POLICY BRIEF

EMPOWERING FARMERS FOR A JUST ZERO FOOD WASTE TRANSITION

ZeroW tackles Food Loss and Waste (FLW) through a coordinated set of innovations piloted in nine real-world Systemic Innovation Living Labs (SILLs) aiming to achieve significant reductions across all stages of the food supply chain - from pre-harvest to consumption. A dedicated Policy Team complements this work by defining a 'Just Transition Pathway' toward near-zero FLW, offering a practical framework to bridge systemic barriers (e.g., fragmented and lengthy nature of the food supply chains, the digital divide, challenges in scaling innovative waste reduction technologies) and on-the-ground FLW solutions. Drawing on economic modelling and insights from the stakeholders and the SILLs, the team identified key recommendations promoting a flexible, equity-focused transition.

Introduction

As Europe needs to move toward more resilient and resource-efficient food systems, reducing primary production losses has become a policy imperative. FLW reduction in primary production is deeply interconnected with broader structural, economic, and technological dynamics, making it necessary to pursue a systemic and just transition that prioritises farmers' needs, especially those of smallholders and marginalised groups.

This policy brief outlines evidence-based recommendations to help governments create enabling environments that support farmers in the EU's Just Transition, which will guide the action plans of Member States for the newly adopted binding targets.

Policy Problem

Despite growing policy attention, food loss at the primary production stage continues to persist across EU Member States. The MAGNET analysis General Equilibrium Model carried out during the project (which captures the effects of FLW reduction measures on the whole economic system) uncovered significant environmental spillovers.

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While reducing FLW lowers greenhouse gas emissions in waste management, it may counterintuitively result in increased emissions in primary agriculture and non-food sectors.

This unintended consequence arises from the intensified agricultural production needed to meet higher food demand and affordability, particularly for commodities with high FLW rates, alongside increased use of chemical fertilisers. Moreover, small-scale farmers face multiple barriers that prevent them from engaging in or benefiting from FLW-reducing innovations. These include limited access to infrastructure, finance, fair markets, and digital technologies. The persistent digital divide, weak enforcement of protections against unfair trading practices (EU Directive 2019/633), and lack of tailored support mechanisms reinforce structural inequalities in the food system. Without targeted policy interventions that address these interconnected challenges, FLW strategies risk exacerbating existing disparities and generating new environmental harms, rather than delivering the just and sustainable transformation that EU policies envision.

Evidence from Project

Economic modelling simulations from the ZeroW project showcased that, regardless of the measures applied, reducing FLW with innovations leads to great efficiency and higher output. While this contributes to food security, the rebound effect, manifested as increased agricultural production, can drive up land use and input intensity, with potentially ecological consequences. As production becomes more efficient and losses decrease, total output tends to rise, especially for loss intensive commodities that benefit most from these gains. It results in biodiversity loss and heightened GHG emissions from both the agricultural and non-food sectors, largely due to increased use of chemical fertilisers and growing demand for non-food goods. Additionally, the use of AI-based innovations could also generate environmental spillovers. This highlights the urgent need to pair FLW reduction strategies with investments in sustainable agricultural practices.

The literature review conducted during the project emphasises the importance of shortening supply chains through mechanisms like public food infrastructure, farmers' markets, and Community Supported Agriculture (CSA). These localised systems not only reduce waste by minimising logistical inefficiencies but also promote fair pricing, support agroecological transitions, and build producer resilience to market shocks and climate change.

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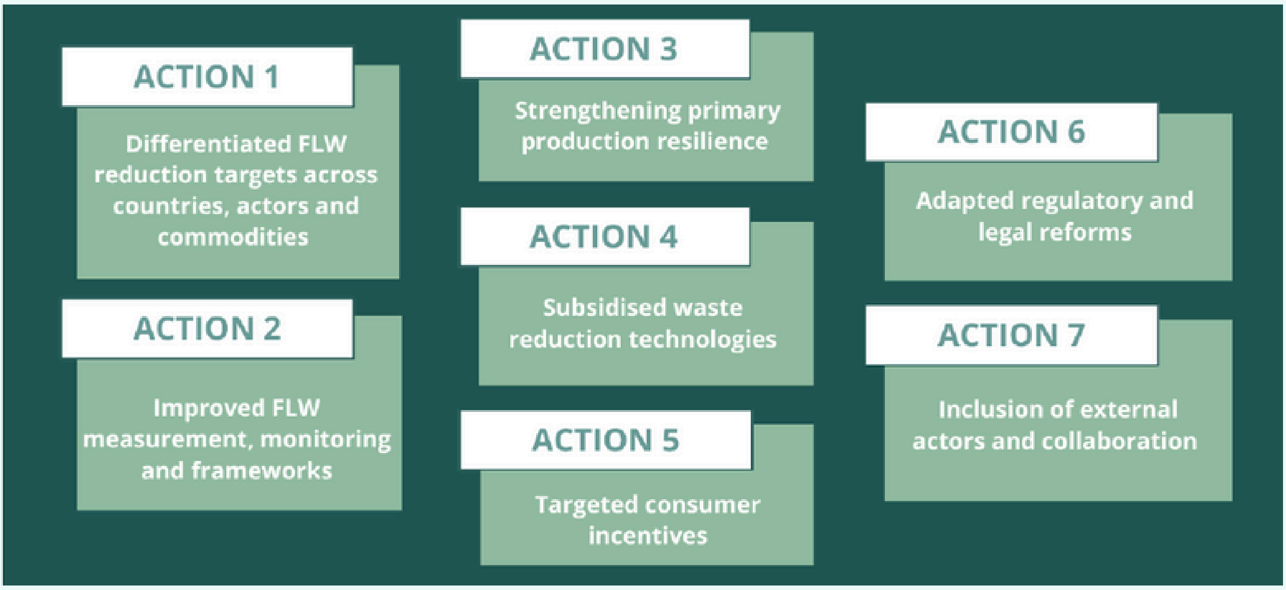
Digital tools play a vital role in optimising production, improve traceability, and enhancing market access. However, a persistent digital divide, rooted in poor connectivity, limited digital literacy, and high costs, prevents many smallholder and vulnerable farmers from reaping these benefits. This divide creates a 'trolley dilemma': while digital innovations can enhance food production and reduce losses, they risk exacerbating inequalities and undermining environmental goals if access is not equitably distributed. Bridging this gap requires coordinated investment in infrastructure, inclusive training programs, and cooperative data-sharing models.

Insights from the ZeroW SILLs and Just Pathway Action 3 underscore the critical role of horizontal peer learning and data sharing in scaling successful innovations across different agricultural contexts. Access to reliable, interoperable data is essential for effective implementation, monitoring, and impact measurement of FLW interventions. Shared platforms and trust-based data governance models, such as those granting farmers control over their own information, are essential to foster cooperation and innovation adoption at scale. SILL 5 - and production-focused innovations more broadly - highlighted two key challenges: first, securing acceptance of the solution from producers; and second, facilitating effective data sharing. In addition, it showed that technology alone will not be enough to improve the situation, requiring a system-wide approach.

Despite the EU directive 2019/633 against unfair trading practices, enforcement remains weak, continuing to disadvantage producers in the FSC. Achieving near-zero FLW will require not just legal frameworks but sustained investment, including subsidised waste reduction technologies and community-based solutions.



Overview of the Just Pathway Actions

SILLs results highlight the importance of government-supported grants and long-term financial mechanisms to facilitate innovation, especially among vulnerable and small-scale producers. Just Pathway Action 4 identifies collaborative investment models, such as shared machinery or joint digital platforms, as effective tools to lower barriers to innovation and resource efficiency. These approaches are particularly impactful when aligned with targeted vocational training and support for knowledge development. Hence, these findings guide the following policy recommendations.

Key Policy Recommendations

Farmers, positioned at the forefront of efforts to create more sustainable food systems, face a direct intersection between climate action and FLW reduction. These vectors are closely linked: both aim to lower GHG emissions and depend on access to timely, actionable data to guide sustainable farming practices. Moreover, reducing FLW contributes to climate resilience by supporting more efficient food systems and easing pressure on ecosystems and natural resources. The remainder of this brief therefore outlines key recommendations that simultaneously advance climate objectives and FLW reduction goals.

1. Enhance farmers' resilience to climate change through sustainable practices

1.1. Accelerate adoption of Climate-Smart Agriculture (CSA)

Climate-Smart Agriculture (CSA) offers a strategic framework for transforming food systems in response to climate change. Defined by the FAO, CSA aims to achieve three interlinked goals: enhancing agricultural productivity and incomes sustainably, building resilience to climate change, and lowering or eliminating GHG emissions where feasible.[1] Its broad scope encompasses both low-tech and high-tech solutions, adaptable to local conditions and capacities. CSA includes a wide array of traditional and ecologically grounded practices that require minimal technological input. These include:

- **Soil Health Improvements**: Practices such as composting, mulching, and crop rotation help maintain soil fertility and reduce dependence on synthetic inputs.
- **Efficient water use**: Techniques like drip irrigation and rainwater harvesting enhance water-use efficiency, especially in drought-prone regions.

- **Climate-resilient crops**: Selecting and cultivating crop varieties adapted to shifting local climate conditions helps safeguard yields.

These methods contribute to both mitigation and productivity. For example, reducing the use of chemical fertilisers and avoiding practices like soil compaction can cut methane emissions and support carbon sequestration through perennial cropping.[2]

Advanced digital and technological tools can amplify the impact of CSA, improving decision-making and reducing environmental footprints. One key example is precision farming, a data-driven management approach that uses sensors, GPS, and real-time analytics to respond to variability in crop and livestock systems.[3] This can lead to higher yields and resource efficiency as well as reduced environmental pressures, such as excessive fertiliser use or water waste, among other benefits.
Moreover, digital technologies can support climate adaptation through better risk management. Sensor networks, for instance, enable early detection of extreme weather events like droughts, informing both individual decisions and public interventions, such as drought early warning systems and improved water governance.[4]

Another systematic approach to rural resilience is the Smart Villages concept, promoted by the European Network for Rural Development (ENRD). It reflects a holistic approach to strengthening rural communities. By integrating digital tools with participatory governance, smart villages foster innovation, improve service delivery, and enhance local economies. This model not only supports CSA but also helps reverse rural decline by making villages more liveable, economically vibrant and self-sustaining.

Nonetheless, this process must be approached with great care, prioritising societal well-being, climate resilience, food security, and the sustainable use of natural resources. Importantly, farmers who choose not to adopt digital technologies should have their decisions respected and be supported through alternative means, recognising the diversity of contexts and needs in agriculture.

1.2. Mobilise policy support to enable CSA implementation

Promoting the adoption of CSA practices requires a comprehensive policy framework that addresses financial, technical, and informational barriers.

A just and effective transition hinges on ensuring that CSA options are accessible and feasible for all actors in the agrifood system, both large and small-scale farmers.[5]

Direct funding is essential, particularly where CSA practices may initially lack cost-efficiency. Instruments such as the eco-schemes under the Common Agricultural Policy (CAP 2023-27) offer vital financial incentives.[6] These schemes reward the adoption of practices that reduce environmental and climate impacts while promoting the transition to more sustainable farming models. Importantly, such incentives support the provision of public goods, such as biodiversity, clean water, and carbon sequestration, that are not adequately priced by market mechanisms. In addition, the CAP 2023–2027 includes provisions for rural development, including funding for the design and implementation of Smart Villages strategies. These aim to revitalise rural areas through innovation, improved connectivity, and inclusive community planning.

Access to technical support is critical to ensure that innovations are effectively utilised and their regulatory framework is understood. Farm advisory services can play a pivotal role by helping farmers navigate digital systems, adopt greening practices, diversify income sources, and comply with regulatory frameworks. Such services are essential to making CSA practices practical, especially for farmers who may be less familiar with new technologies.

At the same time, with assistance or farm advisory services, the modernisation of the CAP administration can have a greater welcome among farmers, by showing them how to navigate the different digitised applications or pre-filled online forms and making them see the benefits: simplification of administrative procedures, reduce bureaucratic complexity, enhance efficiency, and accelerate payment transfers to beneficiaries.[7 8]

Beyond financial and technical support, facilitating knowledge exchange is essential. Governments should invest in networks that promote peer-to-peer learning and horizontal knowledge sharing.

As highlighted in ZeroW Deliverable 8.2 (2025), not all farmers actively engage with centralised hubs or digital platforms.[9] Therefore, outreach efforts must be proactive and tailored, ensuring that valuable information reaches farmers directly and in accessible formats.

1.3. Role of digital tools and innovation in resilience

The integration of digital technologies into agriculture might have the potential to transform the sector's capacity to withstand and adapt to economic, environmental, and social challenges.[10] By facilitating more informed decision-making, improving operational efficiency, and supporting sustainable practices, digital innovation, if well executed, might play a pivotal role in building resilience across the agri-food system.
Digital platforms and precision agriculture tools enable farmers to access real-time data, monitor crop and soil conditions, and make evidence-based choices. This not only improves yields and resource efficiency but also contributes to long-term sustainability by minimising inputs and environmental impacts.

Automation and smart machinery can ease the physical and mental demands of agricultural labour by reducing repetitive and strenuous tasks and thus creating more attractive working environments in rural areas.

2. Support small-scale farmers' digital transition

2.1. Build digital infrastructure and deliver training

Investing in digital and physical infrastructure is essential for advancing digitalisation, along with encouraging the reuse of existing assets. Three main pillars underpin effective infrastructure facilitation:[11]

1. **Access to basic connectivity infrastructure**: This includes broadband and telecommunication services, which form the backbone of digital transformation.
2. **Range of data collection, storage, and analysis** through sensors, modelling, digital platforms, cloud solutions, and software systems.
3. **Supportive regulatory environment** also known as “soft infrastructure”. This refers to the institutional frameworks that establish interoperability standards, data quality norms, and regulations on data ownership and privacy.[12]

Governments play a crucial role across these pillars, acting as planners, enablers, investors, or regulators, depending on the maturity of existing infrastructure. For example, in regions where private investment is not viable, public investment in basic technologies like wireless sensor networks is necessary, creating opportunities for private sector collaboration. This underscores the importance of integrating all stakeholders and fostering public-private partnerships.

As regulators, governments must ensure that technologies used in commercial settings are properly validated and calibrated for policy or regulatory applications. Policymakers should also weigh the potential for increased regulatory burdens on farmers, especially since excessive compliance requirements can discourage technology adoption. Farmers are generally more receptive to technologies that offer operational benefits rather than those designed also to verify their regulatory compliance.[13]

Beyond infrastructure, targeted, hands-on, and in-person training is vital to address both the lack of awareness about digitalisation and the skills gap among farmers. Facilitating knowledge exchange through demonstration farms and familiar communication channels can significantly enhance technology uptake.[14] Such proactive training is particularly important for vulnerable groups, such as small-scale producers, who may not benefit sufficiently from online resources.

To boost participation in training, financial incentives or compensation should be provided, especially for workers displaced by automation in food production. Partnerships with industry leaders can help fund these initiatives.[15]

Training not only accelerates technology adoption but also promotes the generation of high-quality data by teaching best practices in data harmonisation, compatibility, and maintenance. This reduces the risk of poor management decisions based on inaccurate data or models in precision agriculture.[16]

2.2. Promote the use of digital tools' role in farm management efficiency and resource optimisation

Digital technologies significantly improve farm management by enabling precise monitoring and control of resources. These tools allow farmers to apply water, fertilisers, and pesticides with greater accuracy, minimising waste and environmental impact while boosting crop yields. Furthermore, by analysing both consumption (demand) and production (supply) data, digital solutions can help optimise crop planning, thereby reducing overproduction, surplus, and food loss.

Digitalisation also enhances producers' ability to market their products by increasing their visibility to potential buyers. Notably, as Michel-Villarreal and co-authors emphasise, low-cost digital tools - including freeware and social media platforms - can be especially effective in connecting producers with markets, often playing a more significant role than anticipated.[17]

Digital technologies can also contribute to the development of rural areas by providing better accessibility and connections in line with the Long-Term Vision for the EU's Rural Areas.[18]

2.3. Bridging the digital divide among rural farming communities

While digitalisation presents major opportunities for improving agricultural efficiency and reducing food loss and waste, it also risks deepening existing inequalities. Many rural areas still struggle with unreliable or unaffordable internet access, and farmers - often older and with limited digital skills - face barriers such as high costs, geographic isolation, and weak connectivity. To ensure equitable access, digital tools, including application programming interfaces (APIs), must be user-friendly and designed around the expressed needs and capabilities of typical end-users.

To address these challenges and promote equitable access to data, information, and infrastructure - especially in rural areas facing issues like depopulation, limited services, and fewer economic opportunities - the CAP 2023-27 provides a supportive framework and funding for the adoption of innovative and smart solutions.[19]

Regional initiatives are also emerging to help close the digital gap. For example, the CreceA program in Andalusia, Spain, offers personalised, free advisory services to the agricultural sector.[20] The initiative begins by assessing each farmer's situation and identifying their main challenges. Based on this assessment, a tailored action plan is developed, recommending specific digital solutions suited to each business' needs. Farmers and rural SMEs then receive individualised support throughout the digital transformation process, including assistance in securing public funding. In addition, a dedicated Technical and Support Office has been established to provide ongoing support to programme participants.

2.4. Address behavioural and gender barriers to digital adoption

While digitalisation in the primary production stage holds the promise of improving production efficiency, reducing FLW and enhancing rural livelihoods, its success hinges not only on technological readiness but also on behavioural, cultural, and social acceptance. Evidence from the SILLs highlights a recurring challenge: even when innovations are technically functional and capable of generating value, farmers often hesitate to adopt them due to usability concerns, uncertain benefits on the short and long term, lack of trust in data ownership arrangements, and fear of losing autonomy. These behavioural barriers are particularly acute for early adopters, who may bear higher burdens without immediate return on investment.

Beyond these general barriers, cultural, geographical, and gender-specific factors play a significant role in shaping digital uptake. The location of a farm, its size, crop type, and exposure to climate extremes, can either motivate adoption (e.g., to cope with unpredictable weather or labour shortages) or discourage it (e.g., in conflict-adjacent zones like the Ukrainian border, where long-term investments feel riskier). Likewise, labour scarcity, particularly where cultural or policy resistance to migration exists, may prompt farmers to adopt automation and smart tools. Conversely, high-risk environments or instability can create reluctance toward adopting expensive, complex technologies.

Cultural norms around trust and authority also affect adoption dynamics (Quantifarm project)[21]. In more collectivist societies like Greece, Portugal, or Spain, farmers tend to trust people they know personally. In contrast, in more individualistic cultures like the Netherlands or Sweden, credibility is tied more to professional expertise. This has implications for the design of advisory and outreach strategies: in some regions, advisors need to act as embedded community members, while in others, they can function more independently. Tailoring engagement approaches to these trust patterns is essential for effective digital deployment.

Gender norms also influence uptake. In Southern and Eastern Europe, more traditional gender roles persist, which can result in the exclusion of women from technical decision-making even if they are the ones using digital technologies daily. In contrast, egalitarian gender norms which seem to be more prominent in Northern and Western Europe can facilitate women's access to digital tools and training. Therefore, it is critical to identify and directly engage the person, regardless of gender, who will actually operate or interact with the digital technologies. Failure to do so risks poor adoption outcomes and reinforces gender inequalities.

Addressing these behavioural and socio-cultural barriers requires a holistic, inclusive, and context-specific strategy. This includes investment in affordable infrastructure, provision of locally adapted training, co-creation of tools with intended and actual users, and fostering peer-to-peer knowledge exchange, especially through trusted networks. Early adopters should be supported through visible, low-barrier benefits and local champions.

Even when all the constraints are overcome, there is still the possibility that farmers simply do not like the idea of digitalisation and prefer not to invest in it, and their decision should be respected. The digital transition must accommodate hybrid pathways and ensure that innovation does not come at the expense of farmer choice or cultural identity. This requires a flexible policy framework that promotes adoption without penalising non-participation, and that fosters a collaborative governance model to build trust, address liability concerns and clarify data ownership.

2.5. Ensure responsible data use, sharing, and innovation scalability

There are data sharing issues to address for the scalability of SILLs, including monitoring and measurement and horizontal peer learning. Ensuring the production of reliable, high-quality data - and guaranteeing its compatibility across digital tools and machinery - is essential for the scalability of agricultural technologies. Interoperability between different systems facilitates effective data sharing among private stakeholders and public authorities, which is crucial for monitoring, measurement, and horizontal peer learning. To address these needs, the European Commission has committed to developing a common European agricultural data space as part of its broader European data strategy.[22]

Data security and privacy are also significant concerns, as some information may be considered personal or sensitive by farmers. Building trust is vital and can be supported by data governance models that give farmers control over their own data. For example, the Akkerweb Platform allows farmers exclusive access to their data, with the option to grant access to others as they choose.[23] This “controlled access” approach helps foster a sense of security and encourages data sharing.[24]

Conclusion

Reducing FLW at the primary production stage is both a strategic imperative and an opportunity for the EU to enact the Just Transition Pathway. Innovations from the ZeroW project clearly demonstrate that while FLW reduction can boost production efficiency and contribute to food availability, it must be pursued in tandem with robust safeguards against rebound effects, such as intensified input use and land expansion, that risk undermining environmental gains.

Effective FLW strategies must prioritise system-wide approaches that integrate climate-smart agriculture, equitable digital transformation, and strengthened support for small-scale and vulnerable farmers. These strategies will only succeed if they are embedded in inclusive policy frameworks that address access to infrastructure, fair markets, and knowledge. Investing in rural digital infrastructure, cooperative data-sharing platforms, and horizontal learning networks will be critical to ensuring scalable, just, and sustainable innovation.

Critically, these transitions must be participatory and farmer-centered. Respecting the diverse realities and preferences of farmers, particularly those who opt out of digitalisation, is essential to avoid deepening social divides. The tools and technologies promoted must be fit-for-purpose, easy to use, and responsive to the expressed needs of those they are intended to serve.

These policy recommendations are necessary to reach a truly just transition in food systems, one that delivers environmental resilience, economic viability, and fairness for all farmers.

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