PATHWAYS Holistic Policy and Innovation Evaluation Framework

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Towards a Holistic Assessment Framework for Livestock Policy and Innovation in Europe

Executive summary

Livestock production sits at the nexus of pressing sustainability challenges, requiring policies and innovations that integrate multiple dimensions—including environmental, animal welfare, economic, and social objectives. The PATHWAYS project responded to this complexity by developing a holistic evaluation framework, linking sustainability indicators to leverage points capable of catalysing systemic transitions across socio-ecological and socio-technical boundaries. The framework employs a structured, participatory approach: stakeholders prioritised sustainability indicators, proposed intervention strategies, and classified these strategies across three systemic leverage realms—Re-think (knowledge-focused), Re-connect (actor-network focused), and Re-structure (institutional-rules focused). Crucially, the framework also allows independent application, enabling policymakers and researchers to qualitatively evaluate specific policies or practices through systematic indicator mapping, realm assignment, and narrative impact assessment, as demonstrated by an illustrative application to the EU Farm to Fork Strategy. Thus, the PATHWAYS framework provides an adaptable, holistic lens for exploring potential trade-offs and synergies, guiding coherent policy design, and supporting effective transition pathways in Europe's livestock sector. Quantitative effectiveness validation remains an important future extension of the framework.

1. Introduction

1.1. Background

Livestock production is at the nexus of our time's most pressing sustainability issues. It contributes significantly to global greenhouse gas emissions, land use change, and biodiversity loss (Paraskevopoulou et al., 2020; Van Zanten et al., 2019). At the same time, however, it provides farmers' livelihoods and worldwide nutrition (Díaz de Otálora et al., 2021; Hocquette et al., 2018; van Wagenberg et al., 2017). In the European Union, decades of Common Agricultural Policy reforms reshaped the livestock sector—yielding productivity gains but also exacerbating GHG emissions and animal welfare issues. Fragmented regulation, weak targets, and limited stakeholder engagement have further undermined progress toward sustainability objectives (Adams et al., 2024). There is growing recognition that future policies must take a more integrated approach that addresses the interrelatedness of society, animals, and the environment. Put differently, the holistic framework is designed to integrate all sustainability dimensions—along with their inherent trade-offs and synergies—into decision making, so that gains in one area (e.g. productivity or income) do not occur at the expense of another (e.g. environmental health or animal welfare).
Evaluating the sustainability of livestock systems – and the policies and innovations intended to improve them – is a complex task. Traditional evaluation methods often focus on a narrow set of metrics, such as productivity or emissions (see Ghassemi Nejad et al., (2024) for an emissions review) and may overlook essential cross-domain trade-offs and synergies (Ryschawy et al., 2019). In recent years, numerous frameworks and tools have been developed to assess farm and food system sustainability more comprehensively. For instance, the Food and Agriculture Organisation's Sustainability Assessment of Food and Agriculture Systems (SAFA) framework (FAO, 2014) provides a set of indicators across the four dimensions: environmental integrity, economic resilience, social well-being, and good governance. Likewise, initiatives such as RISE (Häni et al., 2003) and the Public Goods (PG) tool (Gerrard et al., 2012) offer holistic, indicator-based assessments at farm or supply chain level (de Olde et al., 2016). These tools establish clear metrics and benchmarks to measure performance across sustainability domains, promoting transparency and continuous improvement. However, while existing sustainability assessment frameworks cover what to measure, they often give less insight into how systemic change can be achieved. In particular, they may lack an explicit connection to the dynamics of sustainability transitions, i.e. the processes by which livestock systems can fundamentally transform toward new, sustainable states.

Measuring a wide range of sustainability indicators is necessary but not sufficient for guiding transformative change. Transformative change refers to a fundamental reconfiguration of socio-technical and socio-ecological systems—beyond incremental efficiency gains—so that the underlying structures, paradigms, and interrelationships evolve toward truly sustainable pathways (Geels, 2011). Without

explicitly orienting indicator data to these deeper system-level goals, decision-makers risk optimising individual metrics in isolation, thereby perpetuating existing trade-offs rather than resolving them.
To make the evaluation framework forward-looking and action-oriented, we integrate concepts from sustainability transition research, especially the idea of leverage points for systemic change. Meadows (1999) pioneered the concept of "places to intervene in a system" (i.e. leverage points) but did not explicitly classify how these points differ in transformative potential. Abson et al., (2017) subsequently organised leverage points into two broad depths: shallow points (parameters, feedback loops) and deep points (system design, goals, and paradigms). In agricultural and food-system contexts, Abson et al. distilled three deep-leverage realms—Re-structure (changing institutions and policies), Re-connect (reinforcing human–nature and actor relationships), and Re-think (transforming mindsets and values). Dorninger et al., (2020) further demonstrate—via a systematic review of food and energy interventions—that empirical studies overwhelmingly target mechanical, shallow interventions, whereas deep leverage points (worldviews, intent, rules) remain under-examined. They argue that true sustainability transformation requires explicitly addressing these deep leverage domains across multiple system characteristics. Below, we adopt this three-realm taxonomy to evaluate livestock interventions for their potential to catalyse systemic shifts following past studies' applications (Davelaar, 2021; Norton et al., 2024; Staton et al., 2024).
Re-think involves challenging and changing the fundamental mindsets, values, and knowledge that underpin the system's goals (for example, questioning the paradigm that success in livestock farming is solely measured by output and profit). Re-connect refers to rebuilding the relationships between people and nature, and between different actors in the system – for instance, reconnecting producers and consumers or integrating animal welfare and environmental health considerations, so that awareness and responsibility are shared across the food chain. Re-structure means changing the institutions, policies, and economic incentives (the "rules of the game") that shape the livestock system, to support new practices and behaviours that are sustainable. These three leverage point areas are deeply interconnected: shifts in mindsets (rethink) can enable new networks and values (reconnect), which in turn build momentum for institutional change (restructure), and all are needed to lock in a new sustainable trajectory.
Against this backdrop, we argue for an evaluation framework that bridges holistic sustainability assessment and transition-oriented analysis. In this report, we present a conceptual framework titled "PATHWAYS Holistic Policy and Innovation Evaluation Framework for Sustainable Livestock Systems" (or simply the "PATHWAYS framework").

To capture the interplay among technology, human behaviour, and ecological processes, the framework uses a concentric schematic illustrating how policies and practices influence socio-technical and socio-ecological systems from core indicators. Managing these complex systems requires understanding the relationships between technological adoption, social structures, and environmental factors. To effectively address sustainability challenges, researchers emphasise the critical need for coordinated policy support in

transitioning livestock production systems away from heavy reliance on external inputs toward a variety of more sustainable practices—such as diversified rotations, agroecological approaches, and resource-efficient technologies—that are tailored to local (Zander et al., 2016). In the Zander's application, the agri-food and agriculture practices and policies can fundamentally shape the socio-technical and socio-ecological systems embedded within them. By recognising and addressing the interconnectedness of technological, social and ecological aspects in agricultural practices, as well as fostering resilience through community engagement and adaptive governance, practitioners and policymakers can effectively work toward sustainable and equitable food systems.

The framework was developed as part of the PATHWAYS project (an EU Horizon 2020 initiative, https://pathways-project.com/) to assess current policies and future scenarios for the European livestock sector in a way that identifies effective transition pathways. It combines multiple theoretical and practical approaches, notably the One Welfare concept (which extends One Health by explicitly linking animal welfare and environmental well-being to human health (Cox, 2022), SAFA-based sustainability indicators (FAO, 2014), and leverage points for system change – to evaluate both what outcomes are achieved (across environmental, social, economic, and animal welfare goals) and how those outcomes contribute to (or detract from) transformative change. By integrating these elements, the approach is intended to be helpful to both researchers (providing a structured method to analyse complex systems change) and policymakers (offering guidance on which interventions work and why, in a holistic sense).
The remainder of this report is structured as follows: in this first section, we outline the objectives of the framework, followed by the conceptual framing that underpins it in the second section. The third section provides a detailed description of the framework's methodology and design, and the fourth section presents the results. We conclude with a discussion and conclusion section that highlights the framework's implications for policy and innovation in sustainable livestock systems, as well as provides suggestions for future application and refinement.

1.2. Objectives of the PATHWAYS Holistic Policy & Innovation Framework

Drawing on the leverage-point perspective outlined above, where sustainable transformation requires re-thinking paradigms, re-connecting actors with nature, and re-structuring institutions, the PATHWAYS framework is designed with four operational objectives:

1. **Provide a decision-ready indicator core:** Building on SAFA and One Welfare principles, the framework supplies a rigorously screened *minimum-metric set* that spans Environmental, Animal Welfare, Economic and Social goals, ensuring that *measuring a wide range of sustainability indicators* is both manageable and policy-relevant.

2. **Link indicators to deep leverage realms and socio-technical/ecological landscapes:** Each sustainability metric is explicitly mapped to one of three systemic 'leverage realms'—(1) Re-think (mindsets and knowledge), (2) Re-connect (human–nature and stakeholder relationships), or (3) Re-structure (institutional rules and incentives)—so that users see how data points correspond to possible system interventions (Meadows, 1999). Linking indicators to leverage realms and illustrating their influence on socio-technical and socio-ecological systems, enables users to see not only what to measure but also how interventions reconfigure networks of actors, institutions, and natural processes.
3. **Catalogue evidence-based interventions:** The framework records workshop-derived policies and practices against their primary indicators and leverage realm, converting qualitative stakeholder knowledge into a structured resource that "*bridges holistic sustainability assessment and transition-oriented analysis.*"
4. **Support iterative, real-world learning:** A built-in monitoring log captures post-implementation evidence, allowing researchers and policymakers to refine indicator sets, adjust portfolios, and lock in "*new sustainable trajectories*" as conditions evolve.

These objectives operationalise PATHWAYS' overarching aim: to deliver an evidence-based, leverage-oriented policy and innovation framework that guides the European livestock sector toward sustainability while accounting for system complexity and real-world viability.

To clarify how the PATHWAYS framework functions in practical policy evaluation, we explicitly demonstrate its application to the European Commission's Farm to Fork (F2F) Strategy. Livestock farming is one of the sectors most closely aligned with the F2F Strategy, which outlines measures that impact the sector from various angles (e.g., environmental, public health, and animal welfare) (European Parliament, 2025). This exercise provides readers with a tangible example of how to systematically assess a policy's impacts across all four sustainability dimensions using our structured approach.

2. Conceptual Framing

2.1. One Welfare

A starting point for our framework is the recognition that livestock sustainability challenges span human, animal, and ecological well-being in an interconnected way. The One Welfare concept encapsulates this by asserting that animal welfare, human well-being, and the environment are intimately linked (Cox, 2022). One Welfare thus demands policies and practices that simultaneously enhance animal care, support human well-being, and protect the environment. For example, improved animal welfare can boost farmer satisfaction (Spigarelli et al., 2021), while extensive or regenerative livestock systems often benefit ecosystem health (Ryschawy et al., 2019). Conversely, social or economic interventions that neglect animal welfare may undermine long-term economic sustainability (Velarde et al., 2015). By providing an integrated ethical and conceptual foundation, One Welfare guides our framework to evaluate outcomes in a way that

does not compartmentalise economic, social, and environmental performance separate from animal welfare. Instead, these are seen as mutually reinforcing elements of a sustainable livestock system. This holistic view is particularly important for policy design, since livestock-related policies (from farm subsidies to animal health regulations) often have cross-cutting impacts. Embracing One Welfare can help ensure policy evaluation captures these interdependencies and identifies win-win strategies (for example, solutions that improve animal care while also strengthening rural livelihoods and reducing environmental harm).

2.2. Multidimensional sustainability assessment

To operationalise our holistic evaluation, we draw on established sustainability assessment frameworks for agriculture and food systems. In particular, the FAO's SAFA (Sustainability Assessment of Food and Agriculture Systems) Guidelines (FAO, 2014) which provide a comprehensive structure of themes, sub-themes, and indicators covering four pillars of sustainability: environmental integrity, economic resilience, social well-being, and good governance. Adapting this approach to livestock systems enables the PATHWAYS framework to encompass a broad range of criteria, including climate and resource use efficiency, farm profitability and viability, labour conditions, rural community vitality, and governance aspects such as participation and fairness. The SAFA framework also emphasises the need to evaluate trade-offs and synergies among these dimensions, rather than maximising one at the expense of others. For example, a policy that boosts productivity might improve economic outcomes but could have negative side effects on the environment or animal welfare – a holistic assessment would make those trade-offs explicit. In our framework, we incorporate the SAFA dimensions (with a slight adaptation to explicitly include animal welfare as a separate category, in line with One Welfare priorities) as the basis for selecting evaluation indicators. By doing so, we ensure that the evaluation is multi-criteria in nature, encompassing the range of outcomes that define a sustainable livestock system. Moreover, using an established framework like SAFA provides consistency with international best practices and allows leveraging of existing indicator sets and benchmarks. It is worth noting that other farm-level sustainability assessment tools (e.g. RISE, the PG Tool) have successfully used similar multi-dimensional indicator approaches (Mullender et al., 2017), demonstrating the feasibility of gathering and analysing data across diverse sustainability metrics on farms and along supply chains. Our framework builds on this foundation but goes further by linking these metrics with a transition's perspective, as discussed next.

2.3. Sustainability transitions and leverage points

As introduced, the evaluation of sustainability indicators is essential but insufficient for enacting transformative change. To enhance the framework, integration of sustainability transition concepts,

particularly leverage points for systemic change, is proposed. Leverage points are critical areas where small interventions can lead to significant shifts in the system. Abson et al. (2017) categorise these points into shallow leverage points (system parameters and feedback) and deep leverage points (system design, goals, paradigms). In transforming agriculture and food systems, emphasis is placed on three deep leverage points: re-structure (changing institutions and policies), re-connect (revitalising relationships between people and nature), and re-think (altering fundamental mindsets and values). These areas are interconnected, with changes in one influencing the others to establish a sustainable trajectory.
By incorporating the leverage points perspective, our evaluation framework goes beyond checking whether a policy or innovation meets specific indicator targets – it also asks whether and how that intervention addresses deeper systemic leverage points. In practical terms, this means we examine the extent to which a given policy or innovation helps to "re-think", "re-connect", or "re-structure" the livestock system in favour of sustainability. For example, consider a policy that supports agroecological grazing practices: our framework would evaluate its outcomes on environmental, economic, social, and welfare indicators (e.g. soil health, farm income, community acceptance, animal stress levels), *and* assess how it contributes to transitions (perhaps it helps reconnect by linking farmers and conservationists, and a rethink of knowledge systems centred on ecosystem processes). Likewise, an innovation like a methane-reducing feed additive would be assessed not only for emission reduction and cost-effectiveness, but also for whether it addresses systemic goals (does it simply tweak an existing intensive system – a shallow change – or does it enable a more fundamental shift in practice or values?). Embedding leverage points in the framework thus serves to highlight the transformative potential of policies and innovations, not just their immediate performance. Recent studies applying leverage point thinking to agriculture reinforce this approach. For instance, Norton et al., (2024) engaged stakeholders in the UK grazing livestock sector to identify intervention points for reconnecting, restructuring, and rethinking towards sustainability. They found that this approach helps reveal interactions among social, economic, and ecological factors that might otherwise be overlooked in conventional evaluations. Similarly, others have used leverage points to design sustainability metrics that align with system change in food and diet contexts (Davelaar, 2021; Dorninger et al., 2020; Staton et al., 2024).

These examples give confidence that combining indicator-based assessment with leverage point analysis can produce richer insights into "what works" for sustainability transitions in livestock systems.

2.4. Summary

In summary, our conceptual framing rests on three pillars: (1) a One Welfare perspective ensuring an integrated consideration of animal, human, and environmental well-being; (2) a comprehensive set of sustainability criteria (drawing from SAFA and related frameworks) to measure multi-dimensional

outcomes; and (3) a transitions lens (leverage points) to evaluate the capacity of interventions to drive systemic change.
The following section describes how we translated this framing into a practical evaluation framework through a structured methodology.

3. Methodology and framework design

Drawing on the above concepts, we developed a stepwise methodology to construct the PATHWAYS Framework . The approach combined expert knowledge, stakeholder input, and iterative refinement to ensure the framework is both scientifically robust and grounded in practical relevance, approaches broadly applied in the literature (Allington et al., 2018; Mayton et al., 2020; Norton et al., 2024; Reed et al., 2013; Staton et al., 2024). The process consisted of three main steps: identifying a comprehensive set of indicators, screening and selecting indicators, and integrating leverage points, as well as gathering transformational strategies.

3.1. Identifying a comprehensive indicator set

We began by compiling a broad list of potential sustainability indicators relevant to livestock systems. This drew from established frameworks and prior research outputs. We used the themes and guidance from SAFA (FAO, 2014) as a foundation to ensure coverage of all key sustainability dimensions. Given the focus on livestock, we included indicators in four primary categories: Environment, Economy, Social, and Animal Welfare (the latter reflecting the One Welfare emphasis, and paralleling SAFA's social and governance elements with a specific animal-centric dimension). Where available, we drew on indicator lists from tools such as the Public Goods (PG) tool and the RISE farm assessment, which are known to align with SAFA principles (Gerrard et al., 2012; Häni et al., 2003) – for example, environmental metrics such as greenhouse gas emissions intensity, nitrogen balance, or biodiversity indices; economic metrics like farm net income or productivity; social metrics like rural employment or working conditions; and animal welfare metrics like animal health scores or behavioural indicators. This step resulted in an initial pool of dozens of indicators (on the order of 80+ indicators in total, roughly 15–30 per category) intended to capture a 360° view of livestock sustainability. Notably, at this stage, we aimed to be inclusive rather than selective, to ensure no significant aspect was overlooked. The output was a draft indicator framework spanning the whole livestock supply chain (from on-farm practices to processing and consumption where relevant) and multiple scales (farm, regional, and national outcomes), reflecting the diverse sustainability goals for livestock systems.

3.2. Screening and selecting relevant indicators

From the comprehensive list, the next step was to narrow down the indicators to those most relevant and feasible for evaluating policies and innovation scenarios. We applied a set of relevance criteria and engaged stakeholders to rank and select indicators against these criteria following past studies (Carlsson et al., 2017; Waas et al., 2014). The relevance criteria included: (a) Broad System Coverage – the indicator should capture impacts across a significant portion of the livestock supply chain, not just a narrow component; (b) Applicability across Systems – it should be meaningful for different types of livestock systems (e.g. dairy, beef, intensive, extensive) and in different regional contexts; (c) Scientific Soundness – the indicator must be based on reliable data and evidence, providing a valid representation of the aspect it measures; (d) Practical Data Collection – data for the indicator should be reasonably obtainable (through existing statistics, farm surveys, models, etc.) without prohibitive cost or complexity; (e) Actionability – the indicator should have clear implications for action or decision-making (i.e. if performance on the indicator changes, it gives insight into what should be done); and (f) Contextual Relevance – the indicator should be interpretable in diverse socio-economic and cultural contexts within the scope of analysis.
To operationalise this selection, we conducted an expert survey (August 2024) and a multi-stakeholder workshop (September 2024). In the survey, 45 experts from the PATHWAYS consortium and broader network were asked to rate each indicator on a 1–5 scale ("Extremely irrelevant"- "Extremely relevant") for overall relevance, taking the above criteria into account (see Table 1 for an example). We then calculated average relevance scores for each indicator.

Table 1. Survey's question example for Animal Welfare and Environmental indicators

Please select a level of "relevance" for each indicator, considering the key aspects stated in the Introduction to this survey.						
Indicator	Extremely irrelevant (1)	Somewhat irrelevant (2)	Neither relevant nor irrelevant (3)	Somewhat relevant (4)	Extremely relevant (5)	Unable to respond
Square meters of space available per animal in livestock facilities	○	○	○	○	○	○
Kilograms of ammonia (NH3) emitted per NUTS 2 region	○	○	○	○	○	○

The multi-stakeholder workshop was conducted during the PATHWAYS general assembly (Romania, September 2024) and therefore drew on the full assembly of project members. In total, 30 participants took part, representing a mix of academic researchers, policymakers and practitioners. Attendees were not

pre-selected; instead, everyone present at the assembly was invited to contribute. For the breakout sessions, participants were distributed by dimensions according to their expertise and ensuring balanced perspectives across each sustainability dimension as follows: eight in Environmental, eight in Animal Welfare, eight in Economic and five in Social. Participants reviewed the 84 indicators. These survey-derived relevance indicators rankings provided participants with guidance during the in-person workshop. In the workshop, participants reviewed the longlist—presented alongside its survey-based scores—and then deliberated to refine and self-rank their top ten indicators per dimension. As a result, a small number of survey-highly-rated indicators did not make the final top ten if participants deemed other measures more actionable or covering broadly European livestock systems. Through this process, the indicator list was distilled to a more manageable set, focusing on those indicators that scored highly on relevance and enjoyed stakeholder support. .

Once the core 40 indicators were chosen, we clustered them into higher-level sub-dimensions (e.g., 'Reducing GHGs,' 'Improving NPK Balance') to serve as thematic prompts in the workshop design. As shown in **Error! Reference source not found.**, these indicators clusters reflect sustainability objectives and f acilitate alignment with leverage point discussions.

Table 2. Examples of indicators and corresponding sub-dimensions

Framework dimension	**Indicator example**	**Sustainability Sub-Dimension**
Environmental	Kilograms CO_2-equivalent emissions per unit, total farm GHG emissions	Reducing GHGs
	Land use per product, arable land transformed	Reducing land use intensity
	Water use per unit	Improving water use efficiency
	Nitrogen balance, phosphorus per hectare	Improving NPK balance
	Biodiversity measures	Improving biodiversity
Animal welfare	Mortality rate, outdoor access, animal life years suffered	Improving animal health and well-being
Economic	Gross margin, total value of livestock products	Improving profitability & industry resilience
	Total volume of livestock products, total domestic demand, total capital investment	Moderating livestock production volume
Social	Supplier relationship score, fair competition score	Equal opportunities in value chains
	Community health & safety score, pesticide use	Improving communities' health & safety

Framework dimension	Indicator example	Sustainability Sub-Dimension
	Sustainability commitment score, fair wage compliance rate, equal opportunities	Improving sustainability reporting to meet standards

3.3. Integrating leverage points and gathering transformational strategies

In the final step, we shifted our focus from indicators alone to how real-world policies and practices can impact those indicators, considering desirable and sustainable improvements while driving systemic change. We accomplished this through participatory workshops that explicitly linked each sub-dimension (e.g., 'Reducing GHGs,' 'Improving NPK Balance') to one of three leverage realms—Re-think, Re-connect, or Re-structure. Rather than mapping indicators solely to theoretical leverage points, the workshops aimed to elicit practical ideas from participants about interventions that could positively influence the grouped indicators, using the sustainability sub-dimensions that contribute to sustainability transitions.

The workshops were conducted online (March 2025) using a collaborative virtual whiteboard platform (Mural), which enabled real-time co-creation and documentation of ideas (see Figure 1). The structure of the whiteboard relied on the participatory leverage point mapping approach of Norton et al. (2024) but was adapted to focus on practical, actionable ideas relevant to the PATHWAYS evaluation framework. This approach encouraged participants not only to consider incremental improvements but also to think strategically about what kinds of interventions could catalyse more profound transformations.

Participants—including researchers, policymakers, practitioners, and representatives from industry and consumer organizations—were prompted to propose specific interventions (policies or practices) that would enhance the pre-defined sustainability indicators (e.g. reducing GHG emissions, improving animal welfare) by placing digital sticky notes on the shared whiteboard. The structure of the whiteboard followed a matrix format, with rows representing the sustainability sub-dimensions (e.g., "Improving biodiversity", "Reducing GHGs"), and columns corresponding to the three leverage realms—Re-think Knowledge, Re-connect to Nature, and Re-structure Systems. Participants placed their proposed interventions on a virtual whiteboard organised by sub-dimensions (rows) and leverage realms (columns). Although the original workshop did not explicitly label these axes as socio-ecological versus socio-technical, we can now contextualise them as follows: each row (e.g. 'Reducing GHGs,' 'Improving Biodiversity') corresponds to an ecological subsystem or sustainability objective, while each column (Re-think, Re-connect, Re-structure) aligns with a socio-technical lever—knowledge systems, actor networks, or institutional rules, respectively. By interpreting the grid this way, every sticky note's position also indicates the ecological domain and

technical or governance mechanism that the proposed practice or policy aims to rewire[3]. This layout ensured that each proposed idea was grounded in both a thematic area and a transformation strategy.

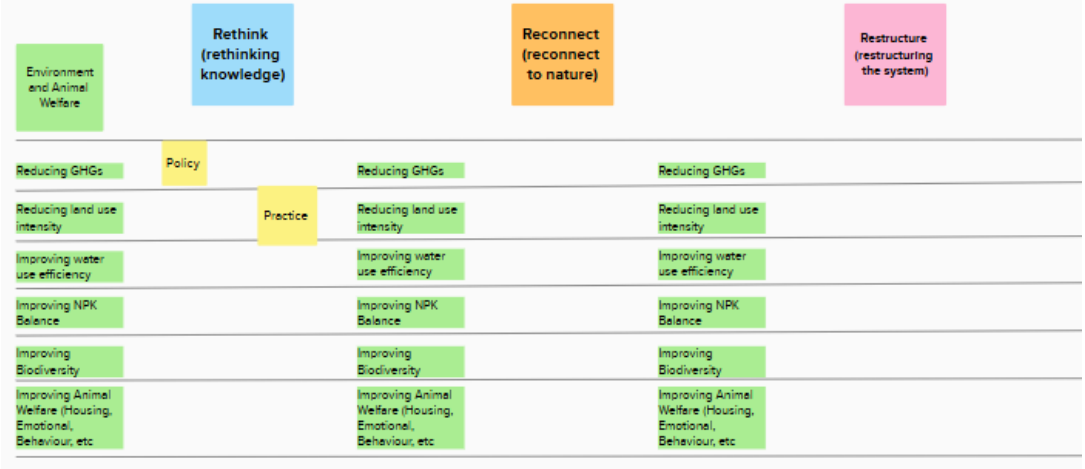

Figure 1. Workshop's collaborative virtual whiteboard for the Environmental & Animal Welfare discussions in which participants contribute interventions by placing digital coloured sticky notes on the shared whiteboard

During the workshops participants were prompted with:

- What actions or interventions could improve this indicator's performance?
- Would the intervention mainly contribute to rethinking knowledge, reconnecting to nature, or restructuring systems?

Participants were first shown a set of sub-dimensions (e.g., 'Reducing GHGs,' 'Improving Biodiversity') that each encapsulate a cluster of related indicators (see Table 2). In the virtual whiteboard layout (Figure 1), these sub-dimensions appear as the row headers along the left side. When prompted—"What actions or interventions could improve this indicator's performance?" and "Would the intervention mainly contribute to rethinking knowledge, reconnecting to nature, or restructuring systems?"—participants implicitly linked each underlying indicator to a specific sub-dimension (row) and placed their sticky note into the column corresponding to the chosen leverage realm (Re-think, Re-connect, or Re-structure). Figure 1 thus visualises the mapping from each indicator (via its sub-dimension) into one of the three system-change realms.
To systematically classify the proposed interventions into either practices or policies, a two-stage analytical procedure was applied, combining automated keyword-based screening with manual verification. In the first stage, all sticky-note entries were tabulated and processed using a software-based text analysis routine. This script tokenised each entry, removed English stop-words, and flagged key terms commonly

[3] Note that workshop participants placed notes based on their subjective interpretation of each realm's scope; no formal validation of column placement was performed in real time. In our subsequent analysis, these placements are used to capture stakeholder perceptions of where each intervention is likely to exert leverage. Researchers may choose to apply additional expert review or coding consistency checks if so desired.

associated with either policies (e.g., regulation, mandate, legislation, standard, tax, subsidy) or practices (e.g., implement, adopt, monitor, rotate, benchmark). Based on the presence and dominance of these cues, a preliminary classification was assigned, with three possible outputs: i) Policy: presence of at least one explicit policy-oriented term; ii) Practice: exclusive presence of implementation or management action terms; iii) Check manually: ambiguous or mixed cues. In the second stage, all entries flagged as "Check manually" were reviewed before classifying them as policy or practice considering the context provided during the workshop (e.g., sub-dimension and leverage realm).

With these three steps, the resulting framework is both indicator-driven and theory-informed. The final set of indicators (as refined in step 2. See section 3.2) provides the measurable criteria for evaluating performance across sustainability dimensions. Simultaneously, this integration of leverage points provides a structured way to interpret what high or low performance on those indicators implies for more profound systemic change. For practical applications, the framework can be applied in an ex-ante evaluation of policy or innovation scenarios (e.g. assessing proposed future policy packages or technology adoption scenarios for livestock in Europe). Each scenario would be evaluated by projecting its expected impacts on the chosen sustainability indicators (using models, expert judgment, or empirical data as available). Those impacts would then be analysed considering the One Welfare, SAFA and leverage points perspectives – for instance, checking whether the scenario improves a broad base of indicators (holistic gains without significant trade-offs), and identifying which leverage point realms the scenario activates (does it mainly provide incremental tweaks, or does it also shift paradigms or structures?). The framework's design thus enables a two-level analysis: outcome evaluation (are sustainability targets met?) and process evaluation (are we seeing signs of transformative change?). In the next section, we discuss the significance of this approach and how it can inform more effective policy and innovation strategies for sustainable livestock systems.

3.4. PATHWAYS Conceptual Framework

Having completed the three-step methodology—identifying indicators, refining and selecting indicators, and conducting multi-stakeholder workshops to link indicators with leverage realms by suggesting policy/practice ideas—this section presents the resulting PATHWAYS conceptual framework. We begin by describing the concentric-ring schematic (see Figure 2), which integrates our core indicators, sub-dimensions, workshop-derived interventions, leverage realms and how practices and policies traverse socio-technical (e.g., actor networks) and socio-ecological layers (e.g., ecosystem services). Our conceptualisation follows past studies' approaches (e.g., Mayton et al., 2020) adapted to the PATHWAYS context.

We organise the framework into four nested bands. In the innermost ring, we place the core indicators, which some have named as “minimum metrics” (Mayton et al., 2020), linked to each broad category’s subdimensions. Surrounding this is a band that explicitly lists those sub-dimensions (e.g., for Environmental, Reducing GHGs, Improving NPK Balance), thereby clustering related metrics into coherent thematic areas. The next band outward signifies the three leverage realms—Re-think (yellow), Re-structure (light blue), and Re-connect (light green)—that mark the depth of systemic intervention required to shift the livestock systems. The outermost quadrants (green for Environmental, light purple for Animal Welfare, light grey for Economic, pink for Social) visually anchor each intervention in its domain, including policies (institutional or regulatory shifts) and practices (on-farm or operational changes). Figure 2’s concentric rings depict not only thematic sub-dimensions and leverage realms but also map how practices and policies navigate socio-technical and socio-ecological interfaces. By layering these rings in a single, multidimensional visual, the PATHWAYS framework conveys how each minimum metric is connected to stakeholder-validated pathways for change at both socio-technical and socio-ecological systems.

Agricultural policies and on-farm practices co-evolve with socio-technical infrastructures (e.g., data networks, machinery) and socio-ecological contexts (e.g., soil health, biodiversity). Framework users can thus trace how sustainable interventions recalibrate the dynamics of these coupled systems. For socio-technical systems, i.e., systems that encompass the integration of social and technical elements, the system forms a complex web that dictates how various agricultural innovations are implemented and adopted. For instance, some argue that effective practices and policy mixes are crucial for prompting change within socio-technical systems, enabling them to create positive feedback mechanisms essential for sustainability transitions (Edmondson et al., 2020). This interaction highlights the importance of aligning policies with the social dynamics and technological advancements required to achieve desired outcomes in agricultural systems.

In the context of sustainable agriculture, others illustrate how socio-ecological and socio-technical systems share similar conceptual foundations and exhibit complex, adaptive properties (Durán et al., 2023). This suggests that frameworks for implementing sustainable agricultural practices must account for the complex interconnections among social customs, technological advancements, and environmental outcomes.

Figure 2. Concentric-ring representation of the PATHWAYS Holistic Policy & Innovation Framework. The innermost band displays each sustainability sub-dimension's for Environmental, Animal Welfare, Economic, and Social domains. Surrounding this, the third band labels the sub-dimensions themselves (e.g., "Reducing GHGs," "Improving NPK Balance"). The second band outward delineates the three deep-leverage realms—Re-think (yellow), Re-structure (light blue), and Re-connect (light green). The outermost quadrants (green = Environmental, light purple = Animal Welfare, grey = Economic, pink = Social) encapsulate the full set of workshop-derived interventions within each domain. Each intervention's colour indicates its primary leverage realm. This multi-layered schematic enables users to trace how core sustainability metrics are linked to thematic sub-dimensions and, in turn, to actionable leverage points for policy or practice at socio-ecological and socio-technical system level.

Moreover, farming systems are increasingly recognized as multifunctional components of socio-ecological resilience (López-Estébanez et al., 2022). López-Estébanez et al. highlight the importance of public and private engagement in optimising peri-urban agri-food systems, contributing significantly to identity formation, territorial development, and social innovation. Their findings support the notion that agri-food policies can enhance socio-ecological resilience by fostering community participation and nurturing local identities.

Regarding the socio-ecological aspects, agroecological practices are crucial for enhancing the resilience and sustainability of agri-food systems. To illustrate, some contend that agroecology's innovative approaches can significantly contribute to social-ecological transitions by establishing connections between ecological functions, ecosystem services, and human well-being, thereby fostering a harmonious interaction between agricultural practices and environmental stability (Oteros-Rozas et al., 2019). Furthermore, frameworks that account for the incorporation of localised knowledge are essential for the success of agricultural interventions. Some emphasise that diversifying farming systems should take into consideration the wider social-ecological processes, including governance structures, local norms, community values, and market dynamics that influence sustainable practices (Bacon et al., 2012).

3.5. Applying the PATHWAYS framework to a specific policy

To demonstrate the practical utility of the PATHWAYS Framework, we outline a stepwise approach for evaluating a stand-alone policy. This approach involves three key steps: (1) mapping to indicators, (2) leverage realm assignment, and, optionally, (3) impact estimation including potential trade-offs and synergies. Taken together, these steps enable a comprehensive ex-ante assessment of how a given intervention aligns with sustainability objectives and transformation levers.

First, *Mapping to indicators*, the policy's objectives and measures are mapped onto the framework's multi-dimensional indicator set. Each action or target in the policy is linked to relevant sustainability indicators across the environmental, animal welfare, economic, and social domains. For example, a policy aiming to reduce agricultural pollutant inputs would be mapped to environmental indicators (e.g. pesticide load, water quality), while a policy promoting farm animal housing reforms would map to animal welfare metrics (e.g. welfare compliance scores). This ensures that all intended outcomes of the policy are represented in terms of measurable criteria. In practice, one identifies which core indicators (from the set refined in Section 3.2) the policy is expected to influence.

Next, in the *leverage realm assignment* step, each policy measure is classified according to the leverage point realm it engages – distinguishing whether the intervention primarily entails rethinking knowledge paradigms, reconnecting actors/nature, or restructuring systems (see section 3.3). This step situates the

policy within the three realms of systemic change. A technical or educational initiative (e.g. farmer training or consumer awareness campaigns) would be tagged as “Re-think” (knowledge-focused), whereas measures fostering collaboration or relocalization in the food chain (e.g. shortening supply chains, producer–consumer cooperatives) align with “Re-connect” (actor network-focused). Structural reforms such as new regulations, standards, or economic incentives fall under the “Re-structure” realm, reflecting changes to institutional rules or resource flows. Assigning each component of the policy to a leverage realm illuminates the depth and nature of change targeted – whether the policy acts through incremental adjustments of practices or seeks more transformative shifts in values and systems.

Finally, in the step, impact estimation, the framework is used to qualitatively estimate the policy’s likely impacts on each mapped indicator, drawing on available evidence or expert judgment. Rather than producing a single score, this narrative evaluation considers the direction and magnitude of change in each sustainability dimension, highlighting potential synergies and trade-offs. Importantly, this holistic approach examines whether improvements in one area might entail setbacks in another, thereby reflecting the One Welfare ethos of interconnected well-being. For instance, an intervention that curbs fertiliser and pesticide use would likely yield environmental benefits (lower emissions, improved water and soil health) and public health gains, but it may also impose short-term economic costs on farmers if yields or production efficiency are initially reduced. By systematically reviewing impacts across all indicators, one can identify where compensatory measures or policy mix adjustments might be needed to balance such trade-offs. Conversely, the analysis can pinpoint synergies where a single intervention supports multiple goals simultaneously (e.g. improving animal housing conditions can enhance animal welfare and farm productivity, while also reducing antibiotic reliance and thus benefiting public health). The outcome of this step is a rich qualitative impact profile of the policy across the four sustainability dimensions.

4. Results

In the following subsections, we unpack each layer of the PATHWAYS framework by describing the three steps for its construction and the application to the Farm to Fork Strategy. We describe the indicators selection process, explaining how the 40 “minimum metrics” were identified from an initial pool of 84 candidates. Then we show the linkage between sustainability sub-dimensions and leverage realms, detailing the rationale for mapping each headline metric into the Re-think, Re-connect, and Re-structure categories. Following this linkage, we present the workshop-derived policies and practices, showing how stakeholders’ concrete suggestions populate the framework and reveal both areas of concentrated effort and leverage gaps within each sustainability domain, for the sustainability categories under analysis. Finally, we hipothetize a potential application to the F2F Strategy

4.1. Indicator selection outcomes

The initial longlist of sustainability indicators included over 84 metrics spanning environmental (22 indicators), animal welfare (14 indicators), economic (17 indicators), , and social (31 indicators) domains (see Supplementary Material, section 8.1).

4.2. Indicators refinement by relevance

Following expert scoring using a survey approach (see section 3.2), the indicators' full list was categorised by relevance (see Supplementary Material, section 8.1). Then, the indicator set was narrowed to a core of 40 indicators (10 per category. See Table *3* and Supplementary Material, section 8.1) in the stakeholder workshop designed for this purpose (see section 3.2) and they were chosen based on relevance, data availability, broad system coverage, and potential to inform policy and innovation decisions, as suggested by similar studies in the agri-food domain (Mayton et al., 2020). These indicators capture the primary sustainability dimensions identified in the conceptual approaches used here, encompassing issues such as greenhouse gas (GHG) emissions, land use intensity, biodiversity, profitability, animal welfare compliance, and social equity.

Table 3. Selected indicators by category

Environmental	**Animal Welfare**	**Economic**	**Social**
Kilograms of CO_2-equivalent emissions per unit of livestock product	Square meters of space available per animal in livestock facilities	Gross margin per functional unit (€/kg of meat or €/liter of milk)	Animal welfare compliance score based on adherence to recognized standards for the ethical treatment of animals
Kilograms of CO_2-equivalent emissions per food basket	Staff trained in animal welfare	Percentage of average household income spent on food	Fair wage compliance rate indicating the percentage of workers paid according to industry standards
Total greenhouse gas emissions in million tons of CO_2-equivalent emisisons	Annual mortality rate of growing and adult animals	Number of full-time equivalent (FTE) jobs in the food industry	Equality and non-discrimination index based on company policies and reported cases of discrimination
Total amount of food waste generated in kilotons	Use of external veterinarians or advisors for preventive animal health	Total volume of livestock products produced (tonnes)	Consumer health and safety compliance score based on the implementation of safety standards and practices
Kilograms of CO_2-equivalent emissions per hectare of agricultural land	Space per growing or adult animal in the most densely populated group	Total value of livestock products imported (million dollars)	Health impact score based on the estimated number of disease cases per unit of particulate matter emitted per food basket

Kilograms of nitrogen leached into groundwater per hectare per year	Number of days livestock have access to grazing per year	Total domestic demand for livestock products (million dollars)	Community health and safety impact score based on the influence of company operations on local living conditions and public health
Cubic meters of water equivalent (m^3 eq) per functional unit	Use of biosecurity protocol for new animal entry	Total value of livestock products produced domestically (million dollars)	Cultural heritage respect score based on company policies and practices regarding the protection and promotion of local cultural heritage
Percentage of total agricultural water use attributed to livestock production	Rejection rate of animals at abattoir due to health issues	Total value added by the industry (revenue minus cost of inputs)	Employment contract coverage rate indicating the percentage of workers with formal contracts
Square meters of arable land occupied per year per unit of livestock product	Percentage of animals with outdoor access during housing period	Total food production or availability per capita (kg)	Compliance rate with International Labour Organization (ILO) standards for working hours and overtime compensation
Net nitrogen balance per square kilometer (kg N/ha/year)	Percentage of animals with access to straw or bedding for housed animals	Total value of all food-related imports (million dollars)	Transparency score based on the availability and clarity of information provided by companies regarding their practices

The composition of the core set shows that the *Environmental* indicators emphasise outcome-oriented metrics such as kg CO_2-equivalent emissions per unit, water-equivalent per functional unit, and net nitrogen balance—metrics that can be directly shifted by both farm-level practices (e.g., precision irrigation) and structural policies (e.g., N-balance mandates). For the *Animal welfare* indicators, they blend resource-based (e.g., m^2 per animal) and outcome-based measures (annual mortality rate), reflecting One Welfare guidance. The *Economic* dimension encompasses profitability, value added, and market demand, enabling an analysis of how policy-based measures affect both producer margins and sectoral resilience. *A social* focus on equity and community well-being, including fair wage compliance and community health and safety scores, ensures that trade-offs with nutrition and livelihoods are made explicit.

4.3. Stakeholder Workshop-derived policy and practice ideas

As detailed in our methodology section (see section 3.2), the 40 selected indicators detailed above were grouped into meaningful sustainability sub-categories (see Table 2). As detailed in section 3.3, during the virtual workshops, participants placed digital Post-its on a virtual whiteboard structured by sub-dimension and leverage realm. Each person responded to: “What action improves this indicator?” and “Which realm (Re-think, Re-connect, Re-structure) does it fit?”. Figure 3 shows the completed whiteboard for the Environmental and Animal Welfare workshop for the Rethink realm, as an example of the contributions of participants in the various aspects consulted.

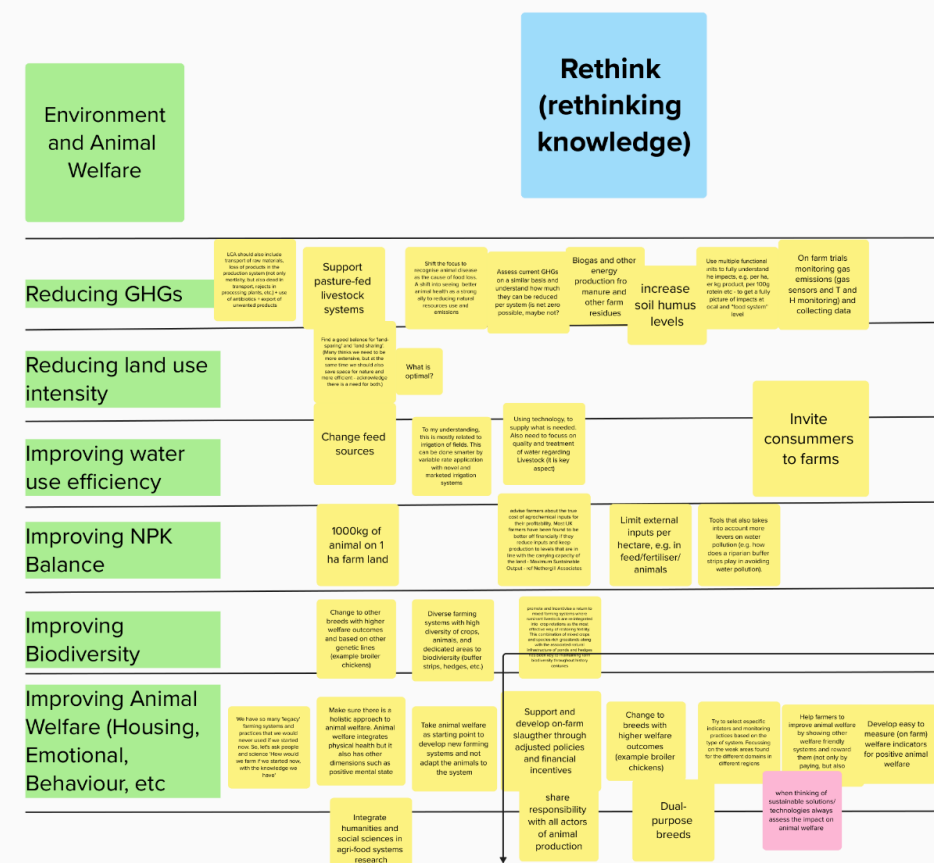

Figure 3. Environmental & Animal Welfare Whiteboard workshop. Example of contributions for the realm Rethink

Following the text-based analysis procedure detailed in section 3.3, each idea was categorised as either a practice or a policy. Table 4 below shows the distribution of this classification by dimension, sustainability sub-dimension and leverage point real. The Supplementary Material (section 8.2) contains the raw text data analysed and its classification as practice or policy per dimension.

Across all four dimensions, workshop participants generated a total of 70 practices and 67 policies, revealing a clear emphasis on on-the-ground actions (practices) while also identifying critical leverage points for institutional change (policies).

Table 4. Distribution of policies and practice ideas derived from the stakeholders' workshop

Dimension	Sustainability Sub-Dimension	Practices			Policies			Total Practices	Total Policies	Practices + Policies
		Re-connect	Re-structure	Re-think	Re-connect	Re-structure	Re-think			
Env	Improving Biodiversity	2	2	6	1	1	1	10	3	13
	Improving NPK Balance	5	1	3	1	1	1	9	3	12
	Improving water use efficiency	2	1	3	0	2	0	6	2	8
	Reducing GHGs	5	3	6	0	6	2	14	8	22
	Reducing land use intensity	7	2	2	1	2	0	11	3	14
AW	Improving Animal Welfare	7	2	6	9	6	6	15	21	36
Econ	Improving profitability & resilience	1	0	0	2	2	2	1	6	7
	Moderating livestock production	0	0	0	1	2	1	0	4	4
Soc	Equal opportunities in value chains	1	0	0	1	5	1	1	7	8
	Improving communities' health & safety	0	0	0	2	1	1	0	4	4
	Improving sustainability reporting	0	0	3	0	2	2	3	4	7
	Increasing the economic contribution of the livestock sector	0	0	0	0	0	2	0	2	2
		Total						70	67	137

Note: Env, AW, Econ and Soc stand for Environmental, Animal Welfare, Economic and Social dimensions, respectively.

In the *Environmental* domain, for example, "*Reducing GHGs"* attracted 14 practice suggestions (distributed roughly equally across Re-think, Re-connect, and Re-structure realms) but only eight policy proposals—most clustered in Re-structure—indicating that participants see immediate opportunities in farm-level, technical interventions while recognizing the need for systemic incentives (e.g., payments or regulatory mandates) to sustain those gains. Similarly, *Improving NPK Balance* yielded nine practices (predominantly Re-connect and Re-think) versus only three policies, underscoring a tendency to focus first on agronomic adjustments and knowledge sharing before drafting fertilizer-use regulations. In *Animal Welfare*, however, the balance tipped toward policies: 21 policies (especially in Re-think and Re-structure) versus 15 practices, suggesting that participants viewed regulatory frameworks as more urgent levers for animal well-being than incremental husbandry changes alone. Finally, the *Economic* and *Social* dimensions each exhibited smaller totals but still followed this pattern: participants identified far more concrete practices than policy reforms, yet the policy ideas they did generate were concentrated in the Re-structure realm.

Overall, this distribution reinforces the PATHWAYS framework's core premise: shallow-realm practices i.e. most of them in the Re-think/Re-connect realms, are essential for near-term improvements, but deep-realm policies (Re-structure) remain vital for locking in systemic transformation (Abson et al., 2017; Davelaar, 2021; Mayton et al., 2020; Staton et al., 2024). We recall these aspects in the section 4.4. In the following, we present the main insights from this participatory mapping process in which stakeholders identified how improvements in each dimension and sub-dimension could reflect deeper systemic change or might require interventions at different leverage levels.

4.3.1. ENVIRONMENTAL DIMENSION

The Environmental dimension generated a total of 69 unique interventions (see Table 4), proposed and discussed during the participatory workshop. These were distributed across all sub-dimensions and leverage realms and were categorised as either practices (n = 50) or policies (n = 19).

Reducing GHGs

The sub-dimension "*Reducing GHGs"* was associated with the largest number of contributions, with 22 items. Notably, a substantial number of policy proposals emerged under the *Re-structure* realm (six policies, three practices), reflecting strong interest in system-level changes such as: *"Use carrot and stick support payments/taxes to stimulate structural change..."* and *"Science supporting decision making – measure economic impact..."*. In contrast, most entries under the *Re-think* and *Re-connect* realms for this sub-dimension were practices, including: *"Produce for local/regional needs:"* (Re-connect) and *"Biogas and other energy production from manure and other farm residues"* (Re-think).

Reducing land use intensity

The sub-dimension "*Reducing land use intensity"* accounted for 14 interventions, of which 11 were practices. These practices were predominantly associated with the *Re-connect* realm and included diverse agronomic strategies such as *"Multiple crops"* and *"Intercropping, winter cereal grazing, cover crops..."*. Only 3 policy items were recorded under this sub-dimension, all within the *Re-structure* and *Re-connect* realms. For example: *"Need of rule-based retail sector and their integration..."*.

Improving water use efficiency, NPK Balance and Biodiversity

Improving water use efficiency as sub-dimension generated six practices and two policies across all realms. For instance: "*Using technology to supply what is needed...*" (Practice, Re-think) and "*Better access to information and benefits of better water utilisation and management*" (Policy, Re-structure)
Regarding Improving NPK Balance, this sub-dimension yielded 12 ideas, with a majority (nine) being practical strategies such as "*Limit external inputs per hectare...*" (Re-think) and "*Balance livestock and crop*

production" (Re-structure). Also, three policy suggestions were identified in this area, including: "*Require all farms to complete NPK balances to ensure limits are not exceeded...*".
Finally, Improving Biodiversity saw a total of 13 entries, 10 of which were practices, such as "*Walking paths/trials... for people to 'get closer to nature'*" (Re-think), "*Animals as part of the cropping system*" (appearing in both Re-think and Re-connect). Policy-oriented interventions for biodiversity were rare but notable: "*Adopting a formal EU One Health Strategy...*" (Re-structure).

Policy/Practice balance and synthesis

Overall, a clear trend across all sub-dimensions is the concentration of policy proposals in the *Re-structure* realm, where institutional and systemic levers were expected. In contrast, *Re-think* and *Re-connect* realms were dominated by practical interventions focused on knowledge, behaviour, and local innovation. Also, the presence of specific technical ideas, such as "*introduce carbon-related assessments on farm level*" and "*variable rate application with novel irrigation systems*", demonstrates the practical grounding of many contributions. These were often complemented by systemic proposals to embed sustainability criteria into governance and incentive frameworks, signalling a dual recognition of both ground-level change and enabling policy environments. These findings confirm that the Environmental discussions were both operationally rich and strategically varied, offering inputs that span from immediate farm practices to long-term policy structures.

4.3.2. ANIMAL WELFARE DIMENSION

Within the Animal Welfare dimension, participants generated 36 interventions (see Table 4) for the unique sub-dimension "*Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)*". 21 interventions were labelled as Practice and 15 as Policy. Table 4 summarises the distribution of Policy versus Practice entries across the three leverage realms.
In the Re-think realm, participants evenly split between proposing direct on-farm changes (e.g., "*Change to breeds with higher welfare outcomes*") and calling for system-wide shifts in mindset or measurement (e.g., "*Take animal welfare as starting point…*"). Six policy proposals advocate embedding welfare principles into research agendas, indicator selection, and incentive structures.
Under Re-connect, the majority of suggestions (nine out of 16) were policy-oriented, aiming to re-align knowledge flows between farmers, citizens, and regulators. Participants envisioned new platforms, educational initiatives, and governance mechanisms—e.g., "*Create a dedicated hub…*" and "*Include learning about One Health in education programs for kids*"—that bridge the gap between human communities and animal systems. Practical ideas (seven) leveraged technologies such as artificial intelligence (AI) or on-farm visitor programs to foster empathy and transparency: "*Use more AI to enable human 'connection' with animals*" and "*Introduce 'window show' on farms for citizens to visit.*"

In the Re-structure realm, policy proposals (six of eight) dominated. Citizens and stakeholders called for concrete legislative reforms—such as "*We need new EU laws – to end the cage age*" and "*Revision of the minimum animal welfare standards…*"—that would codify welfare best practices. Only two practice entries surfaced here, both focused on agroecological systems and genetic improvement.

Balance and synthesis

From a balance point of view of Policy vs Practice, across all Animal Welfare interventions, 21 (58 %) were classified as Practices and 15 (42 %) as Policies. The Re-think realm exhibited a perfect split (6 Policy vs 6 Practice), indicating that stakeholders value both conceptual reframing and direct on-farm actions equally. Conversely, we observe a dominance of Policy in Re-connect: 9 Policy vs 7 Practice, and Re-structure: 6 Policy vs 2 Practice. This could imply that forging new connections—with citizens, educators, and regulatory bodies—and restructuring systems require formal policy instruments more often than mere behavioural changes.

Also, we observe a repeated emphasis on breed selection. To illustrate, "*Change to breeds with higher welfare outcomes (example broiler chickens)*" appears in all three realms (Re-think, Re-connect, Re-structure) as a Practice. This repetition underscores a consensus that genetic improvement is a cross-cutting lever for advancing welfare, regardless of the broader strategic approach. Similarly, the integration of welfare in education and governance is highlighted given the multiple policy entries in Re-connect and Re-structure, such as call for: education programs targeting both future farmers and the public (e.g., One Health curricula for children), and harmonised audit and regulatory frameworks (e.g., "*Focus on animal-based indicators in legal requirements*"). These proposals reflect a desire for community-level literacy on welfare issues as well as coherent governance across jurisdictions.

Together, these results demonstrate that workshop participants articulated a multi-pronged strategy compounds by, among others, practical on-farm interventions (e.g., breed selection, AI tools, agroforestry) to directly improve daily animal conditions; policy and regulatory reforms (e.g., EU cage bans, welfare dataspace) to embed welfare principles into the institutional architecture, and; educational and connectivity initiatives (e.g., dedicated hubs, One Health programs) to align stakeholders' mindsets and build collective capacity. By balancing these approaches across all three leverage realms, the Animal Welfare dimension offers a comprehensive blueprint for both near-term action and longer-term transformation within the livestock sector.

4.3.3. ECONOMIC DIMENSION

Within the Economic dimension, participants proposed 11 interventions across two subdimensions: "*Improving profitability and industry resilience"* (seven items) and "*Moderating livestock production volume"* (four items), as summarised in Table 4. Only one practice is observed ("*Improving profitability and industry resilience"* – Re-connect), suggesting that participants viewed economic sustainability as mainly a function of system-wide reforms, rather than solely on-farm practices.

Improving Profitability & Industry Resilience

In this sub-dimension, seven ideas emerged, of which six were classified as Policy and one as Practice. Two policy proposals in Re-think called for reshaping the way the livestock sector is perceived and supported. The first, "*Work more on launching farmers as environmental heroes..*" suggests a concerted communications campaign to reframe farmers as sustainability champions. The second, "*Provide legislative/harmonisation/education support where needed,*" advocates for aligned regulatory frameworks and targeted training programs, so that farmers can adopt best-practice management without being hindered by inconsistent rules or knowledge gaps. Under Re-connect, participants proposed one Practice and two Policies. The single practice—"*Using certification schemes to help consumers make sustainable food choices*"—leverages market signals and labels to create direct linkages between producers and consumers, thereby creating a premium for sustainably raised products. Two policy ideas in this realm focus on aligning market incentives more broadly. First, "*Using market forces to engage changes in production methods—the farmers will produce what has added value*" encourages governments to facilitate demand for higher-value, sustainably produced livestock by, for example, reducing trade barriers or funding promotional campaigns. Second, "*Support RES market and energy policy at rural areas to decrease input costs of livestock houses maintenance*" proposes regional feed-in tariffs or grants for on-farm renewable energy installations, lowering operating expenses and improving profitability.

Two policy interventions in Re-structure addressed institutional and fiscal levers. The first, "*Include farming and food systems in national education,*" calls for curricular changes so that future generations of consumers, policymakers, and farmers understand the economics of livestock production from an early age. The second, "*Change legislation so that it aids — not hampers — sustainable production methods,*" urges revision of existing agricultural laws to eliminate perverse incentives (e.g., subsidies for high-input, intensive operations) and create legal space for more resilient, lower-carbon business models.

Taken together, in the Improving Profitability & Industry Resilience sub-dimension, nearly all (six of seven) interventions rely on policy tools—whether communications, education reforms, renewable-energy grants, or legislative overhauls—while the single practice (certification schemes) bridges the market and farm levels to reward value-added production.

Moderating Livestock Production Volume

The sub-dimension "Moderating Livestock Production Volume" produced four interventions, all of which were classified as Policy. One Re-think policy—"*Improve public education about livestock production and its impacts*"—focuses on changing societal mindsets through awareness campaigns, school curricula, and public-service messaging. By educating consumers and communities about the environmental and social footprints of different livestock systems, this intervention aims to moderate demand for high-intensity production methods. In Re-connect, the sole policy proposal—"*Creating immersion programs (farm visits, production facilities) where other actors who are not directly linked to these sectors can learn about the bigger picture*"—seeks to reconnect urban consumers, policy analysts, and food-industry stakeholders with the realities of livestock farming. By exposing non-farming actors to on-farm practices and limiting overall production volume to sustainable levels, this policy intervention uses experiential learning to foster a shared understanding of why moderation is necessary. Regarding Re-structure, two policies directly address economic levers to curb volume. The first, "*True Cost Accounting,*" proposes that all livestock commodities internalize their environmental and social externalities—whether by a carbon tax, a nutrient pollution surcharge, or a biodiversity fee—so that real costs appear on price tags and reduce overproduction. The second, "*Adapt taxes: make them higher for animal proteins / lower them for plant proteins,*" outlines a fiscal shift, raising excise or VAT rates on high-emission animal goods and subsidising plant-based alternatives, thereby steering consumption away from volume-driven livestock.
Here, all four interventions leverage policy measures—public education, immersion programs, cost-internalization taxes, and differential taxation—to moderate livestock numbers. No farm-level practices were proposed, indicating a clear consensus: substantial reductions in production volume require policy frameworks rather than discrete operational changes.

Balance and synthesis

Across both Economic sub-dimensions, policies predominate: 10 of 11 interventions (≈ 91%) rely on legislative, fiscal, or educational reforms to enhance profitability, resilience, and volume moderation. Only one intervention—"*Using certification schemes to help consumers make sustainable food choices*"—was classified as a Practice, revealing a strong belief among participants that meaningful economic change in the livestock sector depends on systemic adjustments (policy measures) rather than exclusively on producer-driven actions. This finding aligns with the broader PATHWAYS conceptual framework: shallow-realm practices can deliver near-term market signals, but deep-realm policies are essential for sustainable, long-term transformation of the livestock economy.

4.3.4. SOCIAL DIMENSION

In the Social dimension, participants proposed 21 distinct interventions clustered under four dimensions (see Table 4). 17 interventions were labelled as Policy and four as Practice.

Increasing Economic Contribution of the Livestock Sector

In "Increasing Economic Contribution of the Livestock Sector", two ideas were proposed and all in Re-think and all Policy: "*Cooperation between farmers, processors, and service providers*" and "*Provide legislative/harmonisation/education support where needed*". In the former, participants argued that formal partnerships among supply-chain stakeholders could reduce transaction costs and open new markets, thereby boosting overall sector revenue. The latter called for uniform regulations and training programs—possibly funded by the government—to align producers' practices with best-practice standards, enabling economies of scale and enhancing export opportunities. No entries in Re-connect or Re-structure for this sub-dimension suggest that participants viewed economic-contribution increases as primarily requiring systemic knowledge and policy-level interventions.

Equal Opportunities in Value Chains

For "Equal Opportunities in Value Chains", across the three realms, seven of nine proposals were labelled as Policy and one as a Practice. In the Re-think realm, a single Policy—"*Publicly sharing monetary indicators of price that should be given to producers…*"—calls for transparent price benchmarks so that farmers understand the minimum fair compensation for meat or milk. The Re-connect realm included one Practice: "*Multiplying days of visit to farms for consumers, buyers of slaughterhouses and dairies and retail…video content on TikTok, etc.*". By fostering direct engagement, this idea helps bridge gaps in understanding between producers and downstream actors. Its companion Policy, "*Creating immersion programs (farm visits…)*", envisions a publicly supported initiative that routinely brings diverse stakeholders into production environments to build mutual empathy. Finally, the Re-structure realm contained five Policy entries. For example, "*Support shorter supply chains: regional food networks, direct farmer-to-consumer sales, and community-supported agriculture (CSA)*" proposes legislative or financial incentives for localised marketing channels. Similarly, "*The cost of food ingredients bought from farmers should be 'sanctuarised'…(French initiative at the EU level)*" would embed a legally protected floor price for commodities, safeguarding farmers' livelihoods. These policy interventions collectively aim to restructure market rules so that small-scale or marginalised producers can participate on more equal footing.

Improving Sustainability Reporting to Meet Standards

In "Improving Sustainability Reporting to Meet Standards", we observe that within Re-think, there are two Policies and three Practices. Policy proposals include "*Develop standardised and objective sustainability metrics*," which calls for a uniform reporting framework that all operations should adopt, and "*New livestock system narrative and quantification of benefits…*"—a directive to craft public-facing stories underpinned by complex data so consumers can appreciate social and environmental co-benefits of various production models. The three Practice entries—"*Find new ways of measuring biodiversity,*" "*Scale-up*

technologies (remote sensing)," and "*Make better use of data collected from farms to give feedback (benchmarking) that nudges/stimulates decisions…"*—focus on novel data-collection methods and on-farm benchmarking tools, enabling farmers to self-monitor and adjust operations in real time. In this sub-dimension, only 2 Policies appeared under Re-structure. One calls for "*Government and society to agree on long-term sustainability objectives that are measured and reported to incentivise achieving them (e.g., direct payments).*" The other—"*Any legislation with the aim of moderating livestock volume must be extremely well informed of the differences between production methods.*"—emphasizes tailoring laws so that diverse systems (e.g., grazing vs. confinement) are accounted for, avoiding one-size-fits-all regulations. No Re-connect entries were recorded, suggesting participants saw reporting as requiring top-down mandates rather than connectivity exercises.

Improving Communities' Health & Safety

In the subdimension "Improving Communities' Health & Safety", participants proposed three initiatives, and all of them were classified as Policy following our established approach. In the Re-think realm, "*Talking about food balance to kids, young couples, elderly people: need for animal protein: not too much but not too little*" urges public-health agencies to develop age-appropriate messaging around balanced diets. Within Re-connect, "*Help people to understand themselves as part of the ecosystem*" calls for community workshops or media campaigns that foster holistic thinking, and "*Support for healthy local food systems, eg, school canteens*" advocates for institutional procurement policies ensuring that schools source fresh, locally produced foods. No practices or Re-structure entries appeared, suggesting consensus that improving health and safety demands policy action rather than individual behaviour change.

Balance and synthesis

Overall, the Social dimension was overwhelmingly policy-oriented: 17 of 21 (≈ 81 %) interventions required structural reform, whether through transparent pricing benchmarks, standardised metrics, or legislative support for local procurement. Only four practices (≈ 19 %)—such as farm immersion programs, remote-sensing, and on-farm benchmarking—were proposed, and these primarily facilitated stakeholders' engagement or data-driven decision-making. This heavy skew toward policy suggests that workshop participants viewed social equity, value-chain inclusion, and community well-being as objectives that cannot be fully realised by farm-level adjustments alone. Instead, enduring social improvements demand coordinated policy frameworks, educational outreach, and restructured market rules, consistent with the PATHWAYS emphasis on multi-level interventions spanning all three leverage realms.

4.4. Framework synthesis and operationalization

The outputs from indicator refinement, leverage point mapping, and policy idea generation were integrated into the final PATHWAYS *Framework*. This participatory process ensured that the framework not only reflects theoretically sound sustainability indicators but also incorporates practical, real-world strategies for change. In particular, stakeholders validated the relevance of each indicator by grounding them in concrete policy and practice ideas generated during the workshops.

After tabulating how many policies versus practices each sub-dimension generated (Table 4), we synthesized these counts in a Sankey-style flow chart (Figure 4). Figure 4 visualizes every intervention's journey—from one of the four dimensions, into its sub-dimension, onto the chosen leverage realm, and finally to either Policy or Practice. The width of each band corresponds to the number of interventions at each stage. For example, the band flowing from "Social" to its sub-dimensions is proportionally wider than the band from "Economic," reflecting a higher total count of social interventions. Similarly, where a sub-dimension has many Re-connect practices but few Re-structure policies, the diagram makes that gap immediately visible.

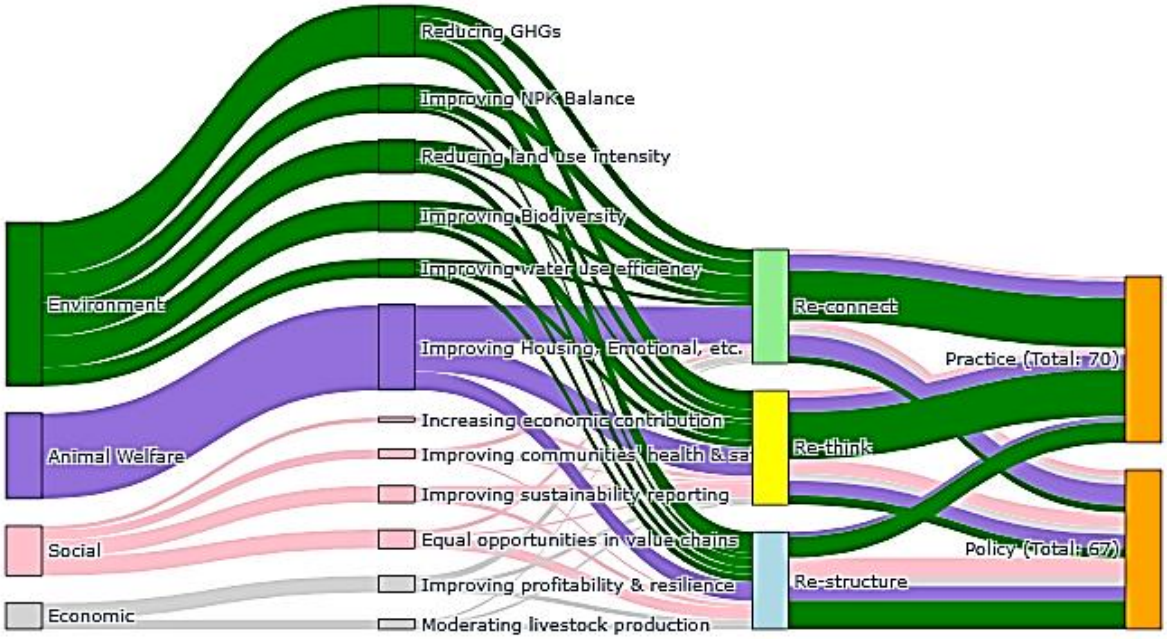

Figure 4. Diagram visualising the flow of sustainability ideas from broader Dimensions to more specific Sub-Dimensions, Realms, and finally to Policies and Practices. (*The width of the bands connecting the nodes represents the total count of policies and practices at each stage of the flow. For example, you can see the total flow originating from each Dimension (e.g., the width of the band from 'Social' to its sub-dimensions represents the total policies and practices within the Social dimension). Following a path, the flow from a 'Sub-Dimension' to a 'Realm' shows the number of policies and practices within that specific sub-dimension that fall under that realm. Finally, the flows from the 'Realm' nodes to the 'Policy' and 'Practice' nodes indicate the total number of policies and practices, respectively, within each realm category across all dimensions and sub-dimensions.)*

First, as discussed above, this policy vs practice distribution reinforces the idea of shallow-realm practices (Re-think/Re-connect) as proposals for near-term improvements, while deep-realm policies (Re-structure) remain vital for locking in systemic transformation. The predominance of deep-realm policy interventions over shallow practices aligns with Meadows' (1999) assertion that systemic rules and paradigms exert the most significant leverage. By overlaying Policy and Practice counts onto each realm and sub-dimension, Figure 4 helps us identify where stakeholder activity has been most concentrated—and where critical gaps remain. For instance, "Improving sustainability reporting" shows relatively balanced flows into both Practice (e.g., remote-sensing technologies) and Policy (e.g., standard-setting mechanisms), whereas "Improving communities' health & safety" is overwhelmingly policy-driven with minimal practice entries. As shown in Figure 5's Sankey diagram, the flow line originating from the "Improving communities' health & safety" node is almost entirely routed to the Policy column, with only a narrow strand continuing to Practice. The relative widths of these bands—wide toward Policy, thin toward Practice—visually demonstrate that participants proposed very few on-the-ground practices for this sub-dimension compared to policy measures.

The suggested framework now enables users to:

- Evaluate policy and innovation scenarios against the selected indicators.
- Interpret indicator trends through the lens of leverage realms.

Identify the depth of interventions by classifying them as shallow-realm practices (aligned with incremental improvements) or deep-realm policies (reflecting participants' perceptions of systemic change pathways). This mapping provides an overview of where proposed actions concentrate but does not in itself assess their real-world effectiveness or consensus support.In consequence, the results of the framework in terms of the distribution of suggested policies and practices, as represented in the flow chart in Figure 4, can guide next steps for targeted innovation and policy-oriented interventions by revealing which sub-dimensions require additional practice-level experimentation versus which demand stronger regulatory or institutional support. This approach encouraged participants not only to consider incremental improvements but also to think strategically about what kinds of interventions could catalyse deeper transformations. For example, proposals included supporting pasture-based systems (Re-connect), developing sustainability-linked insurance schemes (Re-structure), and creating public awareness campaigns on sustainable consumption (Re-think). The workshop dialogues highlighted that while some indicators can be improved through relatively straightforward technical fixes, others require addressing entrenched institutional or cultural factors. Moreover, many proposed actions intersected multiple leverage realms, underscoring the complexity of driving change in livestock systems.

A key insight from this process was that sustainability indicators, although typically treated as static measures, can also serve as entry points for systemic change narratives. Each indicator reflects not only a performance metric but also a story about which actors, institutions, and knowledge systems are

influencing outcomes—and where interventions might have the greatest leverage. The participatory design of the workshop facilitated cross-sector learning and co-production of knowledge, ensuring that the resulting framework does not simply evaluate sustainability in a static sense but actively informs transition-oriented policy and innovation strategies.

4.5. A narrative example: the EU Farm to Fork (F2F) Strategy

As outlined in section 3.5, we apply the PATHWAYS framework to the European Commission's F2F Strategy – a flagship policy aimed at making the EU food system "fair, healthy and environmentally-friendly" (European Parliament, 2025). This strategy is comprehensive in scope, encompassing measures from agricultural production to consumption, and it explicitly targets all four sustainability dimensions. It proposes, for example, to reduce the use of chemical pesticides and fertilizers (environmental dimension), improve farm animal welfare standards (animal welfare dimension), ensure farmers a fair income and new business opportunities in sustainable production (economic dimension), and promote healthier diets for consumers along with food security and affordability (social dimension) (European Parliament, 2025). We follow the four steps outlined in section 3.5 to evaluate how F2F would be situated within the PATHWAYS framework.

Step 1 – Mapping to indicators: we begin by linking the F2F Strategy's key objectives and actions to specific indicators in each sustainability domain. The F2F Strategy sets quantified targets for 2030 that map directly onto our environmental indicators – for instance, a 50% reduction in pesticide use and risk, a 20% reduction in synthetic fertiliser use, and converting 25% of EU farmland to organic production (European Parliament, 2025). These goals align with indicators such as agrochemical input intensity, soil and water quality, and farmland biodiversity status. Likewise, the Strategy's aim to halve antimicrobials in animal husbandry maps to both animal welfare and public health indicators (e.g. antibiotic use per livestock unit, prevalence of antimicrobial resistance). On the animal welfare side, proposed revisions of EU animal welfare legislation (covering transport, housing, and slaughter practices) correspond to indicators of on-farm welfare outcomes (e.g. animal stress and injury rates, compliance with welfare standards). Economic objectives in the F2F strategy – such as improving farmers' income share and creating new market value from sustainability (e.g. via organic premiums or value-added products) – are mapped to economic indicators like farm income levels, cost of production, and market access for sustainable products. Social and health-focused actions (e.g. introducing mandatory front-of-pack nutrition labels, school and consumer education for healthy diets, and food waste reduction initiatives) link to social indicators including rates of obesity and diet-related disease, food affordability, and community food security. By performing this mapping, we obtain a multi-dimensional indicator dashboard for F2F, ensuring that every facet of the Strategy is connected to measurable outcomes in the PATHWAYS framework.

Step 2 – Leverage realm assignment: After mapping the "what" of the Strategy (the targeted outcomes), we examine "how" these changes are to be achieved by categorizing each major F2F initiative into the three

leverage realms. Many core measures in F2F engage the Re-structure realm, as they involve new or strengthened institutional rules and incentives. Notable examples include the proposal for an EU sustainable food systems law and tighter regulatory standards – such as revised animal welfare regulations and a Sustainable Use of Pesticides Regulation – which are classic structural interventions (top-down policy frameworks and legal mandates). Economic instruments, such as adjusting agricultural subsidies (through the Common Agricultural Policy) to reward sustainable practices, also fall under "Re-structure," as they realign financial rules and market signals. Meanwhile, the Strategy's emphasis on consumer and stakeholder engagement activates the Re-think realm. Initiatives like public awareness campaigns for sustainable healthy diets, training programs for farmers in agroecological methods, and research & innovation agendas (e.g. for alternative proteins or agroecological techniques) are leverage points centred on knowledge systems and paradigms. These aim to reshape mindsets, skills, and information flows (for instance, rethinking how producers and consumers value sustainability and animal welfare). Additionally, F2F contains elements of Re-connect – strengthening networks and linkages in the food system. The push for shorter supply chains (bringing producers closer to consumers), the establishment of an EU Code of Conduct for responsible marketing (connecting industry players under shared sustainability commitments), and multi-actor platforms (such as a Food Policy Observatory for coordination in crises) all serve to reconnect various actors and reinforce socio-ecological linkages. By assigning each Farm to Fork action to one (or multiple) of these realms, we create a profile of the Strategy's intervention logic: in this case, a blend of structural reforms (regulatory and market-based), cognitive shifts (knowledge and culture), and network-building efforts. This reveals that F2F is not a purely top-down regulatory agenda; it also seeks to cultivate bottom-up change through education and collaboration.

Step 3 – Impact estimation: With the Strategy's measures mapped and categorised, the framework next facilitates an integrated assessment of expected impacts across all indicators – qualitatively identifying improvements, potential regressions, and their distribution among dimensions. Under the environmental dimension, F2F's ambitious targets to curb synthetic inputs and greenhouse gas emissions signal substantial positive impacts. We anticipate improvements in indicators such as GHG emissions intensity (through climate-friendly farming practices), water and air quality (via reduced agro-chemical runoff and ammonia emissions), and on-farm biodiversity (through expansion of organic farming and habitat protections) (European Parliament, 2025). The reduction in pesticide and fertiliser use, for example, should benefit ecosystems (less pollution and nutrient overload) and also confer health benefits by lowering human exposure to agrochemicals. In the animal welfare dimension, the planned legislative revisions and promotion of higher welfare farming systems are expected to yield direct gains in animal well-being (e.g. lower incidence of stress, injury, and disease in livestock), reflecting progress on One Welfare by concurrently supporting animal health and farm public health. These welfare improvements might modestly affect productivity or costs (for instance, if stocking densities are reduced or infrastructure upgraded), but they align with rising consumer demand for ethically produced food and could open new markets, thus creating economic opportunities rather than purely costs (European Parliament, 2025). In the economic dimension, F2F strives for a more resilient and fair food economy. By rewarding sustainable

practices (e.g. via organic price premiums, eco-scheme payments) and developing new value chains, it aims to improve farmers' income and reduce the risk of income disparities (European Parliament, 2025). We qualitatively estimate a positive trajectory for indicators like farmers' share of consumer expenditure and rural employment in sustainable food sectors. However, we also flag potential economic trade-offs: meeting strict environmental targets could impose adjustment costs on producers (e.g., investing in new equipment, which may result in short-term yield declines). The framework brings these trade-offs to light so that flanking measures (like transition subsidies or technical assistance) can be considered to maintain economic viability during the transition. Finally, in the social dimension, the Strategy's impacts are expected to be broadly beneficial in terms of public health and social inclusion. Policies promoting nutritious diets (such as improved food labelling and school programs) should help lower obesity and diet-related disease rates over time, improving community health outcomes. Likewise, efforts to ensure food affordability and safety (e.g. through food waste reduction and crisis contingency plans) support social indicators related to food security and equity. A possible tension may arise if, for example, sustainability-driven cost increases lead to higher food prices; the framework's holistic lens would catch this issue, prompting complementary social policies (income support or food assistance) to uphold the "fair and healthy" principle (European Parliament, 2025). In summary, the impact estimation step, applied to F2F, suggests potential synergies – notably, reducing antimicrobial use benefits animal welfare, environmental health, and human health simultaneously – while also identifying areas of trade-off, such as economic adjustments needed to achieve ecological and welfare gains. This narrative, evidence-informed evaluation remains qualitative, but it provides decision-makers a clear sense of where the policy excels and where careful monitoring or support is needed.

5. Discussion

The proposed holistic evaluation framework presents a novel, participatory approach to assessing and guiding sustainability transitions in livestock systems. It integrates multidimensional sustainability indicators with systemic leverage point thinking (Abson et al., 2017; Meadows, 1999) and directly incorporates the practical insights of stakeholders across the sector (Allington et al., 2018; Reed et al., 2013). Here, we reflect on how this framework advances current practice, its policy and innovation implications, and areas for further refinement.

5.1 Advancing beyond conventional evaluation

Conventional agricultural policy evaluations often focus narrowly on specific outcomes—such as productivity, emissions, or profitability—and assess these metrics in disciplinary or sectoral silos (Ryschawy et al., 2019). Our framework expands this approach by combining broad-based sustainability assessment with the lens of systemic change. Rather than evaluating whether indicators merely improve (Slätmo et al.,

2017), it examines whether observed or projected changes reflect deeper processes of rethinking knowledge, reconnecting to nature, or restructuring systems.

Our findings suggest that while socio-technical innovations (e.g., AI monitoring) can rapidly tweak system parameters, lasting change demands socio-ecological policy reforms (e.g., landscape-scale biodiversity mandates) that realign ecosystem services with societal welfare. In practical terms, by clustering indicators into meaningful sub-dimensions (such as reducing GHGs, improving water efficiency, or enhancing animal welfare) and mapping each proposed intervention across these sub-dimensions and leverage realms, the framework makes it possible to see which practices or policies span multiple domains. For example, an agroforestry policy may appear under both 'Improving Biodiversity' and 'Reducing GHGs,' highlighting its potential to generate co-benefits—and also exposing where one domain's gain might carry unintended impacts in another. This cross-domain mapping moves beyond static benchmarking and supports learning about how interventions contribute to long-term, systemic transformation—a principle increasingly called for in sustainability transition research.

5.2 Policy and innovation design implications

For policymakers, the PATHWAYS framework provides both a diagnostic tool and a learning platform, which are desirable features for these instruments (Head, 2010). It can identify where current policy portfolios support holistic sustainability goals and where gaps or misalignments exist. By explicitly categorising interventions under the leverage realms, policymakers can balance immediate measures (such as technical improvements or financial incentives) with deeper strategies that address knowledge paradigms, market structures, or institutional arrangements (Abson et al., 2017; Meadows, 1999).

The participatory workshops generated over 100 actionable policy and practice ideas, demonstrating the framework's capacity to translate abstract transition concepts into concrete, stakeholder-generated proposals. For example, suggestions ranged from supporting pasture-based production systems (Re-connect) to developing sustainability-linked insurance schemes (Re-structure) and introducing education reforms that shift societal perspectives on livestock sustainability (Re-think).

For innovation managers and researchers, the framework fosters systems thinking in the design and assessment of new technologies or practices. Rather than assessing innovations solely on isolated performance metrics, the framework prompts analysis of their potential to shift relationships, paradigms, or governance structures—key markers of transformative potential. By activating different leverage realms, interventions reshape both the technological architectures (e.g., data platforms, automation systems) and

ecological regimes (e.g., grazing–vegetation feedback), underscoring the need for policy mixes that span socio-technical governance and ecosystem stewardship.

It is important to note, however, that the PATHWAYS framework provides structured qualitative evaluations and identifies potential trade-offs and synergies based on stakeholder inputs and narrative assessments. The framework itself does not quantify impacts or validate effectiveness without supplemental empirical data, highlighting an important area for future integration with quantitative sustainability assessments.

5.3 Transdisciplinary engagement and stakeholder buy-in

A central strength of the framework is its participatory, co-design approach (Mayton et al., 2020; Reed et al., 2013). By involving diverse stakeholders in clustering indicators, identifying leverage points, and proposing actionable solutions, the framework builds legitimacy and practical relevance. Stakeholders' ability to co-produce the evaluation criteria and systemic change narratives ensures the framework addresses real-world priorities and fosters broad buy-in.

This participatory process also functions as a capacity-building mechanism, encouraging participants to think beyond incremental fixes and engage with the complexity of livestock system transitions. It aligns with principles of reflexive governance, promoting continuous feedback, cross-sector learning, and adaptive policymaking.

5.4 Challenges and limitations

While promising, the framework also presents several challenges. First, the selection of indicators depended on existing data availability—indicators lacking reliable data were excluded—yet the framework itself does not incorporate ongoing data collection or management. Instead, users must supply or secure data externally; adding more indicators does not inherently change the framework's structure or operation. Second, qualitative dimensions such as trust, cultural values, or organizational adaptability resist straightforward quantification and were underrepresented in the final indicator set. Addressing these gaps may require complementary narrative approaches or stakeholder interviews (Benegiamo et al., 2023). Third, the framework surfacespotential leverage points and transformational indicators as identified by workshop participants, but it does not assess their real-world effectiveness or degree of consensus. The over 100 proposed practices and policies inherently reflect subjective participant perspectives rather than independently verified outcomes or consensus views. Therefore, the policy and practice ideas generated through workshops should be considered exploratory than validated recommendations. Further empirical

testing—through pilot studies or case-based evaluations—will be essential to determine which interventions reliably deliver intended outcomes (Feola et al., 2015; Öhlund et al., 2015)..
Finally, the framework's current structure, though developed for EU livestock systems, may require adaptation for other contexts where different sustainability priorities or socio-economic conditions prevail.

5.5 Future applications and research

The combination of multi-dimensional assessment and leverage point analysis developed here has potential beyond livestock systems. With appropriate tailoring of indicators and leverage considerations, the approach could be applied to other agricultural sectors or broader food system challenges.
Future research should explore how the framework complements other emerging tools for monitoring sustainability transitions, such as dynamic system modelling, outcome mapping and sustainability assessments tools (de Olde et al., 2016). Comparative studies could further refine the balance between quantitative rigor and qualitative insight.

The PATHWAYS Framework bridges the gap between sustainability monitoring and transition-oriented analysis. By integrating robust indicators with participatory leverage point mapping, it enables both outcome evaluation and process evaluation, assessing not only whether targets are met but also whether systemic change is underway. This dual approach supports more coherent, integrated policy and innovation strategies, fostering the transformative change needed to achieve sustainability in livestock systems.

6. Conclusion

In this report, we have presented the PATHWAYS Framework for Sustainable Livestock Systems. The framework addresses the need for comprehensive indicators linked to sustainability domains that can guide sustainability transitions in the livestock sector. Grounded in the One Welfare paradigm, multidimensional sustainability assessment (SAFA), and leverage points for system change, it provides a structured approach to evaluating policies and innovations in terms of both the outcomes achieved and their impact on more profound socio-technical/ecological systemic transformations. By integrating diverse indicators across environmental, economic, social, and animal welfare domains with an analysis of how interventions promote rethinking, reconnecting, and restructuring of the system, the framework bridges the gap between conventional performance assessment and transition-oriented evaluation.

The framework is intended to assist both research and policy audiences. For researchers, it provides a template for holistically analysing complex interventions, facilitating interdisciplinary collaboration (e.g. economists, ecologists, and sociologists working with a standard set of metrics and concepts). It also

contributes to methodological advancement in sustainability science by illustrating how qualitative transition concepts can be operationalised alongside quantitative indicators. For policymakers and practitioners, the framework serves as a practical guide to “what matters” when judging the merits of a policy or innovation in livestock systems – encouraging consideration of a broad suite of impacts and the long-term trajectory of change. Using such an evaluation approach can improve strategic decision-making, ensuring that efforts to reform livestock systems are not piecemeal but aligned with transformative pathways towards sustainability. While stakeholder workshops remain critical for generating context-specific insights and proposals, the framework’s systematic process used in analysing the F2F Strategy—indicator mapping, leverage realm assignment, and narrative impact assessment—can also be independently employed by policymakers or researchers. Thus, the PATHWAYS framework is versatile enough to facilitate both participatory scenario generation and standalone evaluation of existing or proposed policies.

Although the framework is comprehensive, it is not static. Next steps include applying the framework to concrete case studies or scenario analyses, such as evaluating upcoming agricultural policy packages or innovation roadmaps in the EU for their sustainability impacts. Also, the framework may be iteratively adjusted – for instance, by adding or removing indicators, sharpening the definition of leverage indicators, or integrating quantitative models to project indicator changes under scenarios. Additionally, expanding the framework to incorporate adaptive evaluation over time could be valuable (monitoring actual changes and feeding back into policy learning cycles).

In conclusion, moving toward sustainable livestock systems requires not only innovative practices and bold policies but also robust ways to learn what works and why. The holistic evaluation framework we propose is a step in that direction, offering a way to evaluate and inform policy and innovation through a sustainability transition lens. By holistically assessing current conditions and future options, and explicitly considering the levers of systemic change, such a framework can support the design of more effective, integrated strategies for achieving a resilient, ethical, and environmentally sound livestock sector. By uniting indicator-based assessment with a socio-technical/ecological leverage-point lens, the PATHWAYS framework equips decision-makers to craft integrated portfolios of policies and practices that co-evolve technologies, institutions, and ecosystems toward sustainability.
Aimed at researchers and policymakers, the PATHWAYS framework provides a structured method to facilitate participatory stakeholder engagement while also enabling independent policy assessment through systematic indicator mapping, realm assignment, and narrative impact estimation. By highlighting potential synergies and trade-offs qualitatively, it supports more coherent and informed policy design; however, empirical validation of these assessments remains a necessary next step to capture effectiveness and outcomes fully.

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8. Supplementary Material

8.1. Indicators identification and refinement by relevance

*Table 5. Identified indicators for the **Environmental** dimension. The table includes the relevance average score from the survey and if the indicator was selected as one of the top ten in the GA stakeholders workshop (see section 3 for details)*

#	Indicator	Average Score Survey	GA Selected (10)
1	Kilograms of CO2 equivalent emissions per unit of livestock product	4.07	yes
2	Kilograms of CO2 equivalent emissions per food basket	4.07	no

3	Total greenhouse gas emissions in million tons of CO2 equivalents	3.97	yes
4	Total amount of food waste generated in kilotons	3.9	no
5	Kilograms of CO2 equivalent emissions per hectare of agricultural land	3.66	yes
6	Kilograms of nitrogen leached into groundwater per hectare per year	3.59	no
7	Cubic meters of water equivalent (m3 eq) per functional unit	3.59	yes
8	Percentage of total agricultural water use attributed to livestock production	3.45	no
9	Square meters of arable land occupied per year per unit of livestock product	3.4	yes
10	Net nitrogen balance per square kilometer (kg N/ha/year)	3.38	yes
11	Cubic meters of water deprivation per food basket	3.38	no
12	Kilograms of phosphorus equivalent (P eq) per unit of livestock product	3.28	yes
13	Kilograms of nitrogen equivalent (N eq) per unit of livestock product	3.28	no
14	Number of different crop and forage species per farm	3.24	no
15	Megajoules (MJ) of fossil fuel energy used per food basket	3.21	no
16	Kilograms of ammonia (NH3) emitted per NUTS 2 region	3.17	no
17	Amount of ammonia (NH3) exceeding the critical load per NUTS 2 region	3.14	yes
18	Square meters of arable land transformed per year per unit of livestock product	3.14	yes
19	Economic value of different waste treatment methods (e.g., landfilling, incineration, composting) expressed in million dollars	3.1	no
20	Megajoules (MJ) of fossil and nuclear energy consumed per unit of livestock product at the farm level	3.07	no
21	Kilograms of carbon (C) change per unit area, often expressed as the net change in soil carbon storage (kg C/ha/year)	3	yes
22	Kilograms of mineral resources consumed per unit of livestock product	3	no

*Table 6. Identified indicators for the **Animal Welfare** dimension. The table includes the relevance average score from the survey and if the indicator was selected as one of the top ten in the GA stakeholders workshop (see section 3 for details)*

#	Indicator	Average Score Survey	GA Selected (10)
1	Square meters of space available per animal in livestock facilities	4.34	yes
2	Staff trained in animal welfare	4.32	yes
3	Annual mortality rate of growing and adult animals	4.21	yes
4	Use of external veterinarians or advisors for preventive animal health	4.1	yes

5	Space per growing or adult animal in the most densely populated group	4.1	no
6	Number of days livestock have access to grazing per year	3.93	yes
7	Use of biosecurity protocol for new animal entry	3.93	no
8	Rejection rate of animals at abattoir due to health issues	3.9	yes
9	Percentage of animals with outdoor access during housing period	3.9	yes
10	Percentage of animals with access to straw or bedding for housed animals	3.9	yes
11	Percentage of animals with access to solid flooring for housed animals	3.45	yes
12	Animal life years suffered (ALYS) per animal or per functional unit	3.03	yes
13	Number of animals affected per unit of product (e.g., per kilogram of meat)	3	no
14	Loss of animal lives (AL) or years of life lost per animal due to early death or slaughter	2.97	no

*Table 7. Identified indicators for the **Economic** dimension. The table includes the relevance average score from the survey and if the indicator was selected as one of the top ten in the GA stakeholders workshop (see section 3 for details)*

#	Economic Category: Please select a level of "relevance" for each indicator,...	Average Score Survey	GA Selected (10)
1	Gross margin per functional unit (€/kg of meat or €/liter of milk)	4.26	yes
2	Percentage of average household income spent on food	4.11	yes
3	Number of full-time equivalent (FTE) jobs in the food industry	4.04	yes
4	Total volume of livestock products produced (tonnes)	3.96	yes
5	Total value of livestock products imported (million dollars)	3.89	yes
6	Total domestic demand for livestock products (million dollars)	3.85	yes
7	Total value of livestock products produced domestically (million dollars)	3.78	yes
8	Total value added by the industry (revenue minus cost of inputs)	3.67	no
9	Total food production or availability per capita (kg)	3.59	yes
10	Total value of all food-related imports (million dollars)	3.52	no
11	Value added per worker	3.52	no
12	Total capital investment required for meat and dairy processing facilities	3.41	yes
13	Gross operating surplus as a percentage of total revenue	3.26	no
14	Total value of production across different sectors within the livestock industry (million dollars)	3.22	yes
15	Total number of active livestock processing firms	3.19	no
16	Value added by capital	3.11	no

17	Estimated value of assets at risk of becoming non-performing due to industry changes or regulations	2.93	no

*Table 8. Identified indicators for the **Social** dimension. The table includes the relevance average score from the survey and if the indicator was selected as one of the top ten in the GA stakeholders workshop (see section 3 for details)*

#	Indicator	Average Score Survey	GA Selected (10)
1	Animal welfare compliance score based on adherence to recognized standards for the ethical treatment of animals	4.43	yes
2	Fair wage compliance rate indicating the percentage of workers paid according to industry standards	4.21	yes
3	Equality and non-discrimination index based on company policies and reported cases of discrimination	4.14	no
4	Consumer health and safety compliance score based on the implementation of safety standards and practices	4.11	no
5	Health impact score based on the estimated number of disease cases per unit of particulate matter emitted per food basket	4.07	no
6	Community health and safety impact score based on the influence of company operations on local living conditions and public health	4.04	yes
7	Cultural heritage respect score based on company policies and practices regarding the protection and promotion of local cultural heritage	4.04	yes
8	Employment contract coverage rate indicating the percentage of workers with formal contracts	4	no
9	Compliance rate with International Labour Organization (ILO) standards for working hours and overtime compensation	4	no
10	Transparency score based on the availability and clarity of information provided by companies regarding their practices	3.96	yes
11	Number of work injuries in your company during	3.89	no
12	Social responsibility score based on the extent and effectiveness of company initiatives to promote responsible practices among suppliers and within their operations	3.89	no
13	Sustainability commitment score based on public declarations, targets, and actions taken by companies to mitigate their environmental and social impacts	3.86	yes

14	Corruption prevention score based on the existence and enforcement of anti-corruption policies and transparency practices	3.86	no
15	Forced labor risk score based on the presence of policies and monitoring practices to prevent forced labor	3.82	no
16	Pesticide use per hectare of cropland (to measure protection of public health and/or exposure risk to residues due to local produced foods)	3.79	yes
17	Poverty reduction impact score based on the effectiveness of company initiatives aimed at reducing poverty	3.75	no
18	Equal opportunities (A reporting organisation's impact of its management practices and working conditions on equal opportunities and discrimination in job or promotion opportunities for workers)	3.75	yes
19	Freedom of association score based on company policies and practices regarding unionization and collective bargaining	3.71	no
20	Migration and resettlement impact score based on the extent of company influence on local population movements and the adequacy of resettlement practices	3.71	no
21	Smallholder engagement score based on the support and inclusion of smallholders in the value chain	3.68	no
22	Social benefits coverage rate indicating the percentage of workers receiving social security and benefits	3.68	yes
23	Percentage of total food production that is derived from animal sources within a specific territory	3.68	no
24	Supplier relationship management score based on the ethical considerations and impact assessments of procurement practices	3.64	no
25	Fair competition score (A reporting organisation's anti-competitive behaviour, anti-trust, and monopoly practices).	3.64	no
26	Innovation participation score based on company involvement in collaborative research and development of sustainable technologies	3.61	no
27	Community engagement score based on the extent of community inclusion in resource access and decision-making processes	3.61	no
28	Indigenous rights respect score based on company policies and actions related to indigenous communities	3.36	no
29	Economic contribution index based on the impact of company operations on local economic growth	3.36	yes
30	Of your total workforce during	3.32	no
31	Economic contribution index based on the impact of company operations on national GDP	3.11	no

8.2. Leverage Points Workshop Results

ENVIRONMENTAL

Sub-Dimension	Realm	Virtual Post-It	Policy - Practice
Reducing GHGs	Re-think	*LCA should also include transport of raw materials, loss of products in the production system (not only mortlaity, but also dead in transport, rejects in processing plants, etc) + use of antibiotics + export of unwanted products*	Practice
Reducing GHGs	Re-think	*Support pasture-fed livestock systems*	Policy
Reducing GHGs	Re-think	*Shift the focus to recognise animal disease as the cause of food loss, A shift into seeing better animal health as a strong ally to reducing natural resources use and emissions*	Practice
Reducing GHGs	Re-think	*Assess current GHGs on a similar basis and understand how much they can be reduced per system (is net zero possible, maybe not?*	Policy
Reducing GHGs	Re-think	*Biogas and other energy production from manure and other farm residues*	Practice
Reducing GHGs	Re-think	*increase soil humus levels*	Practice
Reducing GHGs	Re-think	*Use multiple functional units to fully understand the impacts, eg per ha, per kg product, per 100g protein etc - to get a fully picture of impacts at local and "food system" level*	Practice
Reducing GHGs	Re-think	*On farm trials monitoring gas emissions (gas sensors and T and H monitoring) and collecting data*	Practice
Reducing land use intensity	Re-think	*Find a good balance for 'land-sparing' and 'land sharing'*	Practice
Reducing land use intensity	Re-think	*(Many thinks we need to be more extensive, but at the same time we should also save space for nature and more efficient - acknowledge there is a need for both*	Practice
Improving water use efficiency	Re-think	*Change feed sources*	Practice
Improving water use efficiency	Re-think	*To my understanding, this is mostly related to irrigation of fields, This can be done smarter by variable rate application with novel and marketed irrigation systems*	Practice
Improving water use efficiency	Re-think	*Using technology, to supply what is needed, Also need to focuss on quality and treatment of water regarding Livestock (it is key aspect)*	Practice
Improving NPK Balance	Re-think	*100kg of animal N / 1 ha farmland*	Practice

Improving NPK Balance	Re-think	*advise farmers about the true cost of agrochemical inputs for their profitability, Most UK farmers have been found to be better off financially if they reduce inputs and keep production to levels that are in line with the carrying capacity of the land - Maximum Sustainable Output - ref Nethergill Associates*	Policy
Improving NPK Balance	Re-think	*Limit external inputs per hectare, eg, in feed/fertiliser/animals*	Practice
Improving NPK Balance	Re-think	*Tools that also takes into account more levers on water pollution (eg how does a riparian buffer strips play in avoiding water pollution)*	Practice
Improving Biodiversity	Re-think	*Change to other breeds with higher welfare outcomes and based on other genetic lines (example broiler chickens)*	Practice
Improving Biodiversity	Re-think	*reducing wild animals population*	Practice
Improving Biodiversity	Re-think	*Animals as part of the cropping system*	Practice
Improving Biodiversity	Re-think	*Better explain to consumers how the food system works and why eg, biodiversity is important and how farms cna improve that*	Policy
Improving Biodiversity	Re-think	*Introduce biodiversity assessment for farmers to understand how to improve at farm level*	Practice
Improving Biodiversity	Re-think	*Involve farmers in monitoring on farm biodiversity*	Practice
Improving Biodiversity	Re-think	*Walking paths/trials, shelters etc for people to 'get closer to nature'*	Practice
Reducing GHGs	Re-connect	*Check for indicators which may help to improve efficiency and profitability of the systems trough better AW and Health (try to focuss in young animals)*	Practice
Reducing GHGs	Re-connect	*Introduce CF assessments on farm level*	Practice
Reducing GHGs	Re-connect	*Use of local raw materials for animal feed (reduction of transport)*	Practice
Reducing GHGs	Re-connect	*Reduce raw materials for animal feeds with no Land Use Change component (eg, soya witout LUC)*	Practice
Reducing GHGs	Re-connect	*Produce for local/regional needs:*	Practice
Reducing land use intensity	Re-connect	*Re-connection of crops and livestock - increased circularity, but reduced intensity also essential*	Practice
Reducing land use intensity	Re-connect	*Integration of nature into agriculture - less land sparing and more land sharing approach*	Practice
Reducing land use intensity	Re-connect	*Intercropping*	Practice
Reducing land use intensity	Re-connect	*Multiple crops*	Practice

Reducing land use intensity	Re-connect	*Targeting 100% animal feed self-sufficiency*	Practice
Reducing land use intensity	Re-connect	*dispersed livestock production*	Policy
Reducing land use intensity	Re-connect	*Intercropping, winter cereal grazing, cover crops to provide feed sources alongside "human" crops - multi-use/temporal use of land to "maximise" sustainable output*	Practice
Reducing land use intensity	Re-connect	*More opportunity for interaction*	Practice
Improving water use efficiency	Re-connect	*Can be easily done with existing technology*	Practice
Improving water use efficiency	Re-connect	*Increase soil humus levels*	Practice
Improving NPK Balance	Re-connect	*Re-connection of crops and livestock - increased circularity, but reduced intensity also essential*	Practice
Improving NPK Balance	Re-connect	*Intercropping and smart agriculture*	Practice
Improving NPK Balance	Re-connect	*More farm visits for customers / citizens*	Practice
Improving NPK Balance	Re-connect	*Virtual farm visits*	Practice
Improving NPK Balance	Re-connect	*phisical farm Visits*	Practice
Improving NPK Balance	Re-connect	*Balanced dialogue and exposition of what is being done right (and case examples) vs what is being done wrong (and case examples) and MOST IMPORTANTLY how can we shit for what is being done right being the most common*	Policy
Improving Biodiversity	Re-connect	*Animals as part of the cropping system*	Practice
Improving Biodiversity	Re-connect	*Reduce wildlife population pressure where appropriate*	Practice
Improving Biodiversity	Re-connect	*More interaction opportunities for consumers*	Policy
Reducing GHGs	Re-structure	*use carrot and stick support payments/taxes to stimulate structural change - but requires an acceptable GHG assessment system*	Policy
Reducing GHGs	Re-structure	*Introduce novel manure treatment to reduce both methane and ammonia, from stables and from field application*	Practice
Reducing GHGs	Re-structure	*Expand vaccine banks (not only number of diseases but also number of vaccines)*	Policy
Reducing GHGs	Re-structure	*Develop live GHG reporting feedback mechanism, with support structure to farmers, eg, supply chain support*	Practice

Reducing GHGs	Re-structure	*Encourage Farmers with an associated payment*	Policy
Reducing GHGs	Re-structure	*Knowledge exchange and interaction with farmers and industry to show the benefits of different strategies to reduce GHGs*	Policy
Reducing GHGs	Re-structure	*Incentivice farmers to mitigate climate change, eg pay extra for levers to reduce GHG emissions*	Policy
Reducing GHGs	Re-structure	*Science supporting decision making - measure economic impact (investment vs outcome, for example) of measures that can be used to reduce emissions, Associate this work with special conditions for bank loans*	Policy
Reducing GHGs	Re-structure	*Produce for local/regional needs:*	Practice
Reducing land use intensity	Re-structure	*Similar to NPK balancing, limit to stocking density (or rather N & P intensity per ha)*	Practice
Reducing land use intensity	Re-structure	*Encourage mixed farming at a distance*	Practice
Reducing land use intensity	Re-structure	*Need of rule based retail sector and their integration and thus understanding of need of them to take action on this topic*	Policy
Reducing land use intensity	Re-structure	*Reform education system to give greater emphasis to farming (and livestock) systems*	Policy
Improving water use efficiency	Re-structure	*Suitable crops per region, avoiding water demanding crops in dry regions etc - probably requires policy/legal framework and needs local context*	Practice
Improving water use efficiency	Re-structure	*better access to information and benefits of better water utilization and management*	Policy
Improving water use efficiency	Re-structure	*Needs to better integrate, livestock, agriculture and governance (in some regions is being an issue right now)*	Policy
Improving NPK Balance	Re-structure	*Balance livestock and crop production*	Practice
Improving NPK Balance	Re-structure	*Require all farms to complete NPK balances to ensure limits are not exceeded (could be reeducing maximum limit over time)*	Policy
Improving Biodiversity	Re-structure	*Adopting a formal EU One Health Strategy with short, medium and long term goals*	Policy
Improving Biodiversity	Re-structure	*Change to breeds with higher welfare outcomes (example broiler chickens)*	Practice
Improving Biodiversity	Re-structure	*balance livestock and crop production*	Practice

ANIMAL WELFARE

Sub-Dimension	Realm	Virtual Post-It	Policy - Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-think	*We have so many 'legacy' farming systems and practices that we would never used if we started now, So, let's ask people and science 'How would we farm if we started now, with the knowledge we have'*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-think	*Make sure there is a holistic approach to animal welfare, Animal welfare integrates physical health but it also has other dimensions such as positive mental state*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-think	*Take animal welfare as starting point to develop new farming systems and not adapt the animals to the system*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-think	*Support and develop on-farm slaugther through adjusted policies and financial incentives*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-think	*Change to breeds with higher welfare outcomes (example broiler chickens)*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-think	*Try to select especific indicators and monitoring practices based on the type of system, Focussing on the weak areas found for the different domains in different regions*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-think	*Help farmers to improve animal welfare by showing other welfare friendly systems and reward them (not only by paying, but also respect)*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-think	*Develop easy to measure (on farm) welfare indicators for positive animal welfare*	Practice

Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-think	*share responsibility with all actors of animal production*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-think	*Dual-purpose breeds*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-think	*when thinking of sustainable solutions and technologies always assess the impact on animal welfare*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-think	*Integrate humanities and social sciences in agri-food systems research*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*Group information and digest so it fits policymakers framework and way of thinking*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*Do we reconnect only with nature in this category- or also with farmed animals? The packet QR code could be a great way to do both!*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*Create a dedicated hub for the future of the livestock sector to be discussed at a higher level, Information from the project can be fed into that hub*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*Change to breeds with higher welfare outcomes (example broiler chickens)*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*Including knowledge on (positive) welfare in more education programs: agricultural, veterinary, food sciences*	Policy

Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*Use more AI to enable human 'conenction' with animals*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*AI based understanding of animals/animal behavior in different environments*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*Sharing knowledge with farmers about the benefits of better AW (efficiency, Heath, etc), It is a must for the industry claim by consumers*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*Provide a full picture on what it would look like for Europe: Where would these systems be, where would we have to reduce, how many aniamls and type of species*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*Introduce "window show" on farms for citizens to visit*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*focus on 'natural behaviour' as a quality aspect of animal products*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*Cow-calf dairy systems*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*More animals outside so people can see them!*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*Include learning about One health in education programs for kids*	Policy

Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*harmonise farm carbon audit methodologies and promote their*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-connect	*Rules about minimum requirements on experience or background of people taking decisions about farming - its not helpful to have people that doesnt understand the complexities taking such big and important decisions*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-structure	*agroforestry - integrating trees and pasture so that methane emissions and removals are reduced, Browsing introduces tannins in tot eh diet as methane mitigants whilst tree bark contains methanotrophes that oxidize atmospheric methane*	Practice
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-structure	*We need new EU laws- to end the cage age- and more!*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-structure	*Focus on animal based indicators in legal requirements and monitoring*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-structure	*New/adapt animal welfare legislation in EU, Rules for import of NON-EU animal products*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-structure	*work on trade barriers that are not allowing farmers to fully protect animal welfare and ultimately animal lives (vaccination restrictions for example)*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-structure	*Revision of the minimum animal welfare standards that include important systemic change points to get EU production closer to the systems needed for a sustainable pathway (eg no cages)*	Policy
Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-structure	*Change to breeds with higher welfare outcomes (example broiler chickens)*	Practice

Improving Animal Welfare (Housing, Emotional, Behaviour, etc.)	Re-structure	*Start collecting real world data, for example by establishing an Animal Health and Welfare Dataspace, This would help to take not only scientifically sound decisions but also to create data-driven policies (and monitor it)*	Policy

ECONOMIC DIMENSION

Sub-Dimension	Realm	Virtual Post-It	Policy - Practice
Improving profitability & industry resilience	Re-think	*Work more on launching farmers as environmental heroes*	Policy
Improving profitability & industry resilience	Re-think	*Provide legislative/harmonisation/education support where needed*	Policy
Moderating livestock production volume	Re-think	*Improve public education about livestock production & its impacts*	Policy
Improving profitability & industry resilience	Re-connect	*Using certification schemes to help consumers make sustainable food choices*	Practice
Improving profitability & industry resilience	Re-connect	*Using market forces to engage changes in production methods—the farmers will produce what has added value*	Policy
Improving profitability & industry resilience	Re-connect	*Support RES market and energy policy at rural areas to decrease input costs of livestock houses maintenance*	Policy
Moderating livestock production volume	Re-connect	*Creating immersion programs (farm visits, production facilities) where other actors who are not directly linked to these sectors can learn about the bigger picture*	Policy
Improving profitability & industry resilience	Re-structure	*Include farming and food systems in national education*	Policy
Improving profitability &	Re-structure	*Change legislation so that it aides - not hampers - sustainable production methods*	Policy

industry resilience			
Moderating livestock production volume	Re-structure	*True Cost Accounting*	Policy
Moderating livestock production volume	Re-structure	*Adapt taxes: make them higher for animal proteins / lower them for plant proteins*	Policy

SOCIAL DIMENSION

Sub-Dimension	Realm	Virtual Post-It	Policy - Practice
Increasing economic contribution of the livestock sector	Re-think	*Cooperation between farmers, processors, and service providers*	Policy
Increasing economic contribution of the livestock sector	Re-think	*Provide legislative/harmonisation/education support where needed*	Policy
Equal opportunities in value chains	Re-think	*publicly sharing monetary indicators of price that should be given to producer, by kg of meat or L of milk for farmers, so they know how much they should be earning to be able to live correctly (ie : France)*	Policy
Improving sustainability reporting to meet standards	Re-think	*Develop standardised and objective sustainability metrics*	Policy
Improving sustainability reporting to meet standards	Re-think	*Find new ways of measuring biodiversity*	Practice
Improving sustainability reporting to	Re-think	*New livestock system narrative and quantification of benefits to make consumers aware of them*	Policy

meet standards			
Improving sustainability reporting to meet standards	Re-think	*Scale-up technologies (remote sensing)*	Practice
Improving sustainability reporting to meet standards	Re-think	*make better use of data collected from farms to give feedback (benchmarking) that nudges / stimulates to take descison that fosters sustainability*	Practice
Improving communities' health & safety	Re-think	*talking about food balance to kids, young couples , elderly people : need for animal protein : not too much but not too little*	Policy
Equal opportunities in value chains	Re-connect	*multipliing days of visit to farms for consumers, buyers of slaughterhouses and dairies and retail so each party better understands the other; and video content on tiktok, etc*	Practice
Equal opportunities in value chains	Re-connect	*Creating immersion programs (farm visits, production facilities) where other actors who are not directly linked to these sectors can learn about the bigger picture*	Policy
Improving communities' health & safety	Re-connect	*Help people to undesrtand themselves as part of ecosystem*	Policy
Improving communities' health & safety	Re-connect	*Support for healthy local food systems, eg, school canteens*	Policy
Equal opportunities in value chains	Re-structure	*Support shorter supply chains regional food networks, direct farmer-to-consumer sales, and community-supported agriculture (CSA)*	Policy
Equal opportunities in value chains	Re-structure	*The cost of food ingredients bought from farmers shoudl be "sanctuarized" in negociations between the industry and retail to be sure that farlmers have enough income to live and do sustainable agriculture (French inititive at EU level)*	Policy
Equal opportunities in value chains	Re-structure	*This is very challenging issue in terms of market consolidation, dominated by international corporations, so needs large changes at institutional level*	Policy
Equal opportunities in value chains	Re-structure	*Increase forms of integration/cooperation to overcome, for example, bureaucratic difficulties and the costs*	Policy
Equal opportunities in value chains	Re-structure	*Reforming public procurement procedures (tenders, standards) where environmental/social impact are given a greater consideration*	Policy

Improving sustainability reporting to meet standards	Re-structure	*goverment and society should agree on longterm sustainability objectices that are measured and reported to incentivise for achiving them (eg direct payments)*	Policy
Improving sustainability reporting to meet standards	Re-structure	*Any legislation with the aim of modersting livestock volume must be extremely well informed of the differences between different production methods*	Policy
Improving communities' health & safety	Re-structure	*goverment and society should agree on longterm sustainability objectices that are measured and reported to incentivise for achiving them (eg direct payments)*	Policy