FABRE • TP
Farm Animal Breeding
& Reproduction
Technology Platform

FABRE TP

Towards Sustainable and Competitive EU Aquaculture: Priorities in Aquaculture Breeding and Genetics

Input for Horizon Europe
from the public and private R&I sectors
of Animal Breeding and Reproduction sectors

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FABRE • TP
Farm Animal Breeding & Reproduction Technology Platform

The Farm Animal Breeding and Reproduction Technology Platform (FABRE TP) promotes research and innovation for sustainable European animal breeding and reproduction. FABRE TP is the main contact point for European farm animal breeding and reproduction organisations, aiming to mobilise research, technological development, and innovation efforts. We bring together key stakeholders around a common vision for developing technologies and responsible practices around farm animal breeding and reproduction. Founded in 2006, , FABRE TP has been an official European Technology Platform since 2009.

- Promotes sustainable farm animal breeding and reproduction in the EU.
- Develops research and innovation agendas and sets priorities.
- Connects the private sector, knowledge institutes and policy.
- Supports knowledge transfer and implementation of R&I.

Acknowledgement

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Executive Summary

The strategic integration of science and innovation in aquaculture breeding and genetics is central to the European Union's (EU) vision for a resilient, competitive, and sustainable seafood sector. This document highlights the critical role of the Blue Bioeconomy and underscores the need for continued innovation and research and development (R&D) to meet the EU's ambitious goals. Collaboration with the private sector is also essential in achieving these objectives.

The EU's aquaculture sector is diverse, spanning numerous species and farming systems, which necessitates a tailored approach to breeding and genetics. This approach must address the unique biological requirements of different species, incorporate technological advancements, and ensure that breeding practices align with the United Nations' Sustainable Development Goals (UN SDGs). Responsible breeding, which focuses on environmental sustainability, animal welfare, and resource efficiency, is a key element of this strategy.

Research and innovation are crucial to overcoming the challenges facing the EU aquaculture and food sectors. Horizon Europe provides a framework to guide the sector's future, focusing on species prioritization, genomics, and sustainability. The four key pillars—resilience and competitiveness, the Green Transition, social acceptance, and knowledge and innovation—offer a comprehensive roadmap for advancing a scientifically informed, socially responsible, and environmentally conscious aquaculture sector.

Key areas for development include strengthening breeding programs to enhance resilience and competitiveness, engaging in sustainable practices that support the Green Transition, fostering social acceptance through transparency, and promoting the adoption of innovative breeding techniques and biotechnologies. This holistic, multi-disciplinary approach balances the needs of both established and emerging species, while addressing sustainability concerns and integrating aquaculture products into European markets. Given the long generational timelines in breeding programmes, investment and coordinated action are urgently needed today to ensure results tomorrow. Delayed progress risks widening the competitive gap between the EU and other leading aquaculture-producing regions, threatening both food security and economic opportunity

Looking forward, the EU's commitment to a sustainable and competitive aquaculture sector is clear. By aligning with Horizon Europe's strategic guidelines, the EU is setting an ambitious and achievable course for the future. Through ongoing research, innovation, and cross-sector collaboration, the EU can ensure its aquaculture industry thrives, contributing to global food security, economic resilience, and environmental stewardship for generations to come.

1 Introduction

Aquaculture plays a crucial role in achieving the European Union's (EU) goals for sustainable food systems, addressing food security, and enhancing economic resilience. While aquaculture contributes 15.8% to the global protein supply (Boyd et al., 2018), the EU's share is currently below 1%, highlighting a significant growth opportunity for the sector. This white paper outlines the breeding and genetics priorities essential to positioning the EU's aquaculture industry as a resilient, competitive, and environmentally responsible force in global food production.

The EU's aquaculture sector is diverse, encompassing over 40 species and a range of production systems, from finfish farming to low-trophic species like mussels and algae, including sub-tropical and tropical species reared in tropical Outermost Regions [1] (ORs) and Overseas Countries and Territories (OCT)[2]. This diversity requires tailored genetic strategies that address the unique challenges of each species while aligning with broader EU goals for sustainability and resilience. By focusing on genetic advancements that improve disease resistance, feed efficiency, and environmental adaptability, the EU can enhance the productivity and sustainability of its aquaculture systems.

This document also highlights the importance of continued research, innovation, and private-sector collaboration in achieving the EU's ambitious goals. By aligning with key EU policies, such as **Horizon Europe**, the **European Green Deal**, and the **Farm-to-Fork Strategy**, this white paper outlines critical priorities that will advance the EU's aquaculture sector towards sustainable growth. The paper presents a roadmap for integrating innovative breeding and genetics technologies to support the EU's sustainable food system and strengthen its global aquaculture competitiveness and reinforce the European Aquaculture genetic sector.

[1] Outermost Regions defined by the European Parliament

[2] Overseas Countries and Territories defined by the European Parliament

2 Priorities in aquaculture breeding and genetics for a resilient and sustainable EU aquaculture

Research and innovation in animal breeding and reproduction play a crucial role in improving a wide range of desirable qualities in aquaculture species, from growth and health to feed efficiency and environmental sustainability. By using advanced techniques responsibly, these innovations contribute not only to the efficiency of aquaculture but also to human nutrition, health and the preservation of genetic resources. They help reduce the environmental impact of production systems, promote sustainability, and align with the United Nations' Sustainable Development Goals (UN SDGs), particularly those focused on environmental stewardship and animal welfare.

Balanced and responsible breeding practices are fundamental to sustainable aquaculture, driving a 5-10% genetic gain per generation in key traits such as growth, survivability, feed efficiency, health, and product quality. This genetic progress enhances the competitiveness of the sector while ensuring that aquaculture systems remain resilient and sustainable.

These breeding and genetic priorities align with key EU strategies, including:

- Strategic guidelines for a sustainable and competitive EU aquaculture[3]: Highlighting aquaculture's role in sustainable food production and environmental impact reduction.
- Open Strategic Autonomy[4]: Supporting resilient, self-reliant food production through investments in research and sustainable practices.

To achieve these ambitious goals, EU initiatives such as **Horizon Europe** clusters[5] and the **EIC Pathfinder**[6] program should be leveraged to fund research in breeding and genetics. For example, **Horizon Europe's** clusters focus on green technologies and innovations that can support advancements in aquaculture, including in breeding programs aimed at improving sustainability and productivity. Additionally, past EU-funded projects like **Aqua-Impact**, **Aqua-FAANG** and **AquaExcel** have already demonstrated how collaborative research can advance breeding and genetics in aquaculture, producing impactful outcomes that align with EU sustainability and food security goals.

[3] European Green Deal: Commission adopts strategic guidelines for sustainable and competitive EU aquaculture

[4] A resilient, competitive, fair and sustainable EU: Industrial Innovation for Open Strategic Autonomy

[5] Horizon Europe clusters

[6] EIC PathFinders

3 How research can help to answer the challenges of the European Aquaculture and Food sector

The European aquaculture sector is at a critical juncture, facing interconnected challenges related to sustainability, competitiveness, and environmental impact. These challenges require focused research to ensure a robust, innovative, and sustainable aquaculture sector.

Key Challenges:

- **Economic Competitiveness:** Growing competition from third countries (E.g. USA, Chili, China, Turkey and New Zealand) which will enter the European Market increasing sanitary risks and genetic dependance.
- **Environmental Resilience:** Climate change threatens aquaculture productivity by altering water temperature, oxygen levels and contributing to an increased prevalence of diseases.
- **Sustainability and Resource Use:** Current production systems, as all farming production systems, face challenges to minimize environmental footprints, particularly in areas like marine feed resource management and waste reduction.
- **Social Acceptance and Consumer Trust:** Limited public understanding of breeding practices in aquaculture can hinder market acceptance or limit the public or consumer interest for new traits
- **Knowledge and Innovation Gaps:** Limited technological and genetic advancements for some species and a lack of proof of concept, particularly low-trophic species and algae or, pose barriers to progress.

In response, the European Commission identifies four pillars as essential research priorities in Aquaculture. The adaptation of these four pillars, as outlined in the strategic guidelines for a more sustainable and competitive EU aquaculture (2021 – 2030), provides a clear roadmap for advancing a more sustainable and competitive aquaculture breeding and genetics sector within the EU

- **Pillar 1 (P1): Building resilience and competitiveness**
- **Pillar 2 (P2): Engaging in the Green Transition**
- **Pillar 3 (P3): Promoting social acceptance and consumer awareness**
- **Pillar 4 (P4): Promoting knowledge and innovation**

These adaptations address key challenges and opportunities in the sector, providing a framework for future growth and development. This underscores the critical role of research and innovation in improving the resilience, competitiveness, and sustainability in aquaculture productions.

3.1 P1: Building Resilience and Competitiveness

Aquaculture systems must adapt to environmental variability, such as rising or variable temperatures and disease outbreaks, while maintaining economic viability. Moreover, the lack

of selective breeding programs for certain species (freshwater fish, molluscs, algae) hinders the development of rational breeding strategies needed to address these new challenges.

Investing in resilience-building research ensures aquaculture can withstand environmental and economic shocks, improving sector-wide stability. Developing more resilient species and production systems can reduce reliance on external inputs and support long-term sustainability.

Key Research Areas:

- **Genetic adaptation to new environments:** Increase knowledge of genotype by environment interactions under extreme environmental conditions or within new rearing systems (e.g., IMTA, RAS). This understanding will enable the development of selective breeding strategies that are both well-adapted and aligned with societal demands for animal welfare.
- **Genetic Diversity:** Preserve and improve the genetic pool of farmed species to ensure adaptability to future challenges.
- **Emerging Species**: Expand research into the domestication and selective breeding of underutilized species, including algae, low-trophic organisms and sub-tropical and tropical species reared in OCT and ORs.
  While this document recognizes the growing importance of algae-culture, and the urgent need for genetic improvement programmes in algae, it focuses primarily on breeding priorities for animal aquaculture species. Nevertheless, algae remains a critical area where more targeted R&I efforts are needed, especially in collaboration with initiatives specifically addressing low-trophic and primary producer species
- **Animal welfare:** Investigate the potential of genetic improvement to improve recent and future domestication efforts, focusing on survival, welfare, and maintaining the physiological integrity of the animals.
- **Disease Resilience:** Investigate multi-trait genetic resistance to combat evolving pathogens, especially in open rearing systems.
- **Ecological efficiency**: Improvement feed efficiency and survival by genetic selection to limit economical loss, better use natural resources and improve ecological efficiency
- **Wild Population Protection:** Create genomic tools to monitor and prevent genetic introgression from farmed to wild populations.
- **Genetic and reproductive technologies for sustainability:** investigate and develop the use of reproductive technologies (e.g., sperm and larvae cryopreservation, mono-sexing, polyploidy), next generation of genomic technologies and NGTs to improve key traits such as disease resistance, stress tolerance, feed efficiency, and climate resilience. By integrating these advanced techniques with quantitative genetic, we can improve resource efficiency and support more sustainable aquaculture practices
- **Phenotyping:** investigate application of alternative spectroscopic technologies and Artificial Intelligent (A.I.) to decrease cost of phenotyping for actual and future phenotypes but also to develop new genetic data treatment for complex traits.

3.2 P2: Engaging in the Green Transition

Modern aquaculture must shift away from resource-intensive practices toward sustainable methods. This means reducing greenhouse gas emissions, using feed more efficiently, decreasing reliance on wild-caught fish for feed, and adapting farms to climate change impacts. Current farming methods use too many resources to be environmentally sustainable long-term.

If aquaculture has very limited contribution to greenhouse gas emission, its major challenges are in the decrease of aquaculture carbon footprint (mostly driven by artificial feeds production and their use) and in the reduction of mortalities—especially at the hatchery stage—not only improves animal welfare but also significantly enhances production efficiency and resource use. Recent advances demonstrated the positive and rapid genetic adaptation of famed fish strains to the progressive reduction of fish meal and fish oil and their replacement in feeds by vegetal ingredients. A continuous understanding of interactions between innovations in feed and potential of genetic co-selection to better use these new or ingredients are needed, as also to alternative ingredients to limit deforestation and importation and to support local and circular economy. Adaptation to climate change is another area in which genetic selection may contribute producing more robust and resilient genotypes to rapid and extreme variations in temperature but also more resistant organisms to existing or new or unknown pathogens.

Sustainability is essential for maintaining aquaculture's license to operate and meeting EU climate goals. Addressing resource use and environmental impact will align the sector with the European Green Deal.

Key Research Areas:

- **Climate-Resilient Strains:** Introduce new traits in selective breeding program to improved tolerance to temperature fluctuations and variable water quality and animal welfare.
- **Feed Efficiency:** Optimize growth and feed conversion for finfish and shellfish using selective breeding, innovative feeds and local and eco-formulated feeds
- **Circular Systems:** Explore specific genetic needs to improve recirculating aquaculture systems (RAS) and integrated multi-trophic aquaculture (IMTA) resilience and efficiency.
- **Genomics for Sustainability:** Scale the application of reproductive technologies, genomics and gene editing responsibly to improve traits like disease resistance, stress tolerance and resource efficiency.
- **Sterility Techniques:** Advance genetic and reproductive technologies to produce sterile populations, reducing environmental risks from escapees and developing innovative selective breeding strategies adapted for these new genotypes and polyploids genotypes.

3.3 P3: Promoting Social Acceptance and Consumer Awareness

Public skepticism about genetic technologies and breeding practices can limit aquaculture's growth. Misconceptions about product safety and environmental impact pose barriers to market acceptance. It can also prevent investment in the genetic improvement of low trophic species.

Transparent communication and stakeholder engagement are vital for building trust in aquaculture products and practices. Social acceptance will drive market expansion and foster a more inclusive dialogue around innovations. Understanding key social, economic and environmental factors of acceptance of breeding technology is a challenge to politically drive new applications to new species.

Key Research Areas:

- **Social acceptance:** Identify social, environmental and economic factors influencing public acceptance of selective breeding and reproductive technologies, particularly for low trophic species and improvement animal welfare.
- **Transparency in Breeding Practices:** Provide clear information on breeding methods and their impact on sustainability and animal welfare.
- **Consumer Insights:** Understand consumer preferences to align aquaculture products with societal expectations.
- **Educational Campaigns:** Promote awareness of the benefits of genetic advancements in aquaculture, emphasizing safety and sustainability.
- **Policy and Regulation Support**: Develop evidence-based frameworks that balance innovation with ethical and ecological considerations.

3.4 P4: Advancing Knowledge and Innovation

Aquaculture lacks sufficient research infrastructure and collaborations to harness the full potential of advanced technologies, such as genomics, biotechnology, and digital tools.

Knowledge sharing and cutting-edge innovation are critical for sustaining aquaculture's competitiveness. Research can close technological gaps, support emerging technologies, and foster collaboration across sectors. While advanced biotechnologies such as gene editing and next-generation sequencing are being explored globally, regulatory uncertainties and limited uptake in the EU constrain their application. Coordinated efforts are needed to responsibly assess and harness these tools in ways that align with EU values and competitiveness goals.

Key Research Areas:

- **Automation and Digital Tools:** Utilize artificial intelligence, robotics, and sensors for precision aquaculture.
- **Genomic Advancements:** Enhance selective breeding programs with genomic data and develop scalable gene-editing techniques.

- **Farming System Integration:** Innovate land-based and sea-based systems to optimize species performance and resource use. Collaboration Frameworks: Build networks that connect breeders, researchers, and policymakers to drive coordinated action.
- **Expanding investment, research and innovation in quantitative genetics in ORs and OCT:** Build the foundations to develop adapted climate resilient breeding programs ensuring local production and competitiveness.
- **Long-Term Research Agendas:** Support multi-generational studies on breeding impacts, genetic diversity, and sustainability.

4 Conclusions

The future of European aquaculture hinges on a strategic, research-driven approach that effectively addresses the sector's critical challenges—ranging from environmental resilience and sustainability to social acceptance and market competitiveness. By prioritizing targeted research in species-specific breeding, resource efficiency, and the integration of New Genomic Techniques (NGTs), the EU has the opportunity to accelerate progress toward a more sustainable, competitive, and resilient aquaculture industry. Although not addressed in detail here, algae-culture represents a growing sector where breeding innovation is also urgently needed, particularly in alignment with broader Blue Bioeconomy goals.

Advanced genomic tools, combined with a focus on climate adaptation, carbon footprint reduction, and disease resistance, hold transformative potential for the sector. These innovations will not only complement traditional breeding practices but will also boost productivity, environmental sustainability, adaptation to climate change and diverse production systems in EU Regions, Countries and Territories, and minimize the sector's ecological footprint, driving long-term success.

In addition to technological advancements, understanding the social, environmental, and economic factors that influence public acceptance of innovations in selective breeding is crucial. By promoting transparency, engaging consumers, and fostering collaboration between the public and private sectors, the EU can guide the industry toward acceptable practices that build public trust and support market growth. This approach will enable the sector to meet the growing demand for sustainable aquaculture while respecting animal welfare and contributing to the EU’s broader environmental and economic goals.

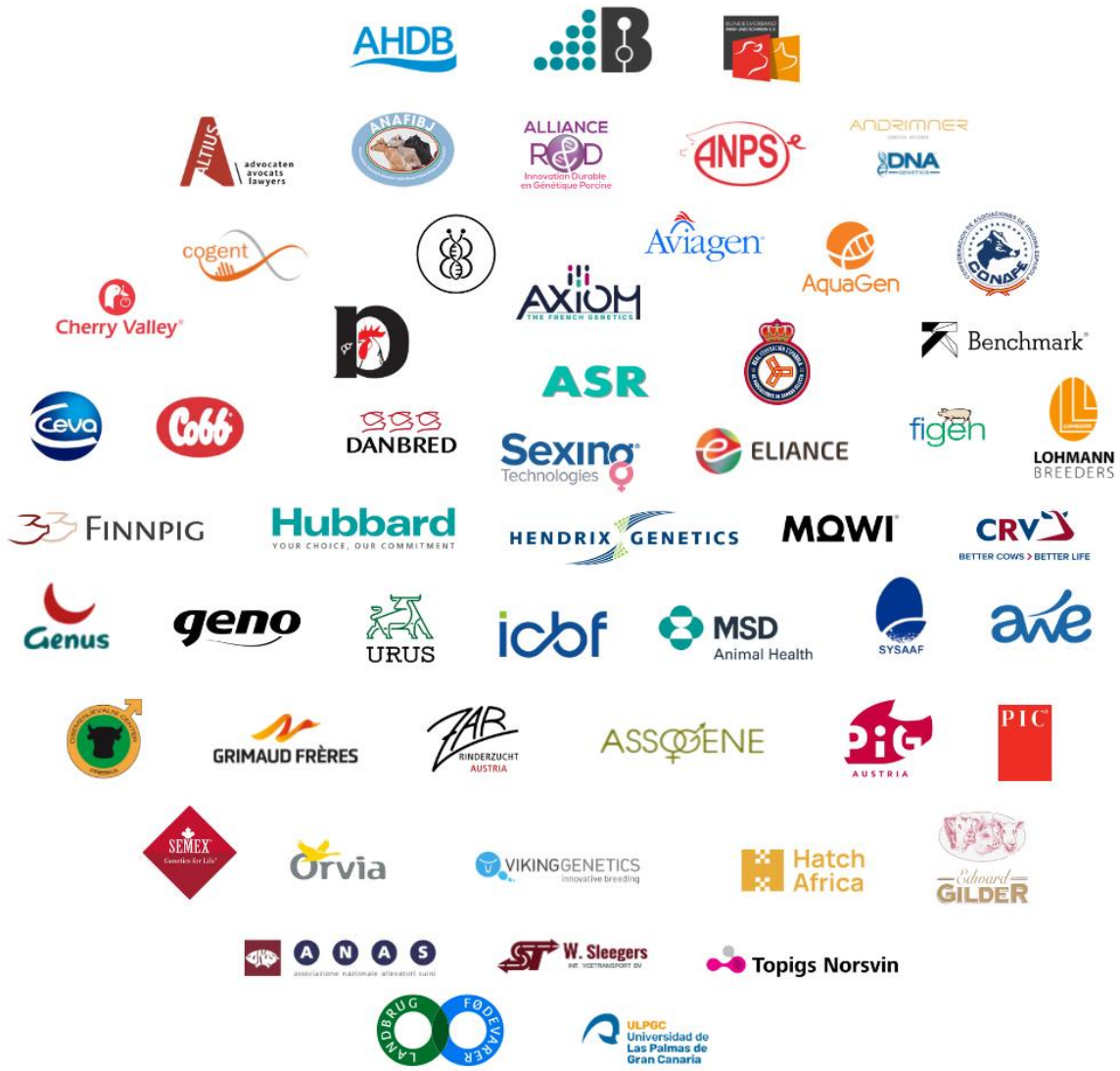
Given the long generational timelines in breeding programmes, investment and coordinated action are urgently needed today to ensure results tomorrow. Delayed progress risks widening the competitive gap between the EU and other leading aquaculture-producing regions, threatening both food security and economic opportunity. With continued investment in research and innovation, the EU can lead the way in developing a resilient, equitable, and environmentally responsible aquaculture industry—securing its position as a vital contributor to global food security and reinforcing its role in the sustainable future of our food systems.

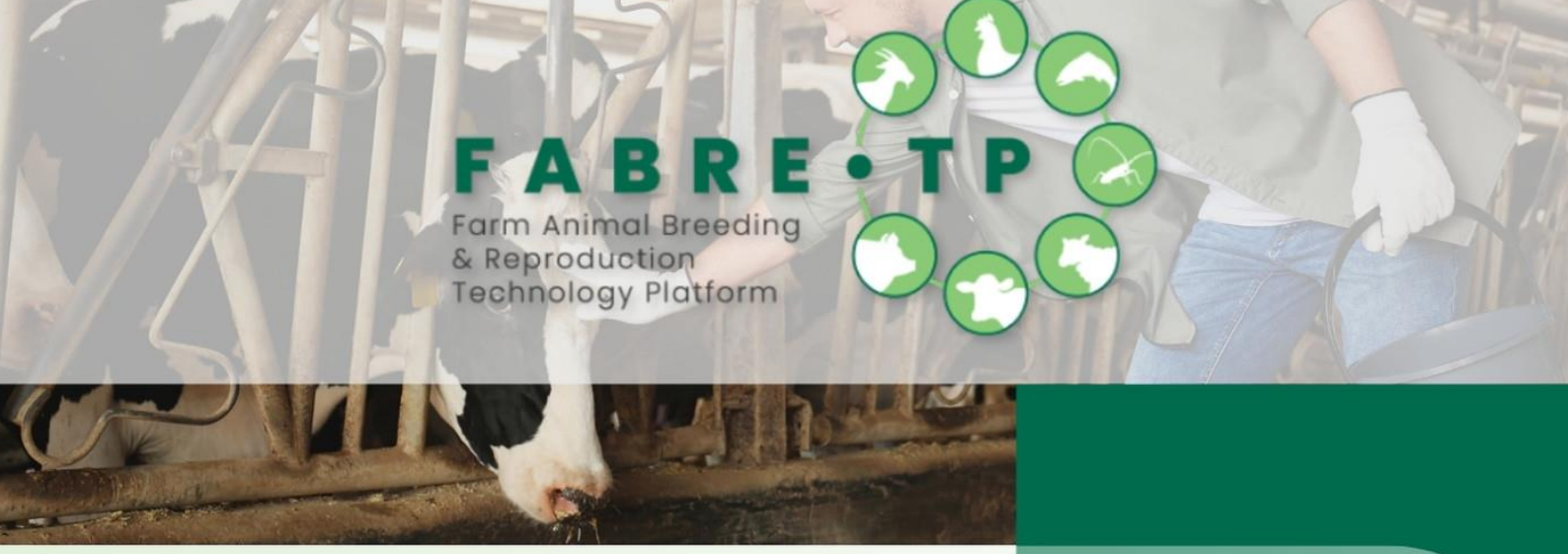
Membership of FABRE-TP

2025 FABRE TP membership comprises Knowledge Institutes, breeding organisations and companies.

Knowledge Institutes

Breeding and reproduction organisations





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The **Farm Animal Breeding and Reproduction Technology Platform** is active promoting research and innovation in **Aquaculture** and **Livestock Breeding** and **Reproduction**

FABRE TP is involved in:

- Supporting sustainable farm Animal Breeding and reproduction in the EU
- Developing research and innovation agendas and setting R&I priorities
- Connecting the private sector, knowledge institutes, policy-makers and stakeholders
- Supporting innovation

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