agri-food system, we propose to identify the boundaries of that system. An agri-food system, by its definition, is comprised of a web of actors, processes, and interactions involved in growing, processing, distributing, consuming, and disposing of foods, from the provision of inputs and farmer training to product packaging and marketing, to waste recycling (IPES 2015). This broad definition poses the risk of resulting in an all-encompassing and rather abstract analysis of the system (Van Berkum 2022). For that reason – and to be able to use systems thinking for practical solutions – the mapping of lock-ins in agri-food systems starts with the definition of the systems' boundaries. Systems thinking studies represent a theoretical exercise aiming to model the 'real system'. It is therefore always an approximation of reality. The modelling process is designed based on the focus the researcher has while defining the system, meaning that the initial research interest already sets some boundaries to the theoretical model of the system itself.

Our analysis (see details in Annex 1.a) has revealed five key recurring actions critical in defining system boundaries. While these actions complement each other, they address distinct methodological requirements and are applied at different stages of the process.

a. Define an explicit purpose

In framing system boundaries, a pivotal step is articulating an explicit purpose through the formulation of a precise research question. The success of any research endeavor hinges on the adept translation of a problem into a research question (Stone 2002; Thabane et al. 2009). Defining the research question inherently establishes the research project's purpose, along with the specific change it aims to contribute to. The system boundaries then align with this purpose, encompassing elements within the system that are instrumental in addressing the research question.

b. Identify key dimensions

In system thinking a founding principle relates to the understanding of the whole around the strategic variables of interest, rather than fragmented parts (Meadows 2008; Williams et al. 2017). In other words, the researcher should account for the system as a whole, rather than the mere sum of its components. Given the inherent challenge of grasping the entirety of systems, particularly when constructing related theoretical models, researchers must explicitly determine the essential dimensions to be included. In the context of the agri-food system, these dimensions span across socio-ecological, technological, environmental, economic, and institutional aspects. The categorization of key dimensions as either exogenous or endogenous, allow to account them outside the model or by the model itself, respectively (Mankiw 2020; Varian and Varian 1992). The identification of key dimensions, and their characterization as exogenous or endogenous to the model contributes to the explicit definition of system boundaries.

c. Work with the constraints

Acknowledging the constraints that bind a research project — both external and internal — is imperative. In project management, the 'Iron Triangle' theory identifies cost, time, and quality

as the primary constraints (Atkinson 1999). Neglecting to effectively manage these constraints may jeopardize the whole project (Van Wyngaard, Pretorius, and Pretorius 2012). Defining system boundaries must account for these constraints, which may significantly impact project resources such as data availability, financial means, or the number of researchers involved. Establishing system boundaries that align with realistic and feasible resource utilization is essential to ensure the project's robustness.

d. Adopt a dynamic process

Embracing the system dynamics' approach in the analysis of complex issues and nonlinear behaviors involves viewing the identification of system boundaries as a dynamic rather than a static process . The three aforementioned actions are thus integral components of an iterative process, with each action influencing both preceding and subsequent steps. For instance, data availability may impact the definition of the research purpose, necessitating re-evaluation and potentially leading to a revised list of key dimensions. Recognizing that system boundaries are established through an iterative and dynamic process enables researchers to respond appropriately and relevantly to changes throughout the research project.

e. Acknowledge the unknown

Given the inherent complexity of systems there will inevitably be aspects that will not be included in the research boundaries, not out of choice, but for mere lack of knowledge. This could be due to high complexity characterizing the systems, researchers understanding of the system, lack of resources, etc. Yet, breaking the myth of completeness, robust research boundaries allow for high relevance of the theoretical exercise in studying the system and defining its model. Going back to the first action on research question, the definition of a clear purpose of the research, along with an iterative (action 4) and feasible (action 3) process of the definition of research boundaries, allow to include all relevant dimensions (action 2), ensuring that the 'unknown' does not impact the robustness of the results.

B. Procedure

To derive best practices from the theoretical insights provided in the previous paragraphs, we have compiled a set of guiding questions to facilitate the definition of the system boundaries (Table 3). Acknowledging the absence of a universal blueprint for delineating system boundaries, our aim is to empower the reader with thoughtful considerations to inform their reflections during this pivotal phase of the research project.

Table 3. Guiding questions to facilitate the definition of the system boundaries.

	Some reflections
Define an explicit purpose	• What is the research question? What is the overall research purpose? • How would you define the 'relevance criteria' derived from both the research question and research purpose? • Does the definition of system boundaries align with the explicit purpose and envisioned change(s) of the research project? • Are the boundaries framed to encapsulate elements crucial for addressing the defined research question and achieving the project's purpose?
Identify key dimensions	• Which dimensions (socio-ecological, technological, environmental, economic, institutional) are key for your research project? • Which one are to be treated as exogenous and which one endogenous to the theoretical model of the system?
Work with the constraints	• What are the time constraints of the project? • What are the financial/other resources constraints of the project? • What is the data availability of the project? • Do the defined boundaries allow for a realistic and feasible research ?
Adopt a dynamic process	• Are there mechanisms in place to adapt boundaries based on evolving factors such as data availability, altering research purposes, or redefined key dimensions? • Which relations (or loops) occurs across the actions to define system boundaries? • How actions affect one another?
Acknowledge the unknown	• How does the model cope with 'unknown' outside the system? • How does the model cope with 'unknown' within the system?

C. Expected output

The process outlined above for defining system boundaries guides the research team through crucial considerations for defining the scope, focus, and feasibility of the study. As a result, researchers should find themselves equipped to effectively complete the canvas presented in

Table 4, providing a general overview of the project. The reflections on the research and its boundaries initiated through this process ensure a realistic project and generate valuable insights to guide the subsequent stages of the study. We suggest using the canvas as an iterative exercise, where new versions are filled in to incorporate incoming changes, especially after integrating the actor's perspective as outlined in step 2.C. This approach helps researchers keeping track of the whole process.

Table 4. Canvas for defining system's boundaries.

Main research question: _____

Sub-set of research question:
a) _____
b) _____
…

Perimeter

Sector(s) involved in the research:	_____ *(agriculture, forestry education, transport, urbanization, …)*
Dimensions to be studied:	_____ *(socio-ecological, technological, environmental, economic, institutional, …)*
Temporal scale:	_____
Geographic focus:	_____

Key question: Does this perimeter address the research question in its whole?

Resources

Time available for the research	_____ (hours/days/month/years)
Staff available to conduct the research	_____ (number, with identification and expertise mobilized)
Available budget	_____ (€)
Do we have access to sources of data needed for the research? If 'partly or no', how can we secure access?	☐ Yes ☐ Partly or no _____

***Key question*:** Does the utilization of these resources allow for realistic and feasible research?

Exogenous factors

= List of factors identified as exerting influence on the system but beyond any direct control, such as geopolitical issues, or intentionally excluded from the system boundaries. If possible, add details regarding the reason why it is considered exogenous, the estimated impact on the robustness of the research results (on a scale from 1, no impact at all, to 5, strongly influencing the results) and other relevant comment.

Factor	Reason for exclusion	Impact	Other comment
• _____	_____	*(1 to 5)*	_____
• _____	_____	*(1 to 5)*	_____
• …	…		…

Key point: Acknowledging these factors and their impact in the evaluation of the research's results or in its limitations will allow for a more nuanced interpretation of the findings and their implications.

2. Mapping actors of the system

A. Purpose and Rationale

Once the contours of the system under scrutiny are clearly defined, the next step involves mapping the diverse actors — individuals or entities wielding varied degrees of influence within the system. This mapping exercise serves a dual purpose:

a. ***Enhance contextual understanding***: gain deeper insights into the system by identifying key actors, organizations, and initiatives that shape its structure and dynamics.
b. ***Inform data gathering***: identify pivotal informants crucial for the subsequent data gathering phase.

Within a system, it is important to recognize that each actor brings distinct values, routines, and norms, influencing their perspectives on actions and issues within the system (Naaldenberg et al. 2009). Actors possess unique resources — be its policy influence, strategic experiences, manpower, methods, materials, knowledge, finances, reputation, linkage, or leadership — that can shape interdependency between actors and power dynamics within the system (Naaldenberg et al. 2009). With individual goals and resources, each actor assumes a role, either enabling or constraining, in the development of alternatives and, consequently, in the system's transition. Analyzing barriers and levers to the emergence of alternative systems hence requires a nuanced understanding of the interplay between system actors and their power dynamics. Mapping these actors ensures a systemic exploration of these influences.

B. Procedure

Practical approaches to identify and map system actors vary across research projects. To encompass this methodological diversity, we conducted a systematic review of scientific papers focusing on systems actors *(see Annex 1.b).* Synthesizing insights from this review, we categorized the main sources of information for conducting an actors' mapping into five primary categories:

1. Using knowledge from the research team's

Approach: Utilizing the research team's existing knowledge of the system.
Our review showed that this method is often used in combination with others.

Example: Rametsteiner et Weiss (2006) initiated with a known set of actors, later employing snowball sampling to identify actors' network in forestry-related innovation policy. Similarly, Hedeler et al. (2020) and Mlala et al. (2022) complemented an initial sample of actors taken from personal contacts with a desk research and a snowball sampling to reach relevant actors for their respective studies.

2. Desktop research

Approach: Leveraging existing literature reviews, institutional reports, online resources, and other documented sources.

Examples: (Alkemade, Kleinschmidt, and Hekkert 2007; McIlroy et al. 2019; Iemmi 2019; Moon and Lee 2021) utilized previous academic research to identify system actors. McIlroy et al. (2019) and Fagerjord and Kueng (2019) based their mapping on institutional and organizational reports and database, while searches were performed in sectorial documents by (Li, Dong, and Mostafavi 2020), in public surveys and consultations by

(Bailey and Eggereide 2020; Lauber et al. 2020), and in existing map analyses by (Barthel et al. 2005).

3. Consulting experts

Approach: Seeking insights from subject matter experts within or outside the system.
We differentiate experts from other actors within a system. An expert is defined as either an individual with a comprehensive understanding of the subject in question, such as academics or institutional agents, or a 'change agent'—someone possessing the expertise and influence to encourage, facilitate, and coordinate efforts for change (Lunenburg 2010).

Examples: (Dickson et al. 2021; Seymour, Murray, and Fernandes 2008) used experts as a stand-alone approach for actor identification, while (McIlroy et al. 2019; Ivory and Trotter 2017) used it in conjunction with other sources, such as desktop.

4. Consulting other actors of the system

Approach: Directly engaging with other (non-"expert") actors of the system.
In our analysis, three distinctive approaches emerged for consulting non-expert actors. The first involves framing the research question to align with a specific actor or segment of the system. The second occurs when key players in the system are identified, and the third involves leveraging resources to engage a diverse range of actors.

Examples: Caic et al. (2019) delved into a care-based actor network, focusing on the viewpoint of elderly beneficiaries. Targeted interviews were conducted to grasp how the elderly conceptualize their care-service, providing a comprehensive understanding from their unique perspective. Tang, Chen, et Chiu (2018) and Assoumou et al. (2019) combined desktop research with interviews of informants considered central (producers in a local agricultural food system and members of an organization implementing community-based HIV testing, respectively) to map the system's actors. On the other side, Alamsyah et al. (2020) enriched knowledge from their research team and a desktop research with interviews targeting a diversity of informants purposively representing various actors of the system.

5. Relying on existing networks

Approach: Utilizing established networks related to the research topic.
This method can be very straightforward but requires similar boundaries both in the network and in the research question.

Example: Romero et al. (2022) identified actors in the national system of innovation in rehabilitation in Colombia by leveraging a pre-established National Innovation System network.

In navigating the diverse landscapes of actors' identification, researchers often combine multiple methods, adapting to the unique characteristics and requirements of each research context. The choice of approach is guided by the specific objectives, available resources, and the complexity of the targeted system. Two primary approaches emerged:

1. A one-step approach, in which one or several sources of information are mobilized in parallel to achieve a holistic mapping (Lauber et al. 2020; Mets 2006; Åm 2021; Alkemade, Kleinschmidt, and Hekkert 2007; Iemmi 2019; Li, Dong, and Mostafavi 2020).
2. A sequential approach, in which actors' identification is initiated using one or more sources from the list above, followed by subsequent consultations with informants. A snowball sampling technique is often employed in this sequential approach (Hedeler et al. 2020; Mlala et al. 2022; Rametsteiner and Weiss 2006; Mwangi, Kituyi, and Ouma 2020; Moore et al. 2022; Basnayake et al. 2021).

When engaging with various actors, it is common to encounter contradicting insights. Depending on the purpose of the research, one may either account for this heterogeneity in vision or privilege one perspective over another based on scientific evidence. In both cases, the research team should remain explicit about the chosen approach.

Snowball sampling technique

In a snowball sampling, researchers identify an initial set of actors, usually based on their own knowledge of the system and personal contacts or on information available online. Actors are then asked to name the most relevant actors for the issue under consideration. The most frequently mentioned people are interviewed in turn, until no more additional information is brought in by new interviews, resulting in a final network gathering a diversity of relevant actors. This method aims at identifying influential stakeholders rather than statistically representative samples.

Table 5 provides an overview of actors commonly engaged in agri-food systems and can serve as a tool for identifying relevant stakeholders. The decision to include or exclude specific groups should be guided by the established boundaries delineated for each specific system (see section 0. Defining the system boundaries).

Table 5. Categories of actors typically included in agri-food systems

Categories	Subcategories	Description & examples
Private sector organizations	*Upstream*	Inputs providers (such as seeds, machinery, chemical and energy input providers) ;
	Transversal service providers	Financial institutions (banks or other financial institutions providing loans or other financial support to the farming/food system), insurance & risk management services ;
	Farming and support to farming	Farmers, farmworkers and farmers unions/ organizations, farming advisory services/consultants, veterinarians ;
	Industry representatives	Industry representatives may represent agribusinesses (Collectors, Logistics, food Processing industry), or other stakeholders who have a direct interest in the profitability of the farming system ;
	Distribution and marketing	Ex: retailers.
Consumers, citizens and voters	/	Local communities (the farming system may have impacts on the surrounding community, including access to food, water, and other resources) ; consumers, citizens and voters, as a whole or specific sub-groups/organizations.
Public sector/ government institutions	/	Government agencies (government agencies, from the local to the regional and national level, may regulate or provide support to the farming system, and their policies can have a significant impact on its sustainability) ; icludes administration & policy makers.
Research/ scientific organizations and education	/	Researchers and academics may provide valuable insights and analysis on the different capitals and how they interact within the farming system ; includes social and economic sciences and natural sciences (e.g., agronomic research and agricultural education institutes).
Civil society organizations or NGOs	/	These organizations may have a particular interest in the social or environmental impacts of the farming system.

C. Refining the scope through iterative processes

To finalize and validate the research scope, we recommend integrating the initial two scoping steps—defining the system boundaries and mapping the actors—into an iterative process. This involves a process of establishing the boundaries and engaging with identified actors (Figure 22). Opening discussions with stakeholders about the initially proposed system boundaries can lead to adaptations. These adaptations may include expanding the boundaries to incorporate previously omitted components or refining them to exclude elements considered irrelevant. This iterative process guarantees the achievement of a mutually agreed-upon and well-defined project scope.

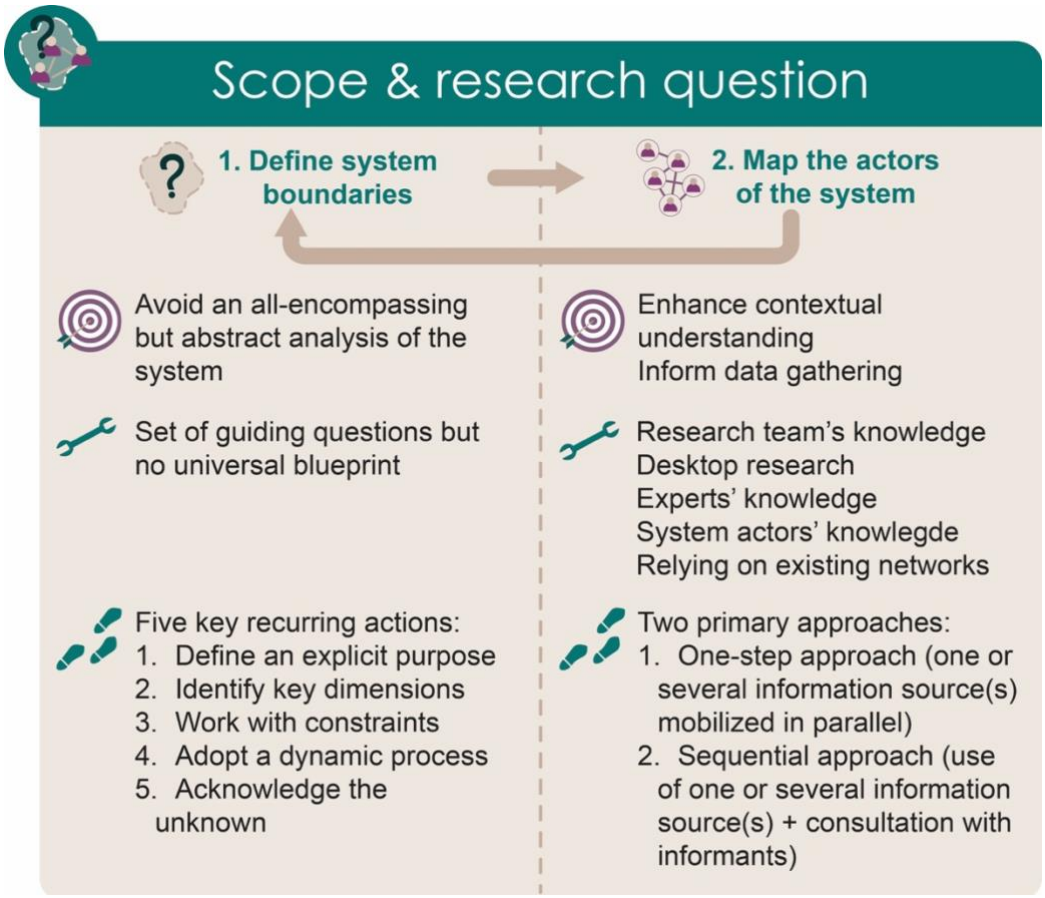

Figure 22. The two-steps approach proposed to define the scope of the research, including an iteration process between step 1 and step 2.

The primary phase, dedicated to scoping the research, was developed to help outline the elements to be investigated—the system boundaries—and identifying the actors to be involved. Subsequently, the second phase delves into the core objective of the guidebook: identifying barriers and levers.

D. Expected output

As a final output, we suggest summarizing the actors mapping into a visual depiction that provides a comprehensive view of the entire system at a glance, facilitating ease of comprehension and communication. Figure 23 provides an example of such visual schema, with actors organized by sector of activity. This schema can be complemented by a table with names of individuals identified in the sectors to be interviewed in the next phase of the research.

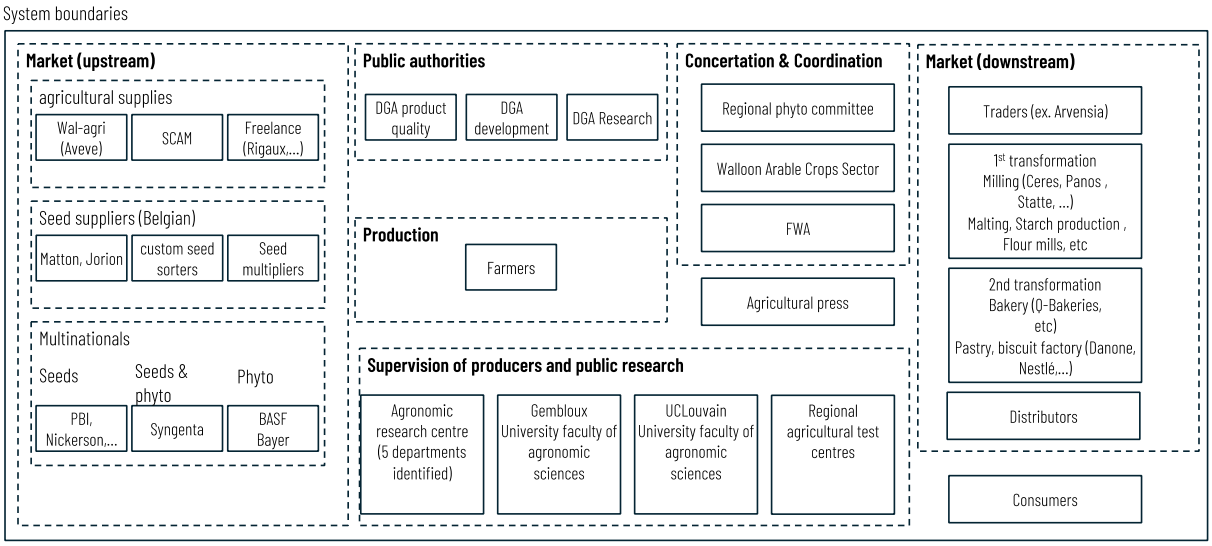

Figure 23. Example of the result of an actor mapping for the Walloon wheat production chain. Translated from (Vanloqueren 2007).

B. IMPLEMENTING THE RESEARCH

Locked-in systems are often stabilized by a complex interplay of barriers that obstruct any change of or within the system. Our methodology aims to identify these barriers that collectively contribute to the emergence and reinforcement of a lock-in. Practically, actors engaged in a system are usually aware of specific elements impeding change. The objective is to collect these tangible elements, which constitute the entry point of the analysis, and to synthetize them into categories of barriers (Figure 24). These barriers are enriched by elements identified through reviews of the literature. In the next phase, we aim to uncover levers to overcome barriers. Levers represent influential factors or mechanisms that can be strategically utilized to exert influence on a system in order to break free from an existing lock-in situation and enable a transition to a more desirable state. To render levers effective, they are translated into actionable operational measures. For optimal impact, these operational measures require endorsement and implementation by key actors within the system. We therefore propose a step linking operational measures with their responsible counterparts.

The interrelation of the different lock-in parameters—barriers, levers, and operational measures—is visually depicted in Figure 24, with the example of a barrier (a lack of access to adapted technical solutions suitable for low-input agricultural production) that contributes to the confinement of the Belgian cereal sector into a high-intensity reliance on chemical inputs.

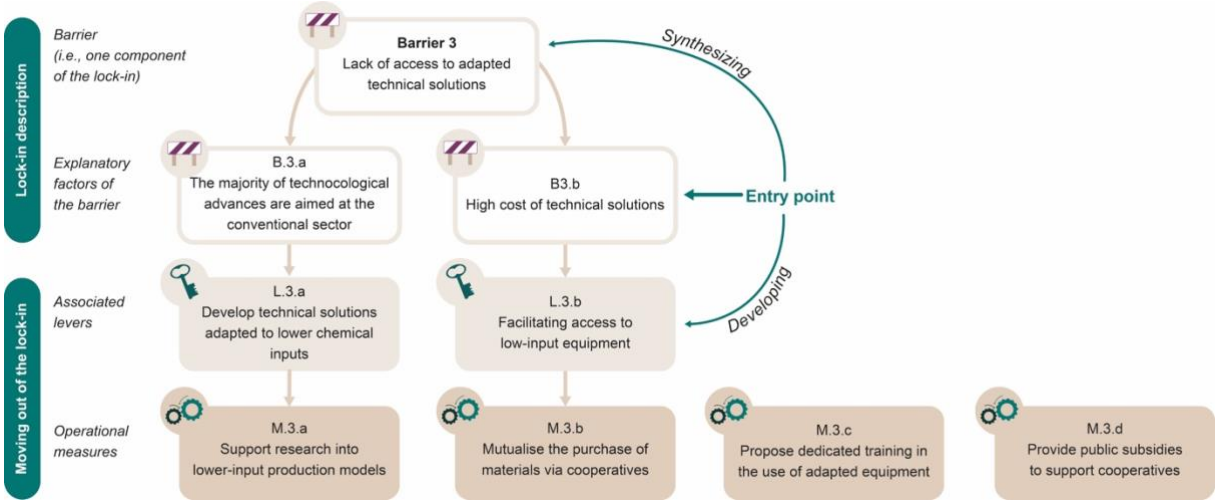

Figure 24. Example of barriers, levers and operational measures identified for the third component of the cereal chain barrier (cfr. Figure 20). Source: (Petel, Antier, and Baret 2019)

To comprehensively assess lock-in parameters, our methodology unfolds in two distinct stages: (1) the identification of barriers and (2) the identification of levers along with their associated operational measures. Both stages are deeply embedded in consultation processes involving key informants from the system, facilitated through interviews and/or workshops and focus groups. While both steps are necessary to provide practical solutions to overcoming a lock-in situation, the timing of their implementation can be flexible based on informant availability and the research team's preference. The approach may entail a simultaneous implementation to identify both barriers and levers during the same interviews/workshops or a sequential strategy to distinctly focus on barriers and levers through several rounds of interviews and/or workshops.

B.1. IDENTIFYING BARRIERS

The following four steps are dedicated to identifying barriers contributing to a lock-in phenomenon (Figure 25). They include

- Data collection
- Data analysis
- Data connection
- Validation

Experience underscores the effectiveness of a multidisciplinary process involving reflection and discussion between the research team and key informants of the system for identifying lock-ins.

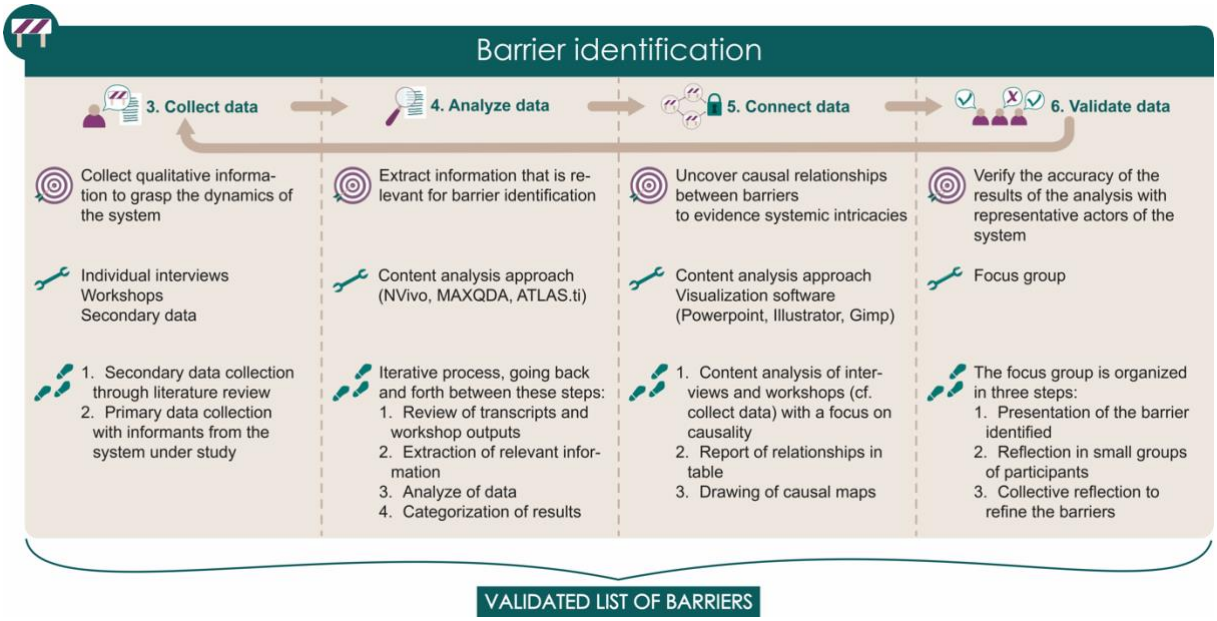

Figure 25. Overview of the 4-step process leading to the identification of barriers

3. Collecting data

When identifying barriers, qualitative information is at the core of the research for grasping intricate networks, cognitive dynamics, and existing pressures within a system. While not an exhaustive guide on collecting qualitative data, this section stresses the important steps in the process.

A. Procedure

Secondary data collection

Begin by conducting a comprehensive review of existing knowledge on lock-ins relevant to the system under consideration. This pre-identification serves as a valuable initial step to prepare the rest of the data collection. Numerous online resources exist to provide robust methodologies in order to conduct a valuable literature review, see i.e. Snyder (2019).

Primary data collection

Given the contextual nature of lock-ins, it is essential to scale from secondary up to primary data collection. Primary data enriches the process by grounding the lock-ins identification in the complexity and specificity of the system under consideration. In the case of lock-ins

identification, primary data consists mainly of qualitative information. Two primary approaches can be adopted by research teams for conducting qualitative data collection:

a. ***Individual interviews***
   Conduct direct interviews with system actors, adopting semi-structured [1] formats for open expression of reasoning, perceptions, and experience. Resources like Ritchie et Lewis (2003) are valuable to help in preparing semi-structured interviews.
b. ***Group interactions***
   Gather actors for collective discussions, employing workshops or similar formats for rapid, dense information collection. This approach benefits from the collective process and group interactions.

The choice between individual interviews and group interactions is a matter of research team preference. A combination of both approaches can be considered. Pros and cons of each technique are summarized in
Table 6.

In both cases, the research team should dedicate sufficient time to prepare the collection of information. As an example, in the DiverIMPACTS project [2], prior to interviewing informants, the research team compiled pre-identified barriers in their system, outlining key investigation points (see Annex 2). Specific questions were tailored to address informants at different levels of the value chain and covered issues such as

- the economic implications and profitability linked to the adoption of an innovation or change of practice in the system;
- the availability of equipment and logistic means;
- the availability of adapted knowledge;
- cultural pressure and behavioral preferences, including risk aversion, that could create resistance to change;
- power balance and type of relationship existing between actors of the value chain.

This example demonstrates an organized approach where the system was studied across various levels of the agri-food value chain, spanning from agricultural inputs and production to policymaking. It can provide a blueprint for collecting pertinent information, ensuring a comprehensive understanding of diverse factors influencing the system's dynamics.

Overall, the collection of data should be organized to achieve two objectives:

- Identify existing barriers (achieved through Step 4. Analyzing data).
- Gain a deeper comprehension of the causes and consequences of these barriers (achieved through Step 5. Connecting barriers).

1 A type of interview where the interviewer attempts to elicit information from the interviewee by asking predetermined questions and leaving space for open responses. The aim is to allow the interviewee to develop issues they feel are important.

2 DiverIMPACTS - Diversification through Rotation, Intercropping, Multiple Cropping, Promoted with Actors and value-Chains towards Sustainability - is a European project that was funded under Horizon 2020, the European Union's framework programme for research and innovation. More information: www.diverimpacts.net and https://zenodo.org/communities/diverimpacts

Table 6. Strengths and weaknesses of interviews and workshops as techniques for collecting qualitative data.

	Primary data collection sources	
	 Individual interviews with actors	 Collective workshops with actors
Strengths	• Lower time commitment from each person interviewed ; • Informants are unaffected by the position and opinions of others; • Informants can feel more at ease sharing their experience and sensitive information in a private interview;	• Lower time commitment from the research team; • Generate a common understanding by all actors of the system, as well as its strengths and weaknesses; • Deeper reflections and creativity can be encouraged by collective intelligence; • Tend to encourage cooperation among participants;
Weaknesses	• Higher time commitment from the research team if many informants are to be interviewed; • Comparing and analysing results from many interviews can be complex; • There is no group ownership of results; • Might necessitate an additional step	• Higher time commitment from participants; • Informants might be reluctant to share some information in groups; • Some informants might dominate the discussion, while others don't feel comfortable speaking up; • Requires good facilitation skills;

B. Expected output

At this stage, the research team should end up with

1. A review of the literature on existing barriers within the topic of their research.
2. Raw transcripts of interviews and/or notes of collective interactions with actors.

4. Analyzing data

A. Procedure

From the data compiled during the data collection process, we move on to analytical phase to extract information that is relevant for the identification of barriers. We advocate for an iterative process during data analysis, involving a continuous back-and-forth movement between reviewing transcripts or workshop outputs, extracting relevant information, analyzing the data and organizing the results (Figure 26).

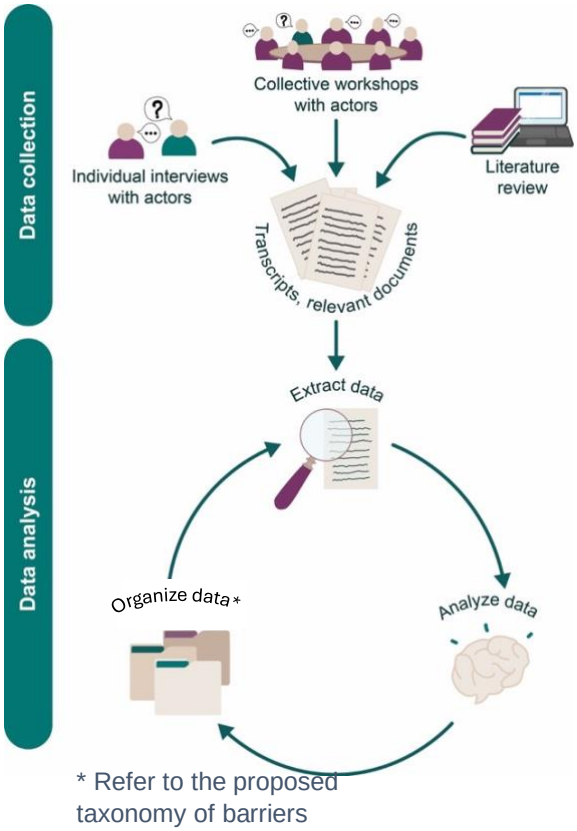

Figure 26. Overview of the data analysis process leading to the identification of barriers

Many researchers have adopted a content analysis approach for qualitative data analysis (e.g. (Morel et al. 2020; Alamsyah et al. 2020; Moore et al. 2022; Assoumou et al. 2019; Jauhiainen and Hooli 2017; Tang, Chen, and Chiu 2018; Zulu et al. 2019). This method involves coding segments of interviews to systematically identify themes, and patterns, and to report the findings numerically or graphically (Sovacool, Axsen, and Sorrell 2018). The overarching objective is to progressively build clusters of barriers based on interview or workshop content, resulting in a clear organization of lock-in impeding the system's transition.

Various qualitative data analysis software tools, such as NVivo, MAXQDA, and ATLAS.ti, can facilitate the identification of emerging themes. Following the data collection, transcripts of the interviews or notes from the workshops are read a first time in full to gain an overall understanding of the data, then re-read to identify general themes. These themes are coded in the analytical software. The codes are combined or contrasted to develop and interpret overarching categories, generating a network of associations. At the end of this process, themes and categories undergo thorough review to ensure accurate representation of the data. Adjustments, such as merging or splitting themes and categories into sub-groups, are made as needed. The analysis can thus result in multiple layers of organization within the data, including various categories, themes, and subtopics. The coding process should be robust and

flexible to accommodate this complexity, ensuring that all relevant aspects of the data are appropriately captured and analyzed.

In
Table 7, we propose a taxonomy of barriers commonly faced when assessing barriers to a transition in agri-food systems. Categories span across technical, organizational, financial, market-related, governance-related, knowledge-related, relational, socio-cultural, and external dimensions. The inclusion or exclusion, and further disaggregation of each category (into, for instance, themes or levels of detail) is to be decided by the research team based on the relevance for their own study. While this taxonomy provides a versatile framework for organizing barriers in various contexts, alternative structuring categories can also be considered.

Table 7. Proposed taxonomy of barriers

Category	Description	Examples
Financial barriers	Barriers linked to (i) the costs and investments related to the implementation of the innovation and (ii) the financial impacts of the innovation.	Cost increase, high-priced products, investments in machinery.
Governance-related barriers	Barriers linked to decision-making process, and legal and regulatory frameworks	Lack of supporting government regulations and policies, lack of subsidies, lack of flexibility of the decision-making process.
Knowledge-related barriers	Barriers linked to the gap of knowledge, awareness and experience of actors regarding the innovation and its implementation.	Lack of awareness regarding the technology/ innovation, lack of advisors experienced in the technology/innovation.
Market-related barriers	Barriers linked to external market conditions.	Lack of downstream actors, quality standards imposed by downstream actors.
Organizational barriers	Barriers linked to the management of both time and tasks by individual actors.	Need for changes in time management, lack of involvement of farmers in research, higher complexity of work and administration procedures.
Relational barriers	Barriers linked to the interactions between actors of a value chain.	Lack of communication between actors, lack of trust between actors.
Socio-cultural barriers	Barriers linked to attitudes, beliefs, norms, and values of actors.	Lack of risk-taking, fear of yield/profit decrease, weight of traditions.
Technical barriers	Barriers linked to the practical implementation of an innovation; it includes technological and infrastructure factors.	Lack of machinery, absence of processing line, crop management difficulties.
External barriers	All other barriers beyond the influence or control of the system's actors.	Inadapted pedoclimatic conditions, increased uncertainty resulting from climate change.

B. Expected output

The data analysis will yield a comprehensive identification of barriers impeding changes within the studied system. Typically, these barriers are listed in a table organized into categories, with potential sub-level classification logics if relevant.

Table 8 provides an example of barriers identified in the context of crop diversification by Morel et al. (2020). In this example, the authors decided to group barriers according to the level of the value chain to which they apply: (i) agricultural production; (ii) downstream operations from farm to retailing; (iii) marketing and consumers; or (iv) contracts and coordination between actors. They further organized the barriers based on three "ideal-types" of food system innovation settings ("Changing from within", "Building outside", "Playing horizontal") used as conceptual categories to discuss barriers.

Table 8. Occurrence of barriers to crop diversification identified in the 25 DiverIMPACTS case studies, and their links to the ideal-types of food system innovation setting. Source: Morel et al. (2020).

	Barriers to crop diversification	Code	n	W	O	H
Agricultural production	Lack of technical knowledge and references	K_Tec	21			
	Lack of economic knowledge and references	K_Eco	16		0	1
	Need for investment for adapted machinery	Machin_Invest	13	0	1	0
	Lack of knowledge and references about impacts on sustainability	K_Sustain	12	1	0	
	Profitability is low, problematic or uncertain	Profit	11	0		1
	Uncertainties, risks and variability of agronomic performances	Uncert_Perf	10			
	Lack of technical knowledge on the impact on farming systems and design	K_Syst	9	1	1	
	Lack of information because of problems with advisory context	Advice	9	1		
	Current situation is still profitable in the short term	Current	9	1		
	Constraints in labour organisation (period, volume), mental or physical load	Work	9		0	1
	Barriers related to CAP*, environmental or sanitary regulations	Reg	9			1
	Lack of adapted plant varieties in the local context	Varieties	8			
	Need for innovation in machinery for field activities	Machin_Innov	8	1	0	
	Low agronomic performance (yield, quality)	Perf	8		1	
	Increased complexity for management and decision-making	Complex	8			
	Cultural barriers, confrontation with farming practices of parent's generation	Trad	7			
	Cognitive frame and ways of thinking need to be changed	Cogni	6			1
	Seeds are hard or expensive to get	Seeds	5			
	Farmers' lack of awareness about issues linked to specialisation	Awar_Farm	5	1	0	
	Lack of available or adapted phytosanitary solutions	Phyto	3	1	0	
From harvest to retail	Volumes are too limited in a given area to be profitably or easily collected	Coll_Vol	16	1	0	
	Equipment for cleaning, drying or storing requires investment	Pre_ProInvest	11			0
	Equipment for processing requires investment	Process_Invest	11			
	Competition on the global market with crops produced cheaper elsewhere (for processors or retailers)	Compet	9		1	0
	Equipment for separation of crops requires investment	Separ_Invest	8		1	0
	Equipment for processing requires innovation	Process_Innov	5		1	
	Regulation issues around sanitary, quality and purity aspects	Qualsan	5			
	Equipment for cleaning, drying or storing requires innovation	Pre_ProInnov	4		1	0
	Administrative, fiscal or accounting issues	Admin	4			1
	Equipment for separation of crops requires innovation	Separ_Innov	3		1	
	Traders are reluctant to support solutions which may reduce the inputs they sell	Input	3	1		
	Dealing with diversification products incurs higher costs	Cost	3		1	
Market	Need to raise consumers' awareness or bad visibility of diversification benefits	Awar_Comm	17	0		1
	Uncertain or unstable market	Uncert_Mark	14		1	
	No pre-existing or very limited market	Exist_Mark	13	1		
	Doubts about willingness of consumers to pay more for diversification products	Willing	9	1		
Coordination between value chain actors	No ensured and/or fair sharing of added value between actors	Price	17		1	0
	No ensured or limited volumes to buy/sell products or establish secure contracts	Quant	12		1	0
	Duration of contracts not enough to secure farmers in taking risks and investing	Dura	10	1		
	Limited or no cooperation between innovative farmers	Orga	8	1	0	
	Individualistic mentality and lack of trust between farmers limit collective action	Indiv	7	1		
	Unbalanced power in bargaining between farmers and traders	Power	7	1	0	
	Finding suitable contracts to address issues related to variability in production (flexibility, sharing risks and reducing control costs)	Variab	7			
	Lack of communication between value chain actors	Comm	6		1	1
	No ensured quality of products to be bought, sold or to establish secure contracts	Qual	4		1	
	No ensured reciprocal benefits in partnership (especially for land arrangements)	Benef	4			1

n: number of occurrences of the related barrier among the 25 case-studies. W: "Changing from within" ideal-type; O: "Building outside" ideal-type; H: "Playing horizontal" ideal-type.

5. Connecting barriers

Rather than addressing each barrier in isolation, it is essential to consider the entire causal chain linking barriers together. As introduced at the beginning of this guidebook, we consider lock-ins as situations that emerge when individual barriers interconnect to block a system or group of actors within a specific system configuration. By displaying these interconnections within the previously established list of barriers, we can gain a deeper understanding of the intricate mechanisms at play and better grasp the importance of systemic approach when confronting lock-ins. Moreover, by identifying and illustrating the interactions between barriers and self-reinforcing loops, we can more effectively assess the levers that can be proposed to overcome a lock-in. This approach enables the identification of multiple points of action at various levels of the food value chain to address a particular issue comprehensively.

A. Procedure

A first identification of connections between barriers can be established by the research team, based on insights gleaned from interviews and/or workshops conducted during the data collection phase. Browsing through transcripts again, mentions of causes, consequences and influences of barriers are translated into connections among the identified barriers. These connections can be easily visualized through diagrams displaying the different barriers, where arrows illustrate the relationships between them.

Optionally, new experts' consultations can then be organized to collectively explore how barriers interconnect with each other.

B. Expected output

Findings of the connection between barriers are presented in visual diagrams, allowing for a clear mapping of the lock-ins created by the interconnection of barriers.

Figure 27 illustrates one of the results of a barrier analysis to intercropping practices conducted in the European project IntercropVALUES [1] across 12 European case studies. The result presented here focuses on a grain sorting issue and clearly illustrates how barriers affecting different levels of the food value chain (color code in the figure) can be related to one another. This serves as a valuable depiction to stress the importance of coordinated commitment from all actors of the food value chain to address such issues. Furthermore, the map highlights the systemic aspect of the intercropping lock-ins, with barriers reinforcing themselves through a complex web of interactions.

[1] European Union Horizon project, running from 2022 to 2026. More info : https://intercropvalues.eu/

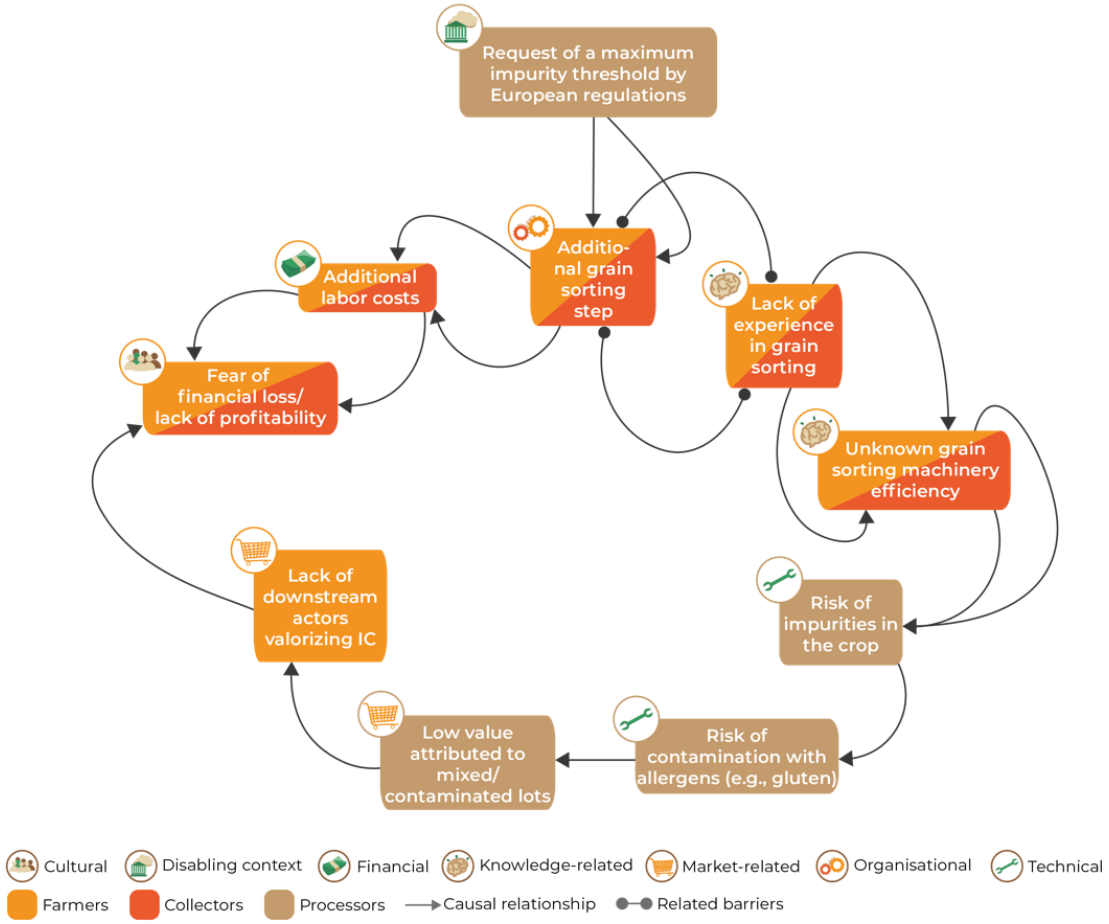

Figure 27. Example of causal chain between barriers to the use of intercropping. Source: (Chevalier et al., n.d.)

6. Validating data

A. Procedure

As good practice, we recommend conducting a validation phase with various actors of the system to ensure an accurate identification of barriers and their interconnections. This step is typically conducted through one or several focus group sessions during which results of the data analysis and connection phases are presented and discussed with either a representative sample of system's actors or selected experts. Reaching a collective consensus regarding the identification and comprehension of the lock-in mechanism is important to facilitate subsequent steps, including the identification of levers and tailored measures to break free from the lock-in situation.

Approach for a group validation session:

a. *The question*: a facilitator from the research team initiates the session by presenting the synthesis of barriers and their links.
b. *Small group reflection*: participants are divided into small groups to discuss the barriers. They are asked to critically assess the work presented, asking themselves questions such as 'Do we recognize the existence of these barriers within our context and experience?'; 'Are there additional barriers that we have encountered or are aware of, which are not currently represented in the synthesis?; 'Do the proposed links and causality between barriers resonate with our understanding of the system dynamics?'; …
c. *Collective reflection*: after the small group discussions, each group presents their key insights and observations to the larger collective. Time should be given for participants to collaboratively refine the barriers and their interconnections based on the information gleaned from the small group discussions. The focus remains on critically assessing the identified barriers and causality chains, with the aim of achieving a validated and comprehensive understanding of the lock-in situation.

It is important for the research team to document every recommendation stemming from the small group discussions, along with the level of consensus reached during the collective reflection. Recommendations supported by consensus should be clearly included in the final synthesis of barriers. In cases where consensus is not unanimous, the inclusion of recommendations should be carefully evaluated. An option is to accompany such elements by a transparent acknowledgment of the degree of consensus surrounding the specific barrier or causality chain. This transparency ensures that the final assessment accurately reflects the collective insights and deliberations of the participants.

B. Expected output

The validation phase results in the compilation of feedback from various actors and/or experts of the system. This feedback is used to improve the list of barriers and their interconnections, leading to a final version that presents a comprehensive and validated depiction of the lock-in situation.

B.2. IDENTIFYING LEVERS

The objective pursued in transition research is to explore how lock-ins can be overcome and to open up a multiplicity of options for the development of agri-food chains. The systemic analysis of barriers, which anchor a system on an unsustainable trajectory, is a fundamental first step towards unlocking the system. However, to effectively catalyze a transition, this understanding must be complemented by the identification of levers—influential factors or mechanisms that can be strategically utilized to exert influence on a system in order to break free from an existing lock-in situation and enable a transition to a more desirable state.

For practical implementation, levers are further disaggregated into operational measures, translating broad strategies into tangible, actionable steps to drive change. The identification of operational measures offers a unique opportunity: pinpointing key actors at various levels of the systems, which are responsible for the implementation of concrete actions. Advocating for active participation from system actors in the identification of levers and operational measures, our guidebook promotes a participative approach (Figure 28) that integrates diverse expectations and enhances the appropriation of results by all actors.

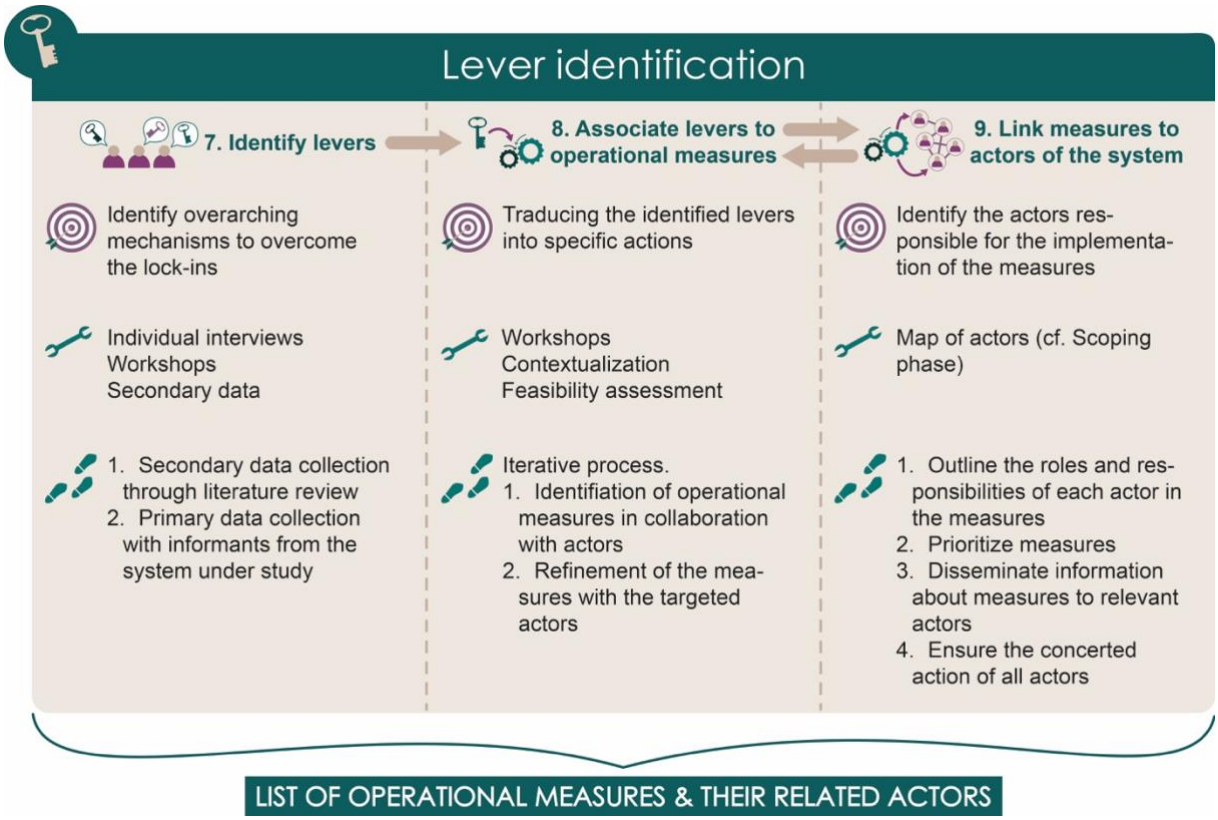

Figure 28. Overview of the process leading to the identification of levers and operational measures

7. Identify levers

A. Procedure

As highlighted earlier, levers can be identified either simultaneously with barrier identification, using the same interviews/workshops, or subsequently through a new round of interviews and/or workshops. One approach is to leverage the validation group session that concludes the barriers' identification phase to initiate the identification of levers.

Adopting a participative approach, the process for identifying levers mirrors that of barriers (see section B.1). Through interviews or collective workshops, the research team collaborates with key informants to explore potential solutions for overcoming the identified barriers. Initially, levers propose overarching mechanisms to address barriers. For instance, if a lack of technical knowledge and references is identified as a barrier to a transition in a system, corresponding levers might involve either developing further knowledge and references or strengthening the accessibility to and distribution of knowledge. These levers will then be further detailed into operational measures.
Similar to the diverse nature of barriers, levers can span a variety of dimensions, including material and technical, financial and economic, or cultural and cognitive aspects. Recognizing and highlighting such categories will help organize and communicate about the levers. As an example,
Table 9 describes the full list of categories of levers used in the European project ENFASYS [1].

When causality chains between barriers are identified, it is a good practice to try and pinpoint specific tension points within these chains where a lever could exert a strong and effective influence. This action should aim at disrupting feedback loops and facilitate the simultaneous resolution of multiple barriers.

[1] EU-funded project - ENcouraging Farmers towards sustainable farming SYstems through policy and business Strategies

Table 9. Categories of levers, with description and examples, used in the European project ENFASYS.

Category	Description	Example
Cultural/ Cognitive levers	Change in the mindset or paradigm out of which the system arises.	Supporting change in farmers' habits (emphasizing a cost-benefits approach on the long term, supporting farmers in reshaping their routines and farming systems) ; integrating alternative farming systems in training and education ; reducing the misinterpretation of risks associated with alternative practices.
Economic levers	Change in the economic variables of the value chain.	Securing sufficient market outcomes ; fair price schemes ; setting insurance mechanisms to overcome low/variable yield situations.
Education/ Information/ Knowledge	Change in terms of the information conveyed or change of the information channels. It can be technical knowledge, economical, market-related, impact-related, etc.	Developing further knowledge through experimentation ; strengthening access to, or distribution of, knowledge to actors (diversification of knowledge networks, provision of trainings, etc.).
Funding/ Financial levers	Change in financial flows (amount and actors involved).	Lowering investment costs at the farm level ; establishing new funding schemes for sustainability transition, etc.
Material & technical levers	Change in the physical amount of inputs, production, infrastructures and change of practices/techniques at the farm, processing or other stages of value chains.	Change of material resources such as machinery, allowing new practices to be implemented ; change of farming practices resulting in a reconfiguration of the farming system ; technical changes at the processing stages, allowing to process new crops, etc.
Organizational levers	Change in the organization of production and all related activities. Organizational changes can be implemented at the farm, value chain, regional, or policy level.	Changing the work organization at the farm level ; managing complexity by developing management tools; reorganizing the crop collection process.

Adapted from the European Project ENFASYS WP2 data collection protocol (Antier C., 2023).

B. Expected output

The identification of levers should result in a compilation of levering strategies acknowledged by the actors of the system has having the potential to overcome identified barriers.

8. Linking levers to operational measures

A. Procedure

Operational measures encompass specific actions essential for implementing identified levers. Using the previous example of barrier emerging from a lack of technical knowledge and references, the lever corresponding to strengthened accessibility to and distribution of knowledge could yield several operation measures, such as diversifying farmers' sources of knowledge (networks, etc.), accessing to knowledge from other regions or other countries, or increasing knowledge through additional trainings.

As these measures are highly contextualized, the establishment of pertinent and effective measures necessitate a collaborative approach with various actors of the system. We thus recommend an approach based on strong participation, engaging key actors in collaborative sessions to develop operational measures aligned with each lever. Such a session can be organized at the same time as the previous point on identifying levers. This approach should ensure that proposed measures are realistic, achievable, and resonate with the experience of actors of the system under study.

We recommended using this group session to conduct a feasibility and an impact assessment for each operational measure. The feasibility assessment evaluates factors such as resource availability, organizational and technological practicability, and alignment with existing practices and regulations. This step ensures that proposed measures are implementable within the constraints of the system. The impact assessment links each operational measure with its expected level of impact and timeframe. It highlights in particular whether a measure is likely to have low or high impact in overcoming a barrier, and whether this effect will be seen in the short or long term. This impact assessment might reveal useful for prioritizing the operationalization of measures and levers. Indeed, just as barriers are woven in lock-in, the various measures must be organized in an unlocking process.

B. Expected output

Levers and operational measures can be organized in a table, linking them together and displaying clearly the barrier(s) they address. Alongside each measure, the results from both feasibility and impact assessments can be provided using a simplified scale, such as 'Low, Medium, High,' to easily communicate their level of impact and feasibility.

9. Linking operational measures to actors

For operational measures to translate into tangible actions, identifying the actors responsible for their implementation is crucial. This linkage ensures accountability and facilitates targeted engagement. In particular, it can be useful to provide a detailed view of

A. the barriers to which each category of actors can contribute and
B. the level of contributions of each actors' categories.

The scheme A-type of illustrations allow a rapid grasp on the diverse contributions needed for overcoming each barrier and highlight the fact that some categories of actors may not play a central role in addressing every barrier. The scheme B-type illustrations ease the visualization of which categories of actors are the main contributors for the different barrier. From an operational standpoint, discerning the crucial role of one actor category over another aids in

directing actor participation in potential collaborative efforts and guides the selection of priority programs or activities based on the number of contributors, for instance.

A. Procedure

To link operational measures to actors and foster effective action, it is useful to:

a. Draw from the initially established map of actors to ensure a comprehensive representation of all actors of the system.
b. Clearly outline the roles and responsibilities of each category of actors for each operational measure. This clarity establishes accountability and fosters a shared understanding of the collective efforts needed for successful implementation.
c. Develop a communication strategy to disseminate information about operational measures to relevant actors. Effective communication ensures that all stakeholders are aware of their roles and contributions, fostering a sense of ownership and commitment.

B. Expected output

By highlighting the responsibility of each category of actors in the proposed solution measures, we can provide a clear visualization of their respective contributions towards overcoming the identified barriers. This serves as a valuable result to communicate about the role and responsibility of each actor in the lock-in situation and to engage in collective action towards alternative paths. Figure 29 and Figure 30 illustrate such output.

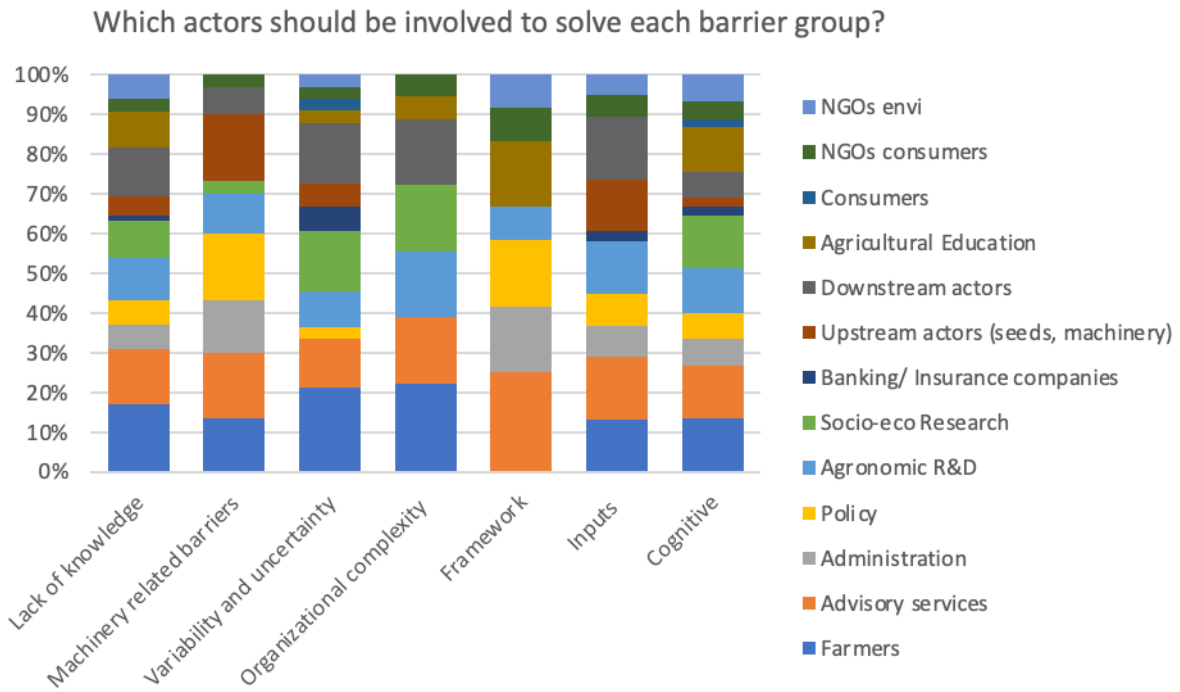

Figure 29. Example of the level of contribution from each category of actors in addressing the barrier groups to crop diversification at the farm level, in the DiverIMPACTS project. Source: (Amrom et Antier, not published)

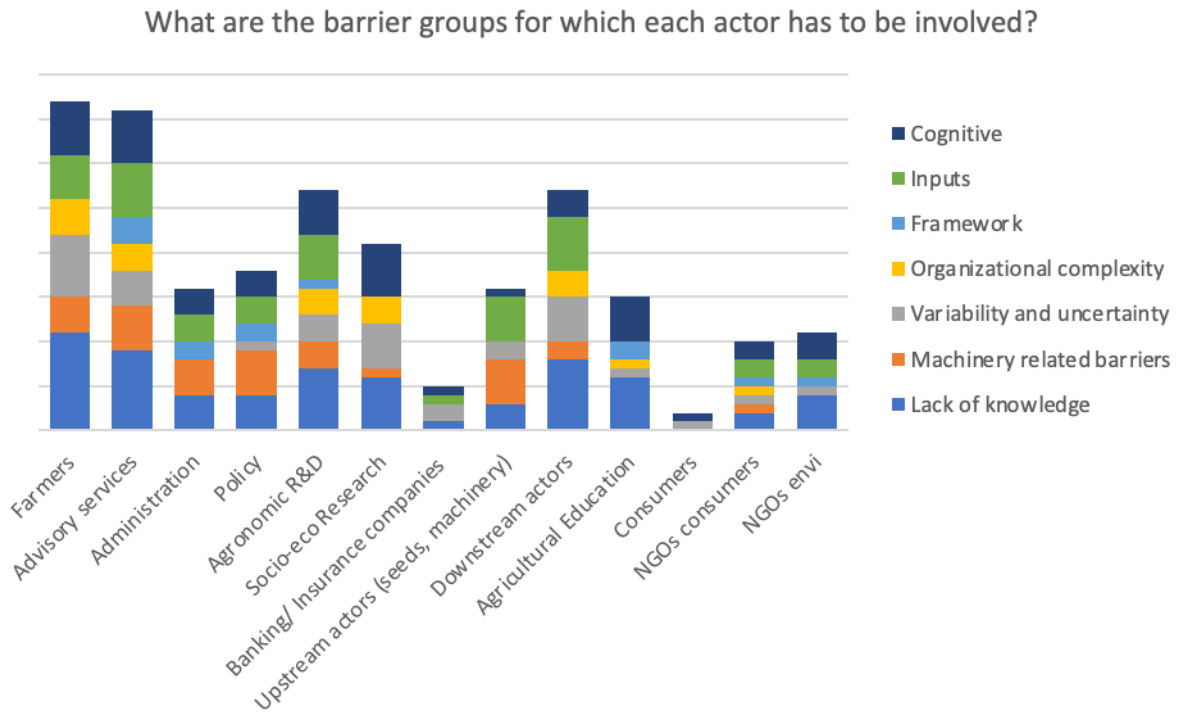

Figure 30. Illustration from the DiverIMPACTS project of the group of barriers to crop diversification that each category of actors can contribute resolving, at the farm level. Source: (Amrom et Antier, not published).

C. Finalizing the research

10. Reporting results

To maximize the potential exploitation of results coming from the identification of barriers, connection into lock-ins, and association with pathways of action, the research team should take a step back and reflect on the way the results were obtained and how they are presented. Ensuring a logical flow from the methodology to results and targeting the right audience in the report will facilitate the understanding and the use of the work.

A. Procedure

Below is a checklist of elements to consider when finalizing the project and reporting results to help maximize its outreach.

Meeting the objectives

- ☐ Does the work respond to the initial research question?
- ☐ Are the methodology and progression from the initial question to results clearly described?
- ☐ Are the relationships between barriers, levers, and operational measures clearly delineated?
- ☐ Have the results been contextualized to account for the unique characteristics and challenges of the system under study?

Reaching the right audience

- ☐ To whom is the report addressed (what actors) and will they easily find results relevant to them?
- ☐ Can every operational measure be linked to actors responsible for their implementation?

Ensuring action-oriented research

- ☐ Are there priorities highlighted for the implementation of operational measures, and, if so, is the rationale behind these priorities clearly explained?
- ☐ Does the report offer insights into the potential long-term impacts of the proposed levers and operational measures to guiding strategic decision-making?
- ☐ Have the results undergone thorough discussion and received approval from a representative group of actors? If certain results are contentious, is this clearly acknowledged and explained?

B. Expected general outcome

The finalization of the research should provide an enhanced understanding of the lock-ins situation generated by the interconnection of barriers at all levels of the system under study. In addition, the list of levers, with their corresponding operational measures and associated actors' contribution, offers valuable insights to effectively trigger the necessary transition.

Conclusion

Our ten-step methodology serves as a dynamic framework for identifying and addressing barriers that impede a system's transition toward sustainability. This guidebook, conceived as a working paper subject to continuous refinement based on feedback, aims to enhance the credibility and applicability of studies focused on identifying barriers and levers.

While recognizing and understanding barriers are pivotal in catalyzing systemic change, it is essential to acknowledge that this alone does not guarantee transformation. Successful transitions necessitate the collective engagement of diverse stakeholders in coordinated efforts. Establishing a shared understanding of the existing situation is fundamental for building consensus on the required changes. Thus, the transparency, reproducibility, and consistency of the scientific approach employed in barrier mapping are indispensable elements.

Moreover, concrete change hinges on effective collaboration among system actors. Recognizing the impracticality of implementing a large set of operational measures simultaneously, prioritization becomes crucial. In addition, it is essential to ensure that actors implement solutions in a concerted manner. This coordination is only possible when all system actors are well-aligned with the common goal(s) and the efforts required to overcome existing barriers.

Finally, we emphasize the need for ongoing assessment and endorsement of levers and operational measures over time. This not only facilitates the updating of data and recommendations but also enables the evaluation of actual implementation and foster continuous dialogue among actors.

Annexes

Annex 1. Analysis performed to validate the guidebook's methodology

Annex 1.a. Defining the system's boundaries

Given the centrality of the agri-food system in diverse fields of research and the complexity of its processes and interactions, studies typically adopt specific and defined perspectives, shedding light on particular facets of its functioning. Our exploration identifies four primary research fields — system analysis, system dynamics, Life Cycle Assessment (LCA), and system thinking — where the definition of system boundaries is integral to assessing the agri-food system's functioning. To explore them we have i) conducted expert consultations with researchers in each research field and ii) used a snowball effect approach to ensure completeness of the research fields we covered. The experts were given the same list of questions (Table A.1), and interviews, lasting 1 to 1.5 hours, were conducted with most of them. The proposed methodology for defining systems boundaries has been drafted as a result of the discussions conducted with these experts.

Table A.1. Questionnaire addressed to experts of system boundaries definition

1.	In which context have you defined system boundaries so far?
2.	Have you developed (or are you adopting) a methodology to define system boundaries in your projects? If so, could you share it with us?
3.	Which are the main challenges you have been facing while defining system boundaries?
4.	Do you have a main (or few) reference(s) in the literature that you think we might include in our study?

Annex 1.b. Mapping actors

Practical approaches to identify and map system actors vary across research projects. To encompass this methodological diversity, we conducted a systematic review of scientific papers focusing on systems actors.

Scopus database was searched in October 2022 to identify relevant studies based on the preferred reporting items for systematic reviews and Meta-analysis (PRISMA) statement. We used the query string “TITLE-ABS-KEY (actor* W/2 map* AND system*)”. We did not focus this review on agri-food systems to account for methodologies used in various disciplines. This resulted in the collection of 159 articles (Figure A.1).
A first title-screening was performed to eliminate articles that did not look specifically into the identification process of key players of a given system. This resulted in the selection of 66 articles.
Studies were included in the qualitative analysis if meeting specific eligibility criteria:

a. The article adopts a systemic approach, meaning that it relies on system thinking to understand how different elements interact within a system or structure.
b. The article clearly identifies actors of a system.
c. The full-text article is available in English or French.

This resulted in the selection of 39 articles. For these articles, we summarized the methodology used to identify actors in an Excel sheet (Table A.2). From the 39 articles assessed, 6 did not explicitly specify the source of their actors’ identification.

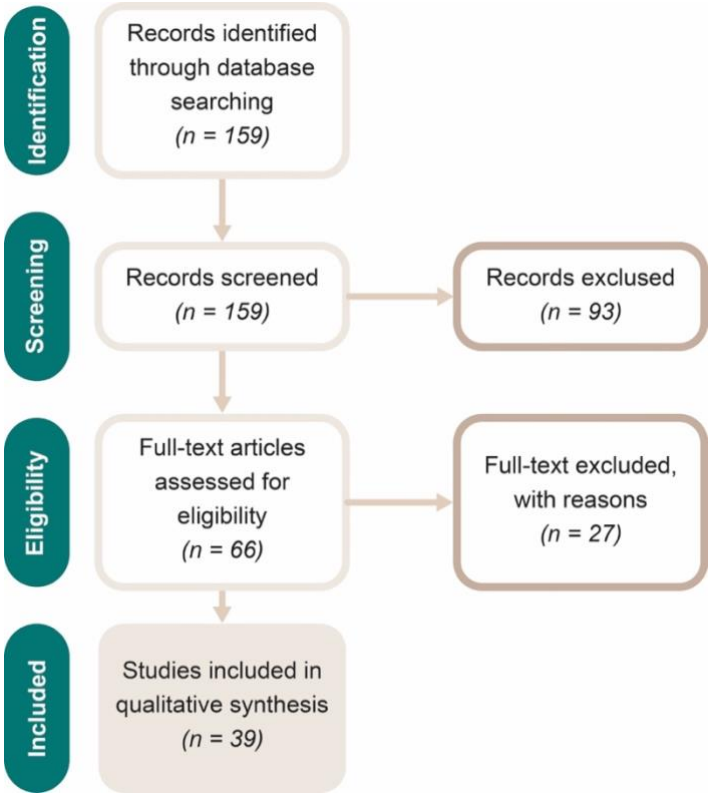

Figure A.1. The PRISMA diagram showing the flow of information for selecting studies in the systematic review of actors mapping in a system.

Table A.2. Categorization of the main sources of information for conducting an actors' mapping

Source of information	Description	# reviewed articles	Example	Strength	Weakness	When to be used
Researchers' knowledge	Use of previous knowledge of the research team to identify actors	5	• (Rametsteiner et Weiss 2006) • (Hedeler et al. 2020) • (Mlala et al. 2022) • (Proietti et Cristiano 2022)	• Quick	• Risk of oversight of relevant actors unknown to the team	When the system is very-well known by the research team and that time is constraining
Desktop research	Use of scientific literature, grey literature, media and other online documentation to identify actors	22	• (Hedeler et al. 2020) • (Mlala et al. 2022) • (Alkemade, Kleinschmidt, et Hekkert 2007) • - (McIlroy et al. 2019) • - (Li, Dong, et Mostafavi 2020) • - (Barthel et al. 2005) • - (Burau 2005)	• Broad scan of many data	• Need a syste-matic search to avoid bias • Time-consuming	Desktop research is always recommended
Experts consultation	Use of the knowledge of subject matter experts to identify actors	5	• (McIlroy et al. 2019) • (Dickson et al. 2021) • (Seymour, Murray, et Fer-nandes 2008) • (Ivory et Trotter 2017) • (Smith et Christie 2021)	• Quickly provides in-depth infor-mation	• Requires the identification of relevant experts	Useful when experts are easily identified (either already known by the research team or publicly know experts)
Other actors consultation	Use of the knowledge of actors of the system to identify actors	10	• (Caic et al. 2019) • (Lindahl, Sakao, et Carlsson 2014) • (Tang, Chen, et Chiu 2018) • (Assoumou et al. 2019) • (Alamsyah et al. 2020)	• Provides data based on actors' own experience	• Time-consuming • Requires the identification of relevant actors	When the research is targeted at a specific segment of the system
Existing networks	Use of existing database of actors involved in a system	1	• (Romero et al. 2022)	• Quick	• The existing network should have similar system • boundaries as the research	Having adapted existing networks is not frequent.

Annex 2. Example of interview focus from the DiverImpacts project

Value chain level	Points to keep in mind when talking with actors	Some pre-identified potential barriers
Agricultural inputs and production	• Why would the actor be reluctant to the transition you propose? • Why would the actor be enthusiastic about the transition you propose? • What are their main issues and priorities? • Can you see common points among the actors who are willing to transition? • Can you see common points among the actors who are not willing to transition (age, size, ecological context, area, values and objectives, type of farms, level of infrastructure and equipment etc.)?	Economic profitability (costs, yields, prices, subsidies) Availability of inputs (seeds, adapted phytosanitary products) Availability of machinery (sowing, harvesting, screening…) Availability of knowledge/advice/references/skills/technics Social pressure (being a "good/normal" farmer) Existing infrastructure, equipment and investment for input production/cultivation/storage/processing Fear of uncertainty, complexity, risks Competition with other actors/crops for land/labor force
Logistic, processing, distribution and trade	• Why would the different actors of the downstream value chain (collectors, processors, distributors and traders) be reluctant to the transition you propose? • Why would they be enthusiastic about the transition you propose? • What are their main issues and priorities? • Do the new products/processes compete with existing products/processes? • Is there a market to sell the products? Which markets?	***Collecting and storage*** Inadequate collecting equipment Missing or inadequate transport means Transport too complicated/expensive for small/variable/scattered quantities Inadequate, insufficient or not flexible storage capacities ***Transformation and processing*** Competition with other sources of raw materials, processing chains not adapted to small quantities Variability in terms of quantity and quality of the raw material Lack of knowledge and adapted methods/technologies to process the products ***Distribution*** Variability in terms of quantity and quality of the processed product No/limited existing market for the products
Consumption and recycling	• In which extent can consumers be aware of the fact that the product they buy comes from a transitioning system? • Would they be ready to value/prefer such products and pay more for them?	Benefits of transition not visible or not valued by consumers
Policy making	•	
Cross-cutting	• Which types of arrangements exist between the different actors of the value chain (farmers, collectors, processors, retailers)? • In which extent are these arrangements favorable or unfavorable to a transition? Why? • Would these arrangements be suitable for the products coming from a transition or should new arrangements be designed? • What are the main challenges in terms of traceability, quality, quantity, sharing of the added value between the actors?	Lack of long-term and formalized coordination between the actors of the value chain No ensured minimal and stable supply of products along the value chain No long-term specifications about the quality and traceability of products Added value is not fairly shared along the value chain Lack of flexibility in arrangements between actors to adjust to hazards and changes

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