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PORTFOLIO ANALYSIS:

EU funded research and innovation on veterinary aspects of the fight against antimicrobial resistance

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EU funded research and innovation on veterinary aspects of the fight against antimicrobial resistance

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Abbreviations

Abbreviation/ Acronym	Definition
AMR	Antimicrobial Resistance
AMU	Antimicrobial Use
AR	Anthelmintic Resistance
AST	Antimicrobial Susceptibility Testing
BEATs	Biosecurity Risk Analysis Tools (specific tool within the HealthyLivestock project)
BRSV	Bovine Respiratory Syncytial Virus (pathogen mentioned in relation to vaccines)
CAP	Common Agricultural Policy
CPE	Carbapenem-resistant *Enterobacterales*
CRISPR-Cas	Clustered Regularly Interspaced Short Palindromic Repeats – CRISPR-associated (molecular tool)
CSA	Coordination & Support Action (EU funding action type)
CTX-M	(Extended-spectrum beta-lactamase enzyme group related to resistance)
DG AGRI	Directorate-General for Agriculture and Rural Development
DG RTD	Directorate-General for Research and Innovation
DIVA	Differentiating Infected from Vaccinated Animals (diagnostic tools)
EARS-Vet	European Antimicrobial Resistance Surveillance network in veterinary medicine
ECDC	European Centre for Disease Prevention and Control
ECOFFs	Epidemiological Cut-Off Values
EFSA	European Food Safety Authority
EJP-One Health EJP	One Health European Joint Programme
ERA-NET ICRAD	European Research Area Network on Antimicrobial Resistance (ICRAD)
ESBL	Extended-spectrum beta-lactamase (a type of enzyme conferring resistance)
ESVAC	European Surveillance of Veterinary Antimicrobial Consumption
EU	European Union
EU-JAMRAI	European Joint Action on Antimicrobial Resistance and Healthcare-Associated Infections (implied from context)
EUPAHW	European Partnership on Animal Health and Welfare
F2F	Farm-to-Fork Strategy
FAIR	Findable, Accessible, Interoperable, Reusable (data principles)
FAO	Food and Agriculture Organization
FEC	Faecal Egg Count (test)
FMD	Foot-and-Mouth Disease
FSK	Food Safety Knowledge (model)
GRADE	Grading of Recommendations Assessment, Development and Evaluation (methodology for guidelines)
HE	Horizon Europe research and innovation framework programme
HEV	*Hepatitis E* Virus
HPAI	Highly Pathogenic Avian Influenza
IA	Innovation Action (EU funding action type)
JIACRA	Joint Inter-Agency Antimicrobial Consumption and Resistance Analysis
JPI-EC-AMR	Joint Programming Initiative on Antimicrobial Resistance
LAMP	Loop-Mediated Isothermal Amplification
LMICs	Low- and Middle-Income Countries
MALDI	Matrix-Assisted Laser Desorption/Ionisation (often used as part of MALDI-TOF)
MCDA	Multi-Criteria Decision Analysis
MCR	Mobile Colistin Resistance (gene)
MGEs	Mobile Genetic Elements
MinION	Specific Nanopore sequencing device

MSCA-ITN-ETN	Marie Skłodowska-Curie Actions – Innovative/European Training Networks
NPIs	Non-pharmaceutical Interventions
OXA	Oxacillinase (gene group related to resistance)
PCR	Polymerase Chain Reaction
PoC	Point-of-Care
PRRSV	Porcine Reproductive and Respiratory Syndrome Virus
qPCR	Quantitative Polymerase Chain Reaction
R&I	Research and Innovation
SoA	State of the Art (often referring to specific activities/projects within EUPAHW, e.g., SoA8, SoA11, SoA12, SoA15, SoA18, SoA19, SoA20, SoA21)
SOPs	Standard Operating Procedures
TRL	Technology Readiness Level
WGS	Whole-Genome Sequencing
WHO	World Health Organization
WOAH	The World Organisation for Animal Health

1. Introduction

Antimicrobial resistance (AMR) is a critical challenge for public health, agriculture, and the environment. In the European Union (EU), AMR is estimated to cause over 35,000 human deaths per year and carries an annual economic burden of €1.5 billion. While the role of antimicrobial use (AMU) in livestock in driving AMR is well recognised, its quantitative contribution remains incompletely understood. The European Commission has prioritised AMR as part of its Green Deal, the Farm-to-Fork Strategy, the Common Agricultural Policy (CAP), the EU One Health Action Plan Against AMR, and the 2023 Council Recommendation on stepping up EU actions to combat AMR.

This report presents an independent analysis of the contribution of EU-funded research and innovation (R&I) projects addressing veterinary aspects of AMR. It focuses on 52 Horizon 2020, Horizon Europe, COST Actions, European Partnerships (EUPAHW, One Health EJP, JPI-EC-AMR), ERA-NET (ICRAD), COST Action, and MSCA-ITN-ETN (European Training Networks), examining how they advance knowledge, deliver practical innovations, and align with EU policy objectives. The analysis explicitly includes projects addressing bacterial, viral, protozoan, and parasitic AMR, including indirect contributors such as vaccines and biosecurity interventions, but it excludes work focused solely on general animal welfare or broader epidemiological studies without AMR relevance.

The purpose of this analysis is to assess the outcomes, impacts, gaps, and success stories within the veterinary AMR R&I portfolio. It aims to identify how these projects contribute to EU policy goals, where their alignment is strongest or weakest.

To achieve this, the report draws on desk research (including CORDIS database review, project websites, and final reports), a systematic categorisation of projects into eight thematic focus areas, and ten targeted interviews with project coordinators and researchers. These combined sources allow for a qualitative analysis of both direct and indirect impacts on AMR, providing a comprehensive mapping of the portfolio's contributions to science, policy, and practice-including both technological and social innovations.

The report is structured as follows:

- Chapter 2 sets out the policy context, summarising key EU and international initiatives on AMR.
- Chapter 3 describes the methodology used, including project selection, categorisation, data sources, and interview approaches.
- Chapter 4 presents the main portfolio analysis, covering thematic results, outputs, and success stories.
- Chapter 5 analyses the alignment of the portfolio with EU policy objectives, identifying strengths, gaps, and underexplored areas.
- Chapter 6 provides overall conclusions, drawing out key findings, cross-cutting lessons, and recommendations to inform future research planning and policymaking.
- Annex: Detailed mapping of portfolio's contributions to EU policy objectives.

By delivering this case study, the report seeks to generate actionable insights for the European Commission (particularly DG AGRI and DG RTD), informing future research planning, supporting evidence-based policymaking, and contributing to EU leadership in addressing the global AMR challenge as part of a coherent One Health approach.

2. Strategic context

Antimicrobial resistance (AMR) is a pressing global challenge, threatening public health, food security, and economic stability. Recognising the interconnected nature of the problem, the European Union (EU) has adopted a One Health approach that integrates human, animal, and environmental health. This approach aligns with the EU One Health Action Plan Against AMR, the Farm-to-Fork Strategy, the Common Agricultural Policy (CAP), and the Animal Health Law (Regulation (EU) 2016/429)**,** which provides a framework for preventing, detecting, and controlling animal diseases while promoting biosecurity and prudent antimicrobial use. Together, these strategies form the cornerstone of the EU's effort to tackle AMR. This chapter outlines the strategic frameworks shaping the EU's efforts to fight against AMR, emphasising their relevance to veterinary research and innovation.

2.1. EU One Health Action Plan Against AMR

Adopted in 2017, the EU One Health Action Plan Against AMR is pivotal in the fight against AMR. The plan is built on three interlinked pillars:

- Making the EU a best-practice region: By fostering prudent antimicrobial use and reducing unnecessary applications.
- By advancing detection methods, diagnostics, vaccines, alternatives to antimicrobials, novel therapeutics, and developing economic models and incentives to promote innovation.
- Shaping the global agenda: By enhancing international collaboration through alignment with the WHO Global Action Plan on AMR and initiatives by the Food and Agriculture Organisation (FAO) and the World Organisation for Animal Health (WOAH).

Key measures include enforcing Regulations 2019/6[1] and 2019/4[2], which together provide a comprehensive framework for veterinary medicinal products and medicated feed. Regulation EU 2019/6 establishes "rules for the placing on the market, manufacturing, import, export, supply, distribution, pharmacovigilance, control, and use of veterinary medicinal products," ensuring high standards of quality, safety, and efficacy while addressing the risks of antimicrobial resistance. Regulation 2019/4 complements this by governing "the manufacture, placing on the market, and use of medicated feed," including provisions for cross-contamination limits, labelling, and storage, with a focus on safe and efficient treatment of animals.

These regulations reflect the EU's commitment to prudent antimicrobial use by requiring prescriptions for veterinary antimicrobials, restricting prophylactic and metaphylactic use, and preserving critical antimicrobials for human medicine. Together, they support sustainable practices and reinforce the One Health approach to combat AMR while safeguarding animal and public health.

2.2. Farm-to-Fork Strategy

The Farm-to-Fork Strategy, a core component of the European Green Deal, emphasises the transition to sustainable food systems. It sets a 50% reduction target in sales of antimicrobials for farmed animals and in aquaculture by 2030, using 2018 as a baseline. It is addressing the misuse of antimicrobials as a driver of resistance. This strategy promotes:

- Research, e.g. on prevention of infectious diseases, including biosecurity and vaccination.
- Innovations in animal management that improve health outcomes and reduce the need for treatment.
- Alignment with consumer demands for safer, more sustainable food production.[3]

By promoting research into alternative approaches to the use of antimicrobials like vaccines and biosecurity, the Farm to Fork Strategy aims to reduce reliance on antimicrobials, ensuring healthier animals without compromising treatment efficacy. Additionally, the emphasis on innovative animal management practices empowers veterinarians and farmers to adopt preventive measures that minimise disease risks, ultimately decreasing the need for antimicrobial interventions.

1 Regulation (EU) 2019/6 of the European Parliament and of the Council of 11 December 2018 on veterinary medicinal products and repealing Directive 2001/82/EC (Text with EEA relevance) PE/45/2018/REV/1 https://eur-lex.europa.eu/eli/reg/2019/6/oj

2 Regulation (EU) 2019/4 of the European Parliament and of the Council of 11 December 2018 on the manufacture, placing on the market and use of medicated feed, amending Regulation (EC) No 183/2005 of the European Parliament and of the Council and repealing Council Directive 90/167/EEC (Text with EEA relevance) PE/43/2018/REV/1 https://eur-lex.europa.eu/eli/reg/2019/4/oj

3 https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

This strategy also reflects the pivotal role of veterinarians in aligning food production systems with societal expectations for safety, sustainability, and reduced AMR risks, thereby reinforcing their central position in combating AMR under the One Health framework.

2.3. Common Agricultural Policy (CAP)

The CAP 2023–2027 integrates AMR-reduction into its sustainability objectives. The CAP has a cross-cutting objective to support knowledge exchange, training, advice and innovation as a key for securing smart and sustainable agriculture, forestry and rural areas. Combatting antimicrobial resistance is part of the key objective 9 that aims to improve the response of EU's agriculture to societal demands on food and health. While CAP does not embody specific AMR targets, its funding mechanisms, such as eco-schemes and innovation grants, indirectly contribute to AMR mitigation. For example, CAP incentivises practices like improved housing, nutrition, and biosecurity, which are instrumental in reducing antimicrobial dependence. This indirect but substantial contribution places CAP as a vital tool in promoting sustainable farming practices and mitigating AMR risks at the intersection of agriculture and veterinary care.

2.4. Complementary policies

Veterinary Guidelines

The 2015 EU guidelines on prudent antimicrobial use in veterinary medicine provide a critical foundation for AMR mitigation[4]. These guidelines advocate for antimicrobial stewardship among veterinarians and farmers, promoting using antibiotics for animals carefully and only when really needed, to protect both animal and human health. By prioritising preventive health measures, such as vaccination, biosecurity, and good animal husbandry practices, the guidelines aim to minimise the need for antimicrobials without compromising animal welfare or productivity.

The guidelines also address the importance of training and awareness-raising within the veterinary and farming communities. This ensures that practitioners are equipped with the knowledge and tools to implement best practices, making them key agents in the fight against AMR. Moreover, the emphasis on preserving critical antimicrobials for human medicine underscores the vital balance between safeguarding public health and maintaining effective veterinary treatment options.

Surveillance and Data

The EU's commitment to evidence-based policymaking is exemplified through robust surveillance systems like the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC). ESVAC collects and analyses data on antimicrobial use in livestock across the EU member states, providing valuable insights into usage patterns, trends, and the effectiveness of interventions.

Such surveillance systems are indispensable for identifying high-risk practices, assessing the impact of AMR mitigation strategies, and informing regulatory decisions. For example, ESVAC data has been pivotal in tracking progress toward the Farm-to-Fork Strategy's 50% antimicrobial reduction target. By creating a transparent and standardised monitoring framework, these systems enable continuous improvement in veterinary practices and foster accountability among stakeholders.

2.5. Global context

The EU's leadership in AMR research and policy development is strengthened through its alignment with key global frameworks. The WHO Global Action Plan on AMR, which emphasises a One Health approach, provides an overarching strategy to combat AMR through cross-sectoral collaboration[5]. Complementary initiatives from the FAO promote sustainable livestock management, including practices that reduce antimicrobial use while ensuring food security. For

4 https://health.ec.europa.eu/system/files/2016-11/2015_prudent_use_guidelines_en_0.pdf

5 https://www.who.int/publications/i/item/9789241509763

example, in 2024 FAO launched their global 10-year initiative to reduce the need for antimicrobials for sustainable agrifood systems transformation[6].

Additionally, WOAH advances veterinary health frameworks that set global standards for prudent antimicrobial use and biosecurity measures[7]. The WOAH Strategy on Antimicrobial Resistance and the Prudent Use of Antimicrobials is aligned with the WHO Global Action Plan and recognises the importance of the One Health approach.

By actively engaging in these global initiatives, the EU not only aligns its policies with international best practices but also positions itself as a global leader in AMR innovation and policy coherence. This alignment enables the EU to influence global research agendas, contribute to shaping harmonised regulatory frameworks, and advocate for AMR reduction strategies that benefit both human and animal health worldwide. These global connections further validate the EU's veterinary AMR strategies as part of a larger, coordinated response to this pressing challenge.

The integration of complementary policies and global initiatives highlights the holistic nature of the EU's AMR strategy. From aligning with international frameworks to establishing robust veterinary guidelines and surveillance mechanisms, these efforts reinforce the central role of veterinarians in combating AMR. They also demonstrate how harmonised actions across sectors and borders can amplify the impact of AMR mitigation strategies, ensuring sustainable livestock systems and healthier ecosystems on a global scale.

2.6. Strategic challenges and opportunities

The restrictions on critical antimicrobials in veterinary medicine highlight the urgent need for innovative treatments that balance animal health and the mitigation of AMR. According to the 2015 EU Guidelines on Prudent Use of Antimicrobials, preserving these critical antimicrobials for human health is essential, but it highlights the necessity of alternative approaches to the use of antimicrobials in veterinary contexts.

This principle is further strengthened by Commission Implementing Regulation (EU) 2022/1255[8], which identifies specific antimicrobials or classes of antimicrobials, such as carbapenems, glycopeptides, and oxazolidinones, that are reserved exclusively for human medicine. Their use in veterinary medicine and medicated feed is strictly prohibited to preserve their critical importance for human health. This regulatory action demonstrates the EU's commitment to addressing antimicrobial resistance by implementing targeted restrictions on the veterinary use of essential antimicrobials.

However, the challenges posed by such restrictions necessitate the development of innovative veterinary solutions, including alternative treatments, advanced diagnostics, and preventive measures like vaccines and improved biosecurity. These approaches are critical not only for compliance with EU regulations but also for maintaining animal health and supporting sustainable farming practices.

Beyond bacterial resistance, the AMR challenge is broadened by resistance in parasites, viruses, and fungi, which requires integrated solutions such as multi-pathogen vaccines and advanced diagnostics. The One Health Action Plan Against AMR also emphasises the importance of addressing AMR across all pathogens to achieve holistic solutions.

In addition, the veterinary sector faces a delicate balance between reducing antimicrobial use and ensuring animal welfare, particularly when immediate treatment is necessary. Research into alternatives, such as probiotics and precision farming technologies, is highlighted as vital by the Farm-to-Fork Strategy, which sets ambitious targets for antimicrobial reduction while safeguarding food safety and sustainability.

6 https://www.fao.org/newsroom/detail/fao-launches-global-10-year-initiative-to-reduce-the-need-for-antimicrobials-for-sustainable-agrifood-systems-transformation/en#:~:text=The%20RENOFARM%20initiative%20aims%20to,enhancing%20food%20security%20and%20nutrition

7 https://www.woah.org/en/document/en_oie-amrstrategy/

8 European Commission (2022) Commission Implementing Regulation (EU) 2022/1255 of 19 July 2022 designating antimicrobials or groups of antimicrobials reserved for treatment of certain infections in humans, in accordance with Regulation (EU) 2019/6 of the European Parliament and of the Council. Official Journal of the European Union, L 191, pp. 58–60. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022R1255

Finally, the EU's ability to shape the global AMR agenda is reliant on continued investment in research and international collaboration. The WHO Global Action Plan, the FAO's Sustainable Livestock Initiatives, and WOAH standards serve as complementary frameworks to EU efforts, enhancing policy alignment and enabling the EU to strengthen its role as a global leader.

The EU's strategic response to AMR integrates its flagship policies, including the One Health Action Plan Against AMR, the Farm-to-Fork Strategy, and the CAP, to address these multifaceted challenges. By fostering innovation, promoting prudent antimicrobial use, and aligning with global frameworks, these policies collectively aim to reduce antimicrobial dependency while safeguarding human and animal health. However, achieving these objectives requires sustained investment, cross-sectoral collaboration, and a clear focus on addressing emerging gaps in research and implementation.

3. Methodology applied

The methodology for this case study report was designed to capture the direct and indirect impacts of EU-funded projects on veterinary AMR. It focuses on understanding how these projects contribute to AMR mitigation through research outputs, practical applications, and alignment with EU policy objectives.

3.1. Data collection

Information on each project was gathered from publicly available databases, including CORDIS, project-specific websites, and supplementary materials provided by the European Commission. Where necessary, project coordinators were contacted to provide additional details, ensuring completeness and accuracy.

To complement desk research, we conducted a series of targeted interviews with project coordinators and key researchers. These interviews provided firsthand insights into project implementation, practical challenges, emerging solutions, and gaps not always visible in formal reports. The discussions covered a range of issues, such as:

- Behavioural and social factors in AMU reduction (e.g., HealthyLivestock, DISARM)
- Development of veterinary guidelines and evidence-based practices (e.g., ENOVAT)
- Testing and scaling of alternatives to antibiotics, including regulatory barriers (e.g., AVANT, NeoGIANT)
- Improving biosecurity standards and practices at the farm and policy levels (e.g., BETTER, BIOSECURE)
- Advances in surveillance and decision-support tools for disease control (e.g., DECIDE, One Health EJP)
- Coordination of large-scale research networks and identification of policy-relevant gaps (e.g., ICRAD, One Health EJP)

In total, we conducted 11 interviews - one each with the coordinators of HealthyLivestock, DISARM, ENOVAT, AVANT, BETTER, ICRAD, BIOSECURE, DECIDE, One Health EJP, NeoGIANT, and COMBAR - which provided crucial firsthand insights that informed our research by highlighting implementation challenges, practical outcomes, behavioural and regulatory barriers, stakeholder engagement dynamics, and the real-world applicability and sustainability of project results beyond formal reports and publications.

These interviews not only validated desk research findings but also revealed critical context around implementation barriers, real-world adoption challenges, interdisciplinary collaboration, and sustainability of results post-project.

3.2. Analytical framework: assessing direct and indirect impacts

The analysis distinguishes between direct and indirect impacts on veterinary AMR:

- Direct impacts are those that specifically target AMR reduction through tangible interventions or research outputs. Examples include the development of vaccines to replace antimicrobials, new diagnostic tools for early resistance detection, or antimicrobial stewardship programs.
- Indirect impacts arise from initiatives that contribute to AMR mitigation by improving animal health and management. These include enhanced biosecurity measures, optimised housing systems, and educational programmes that reduce disease incidence and antimicrobial demand.

To assess these impacts, each project was evaluated using the following criteria:

- Relevance to veterinary AMR: How the project's activities and outputs align with the goals of reducing AMR in veterinary contexts.
- Implementation potential: The extent to which project outputs can be adopted on farms or in veterinary practice.
- Scalability and transferability: The potential for project outcomes to be applied across different regions or livestock systems.
- Policy alignment: How the project supports EU policy objectives, including the Farm-to-Fork Strategy, the EU One Health Action Plan, and the Common Agricultural Policy.

Beyond categorisation by thematic area, the analysis also implicitly considered the typology of R&I outcomes, distinguishing between technological solutions (assessed by estimated Technology Readiness Levels (TRL) to gauge their maturity from early-stage to commercially ready applications) and non-technological solutions (such as policy recommendations, guidelines, models, or improved practices). This holistic perspective ensures an understanding of the diverse forms of innovation generated by the portfolio.

3.3. Categorisation

For the purpose of this analysis, we structured the assessment using the eight thematic categories established by the European Commission, applying a systematic approach to evaluate the relevance and emphasis of each project across key AMR research domains.

Projects were organised into the following thematic categories:

- Understanding AMR
- AMR/AMU surveillance & diagnostics
- Disease surveillance and diagnostics
- AMU stewardship
- Practices to reduce AMU, including biosecurity
- Vaccines
- Antimicrobials and alternatives to antibiotics
- Other disease control measures

Note: Category "Other disease control measures" is not covered as a stand-alone section in Chapter 4, as it represents a diverse set of actions with only indirect links to AMR and would largely duplicate content addressed in other thematic areas.

This methodology enabled the team to systematically map the EC-funded veterinary AMR research portfolio and identify both coverage and gaps. At a high level, the portfolio exhibits strong breadth and integration, with most projects addressing multiple thematic priorities-particularly foundational research, surveillance, and stewardship-demonstrating the EU's commitment to a One Health, cross-sectoral approach.

Under Chapter 4, only the most relevant projects in a given thematic area are analysed in detail, with efforts made to avoid duplication by describing each project primarily in the section where its contribution is most substantial.

3.4. Identifying knowledge gaps and success stories

Identifying knowledge gaps

The study assessed gaps in veterinary AMR research by identifying underrepresented themes or regions in the project portfolio. For example, projects heavily focused on vaccines might highlight gaps in biosecurity innovations or diagnostic tools. Similarly, underdeveloped practical outputs were noted as areas requiring further attention.

Identifying successes

Key success stories were selected based on their:

- Scalability and impact: Projects demonstrating measurable reductions in antimicrobial use or adoption across multiple regions.
- Innovation: Novel approaches, such as multi-pathogen vaccines or precision diagnostic tools.
- Alignment with policy priorities: Contributions that directly support EU targets, such as the Farm-to-Fork Strategy's goal of reducing antimicrobial use by 50% by 2030.

3.5. Quality assurance and data validation

All project data were reviewed for accuracy and completeness. Findings were cross-validated with official EU sources and discussed with relevant stakeholders, ensuring the robustness of the analysis.

4. Analysis of the Portfolio

The distribution of projects by action type shows a strategic mix of partnership-driven, research, and innovation actions, which supports both collaborative knowledge generation and practical application. However, our analysis also indicates that while the portfolio is robust in foundational research and early-stage surveillance tools, there is comparatively less emphasis on developing late-stage technological innovations and implementing new non-technological interventions at scale, highlighting an opportunity for further investment in applied research and real-world impact.

Note: It is important to note that the portfolio presents several completed and ongoing projects, therefore, their results are captured as apparent at the time of writing.

Table 1. Distribution projects across AMR thematic areas

Thematic area	Projects
1. Understanding AMR	ICONIC (JPI AMR); the OneHealth EJP projects RADAR, ARDIG and FED-AMR; CARTNET; DISARM; ROADMAP; AVANT; SAPHIR; PIGS; COMBAT; NEOGIANT; DECIDE; PHAGOVET; BIOSECURE; REPRODIVAC; SPARC TN; the EUPAHW projects SoA8, SoA11, SoA18, SoA19, and SoA21; as well as COMBAR; the OneHealth EJP projects IMPART, FARMED, FULL-FORCE, WORLDCOM and MOMIR-PPC; the ICRAD projects TECHPEPcon, METABOL-AR, PIGIE and HARTEMIS; the JPI AMR projects SEFASI, PHAGE-STOP and FARMCARE.
2. AMR/AMU surveillance & diagnostics	ANTHELMOGRAM (ICRAD); the OneHealth EJP projects FULL-FORCE, IMPART and WORLDCOM; ICONIC (JPI AMR); the EUPAHW projects SoA8, SoA12 and SoA21; ENOVAT; TECHPEPcon (ICRAD); SAPHIR; PIGS; COMBAT; VIVALDI; DECIDE; SPARC TN; VetBioNet; REPRODIVAC; COMBAR; the OneHealth EJP projects BIOPIGEE, ARDIG, RADAR, FARMED and FED-AMR; the ICRAD projects BIOSENS, METABOL-AR BM-FARM and HARTEMIS; PHAGE-STOP (JPI AMR).

3. Disease surveillance and diagnostics	ANTHELMOGRAM (ICRAD); the OneHealth EJP projects ARDIG and BIOPIGEE; BIOSECURE; the ICRAD projects BIOSENS, PIGIE and BM-FARM; COMBAR; COMBAT; DECIDE; ENOVAT; FARMCARE (JPI AMR); the OneHealth EJP projects FARMED, FED-AMR, FULL-FORCE, IMPART, MOMIR-PPC, RADAR and WORLDCOM; HE-FARM; the ICRAD projects METABOL-AR, PIGEE and TECHPEPcon; PHAGE-STOP (JPI AMR); PHAGOVET,; PIGSs; REPRODIVAC; the EUPAHW projects SoA8, SoA11, SoA12, SoA15, SoA18 and SoA21; SAPHIR; SPARC TN; VetBioNet; VIVALDI..
4. AMU stewardship	DISARM; FARMCARE (JPI AMR); COMBAR; SPARC TN; ENOVAT; HealthyLivestock; SAPHIR; NETPOULSAFE; PHAGOVET; ROADMAP; SoA15 and SoA20 (EUPAHW); MOMIR-PPC (OneHealth EJP), the ICRAD projects TECHPEPcon, BM-FARM, BIOSENS and HATEMIS; the JPI AMR projects ENVIRE, SEFASI, Phage-Stop and Phage-EX.
5. Practices to reduce AMU including biosecurity	FARMCARE, MOMIR-PPC, BIOPIGEE, BIOSECURE, SoA8 and SoA15 (EUPAHW), NETPOULSAFE, SPARC TN, DISARM, HealthyLivestock, AVANT, SAPHIR, PIGS, , COMBAT, VetBioNet, COMBAR, DECIDE, PHAGOVET, HE-FARM, ENOVAT, PIGEE, TechPEPcon, PIGIE (ICRAD), HARTEMIS (ICRAD), BM-FARM, BIOSENS, ENVIRE, ICONIC, and ROADMAP represent a diverse group of European animal health and antimicrobial resistance research projects.
6. Vaccines	The ICRAD projects NEOVACC and PIGIE; PARAGONE; SAPHIR; ENVIRE (JPI AMR); PIGSs; REPRODIVAC.
7. Antimicrobials and alternatives to antibiotics	AVANT; PHAGOVET; the JPI AMR projects PHAGE-STOP and PHAGE-EX; NeoGIANT; PIGSS, MOMIR-PPC (OneHealth EJP); CARTNET; SoA19 (EUPAHW), SAPHIR; REPRODIVAC; NEOVACC (ICRAD); COMBAR; SPARC

Source: Compiled by PPMI.

The portfolio demonstrates strong diversity and balance across funding mechanisms, with a substantial share of projects supported through European Partnerships such as EUPAHW, One Health EJP, and JPI-EC-AMR (23 out of 52), highlighting a major emphasis on collaborative, cross-sectoral research. Research and Innovation Actions (9 projects), ERA-NET ICRAD (8 projects), and Innovation Actions (5 projects) are also well represented, reflecting robust support for both fundamental and applied research. Coordination and Support Actions, COST Actions, and European Training Networks further contribute to a comprehensive approach that includes research, innovation, capacity building, and knowledge exchange. This distribution indicates a strategic alignment with EU priorities, leveraging a mix of action types to address complex challenges in animal health and AMR through both partnership-driven and investigator-led initiatives.

Table 2. Projects' distribution by action types

Action Type	Projects	Total Count
CSA (Coordination and Support Action)	DISARM, NETPOULSAFE TN, SPARC TN	3
IA (Innovation Action)	AVANT, NeoGIANT, VIVALDI, PHAGOVET, REPRODIVAC	5
RIA (Research and Innovation Action)	HealthyLivestock, Paragone, SAPHIR, PIGSs, COMBAT, DECIDE, VETBIONET, BIOSECURE, HE-Farm	9
European Partnerships (EUPAHW, One Health EJP, JPI-EC-AMR)	IMPART, ARDIG, RADAR, FARMED, FULL-FORCE, WORLDCOM, FED-AMR, BIOPIGIE, MoMIR-PPC (One Health EJP); SoA8, SoA11, SoA12, SoA15, SoA18, SoA19, SoA21 (EUPAHW); ENVIRE, SEFASI, Phage-Stop AMR, Phage-EX, ICONIC, FARM-CARE (JPI-EC-AMR)	23
ERA-NET (ICRAD)	NEOVACC, PIGIE, TechPEPcon, METABOL-AR, HARTEMIS, ANTHELMOGRAM, BM-Farm, Biosens4PrecisionMastitis	8
COST Action	COMBAR, BETTER, ENOVAT	3
MSCA-ITN-ETN (European Training Networks)	CARTNET	1
	Grand Total	52

Source: Compiled by PPMI by checking against CORDIS.

Below we present the overview of relevant projects, specifically focusing on their outputs, outcomes and results around the eight key thematic areas of veterinary AMR research.

4.1. Understanding AMR

AMR is shaped by complex interactions among animals, humans, and the environment, making it a typical One Health challenge. Despite growing genomic and epidemiological data availability, major gaps remain in understanding the transmission dynamics of resistance genes across these sectors [9][10]. Key research priorities include clarifying the environmental reservoirs of AMR, including how livestock manure and other farm waste streams contribute to resistance gene dissemination and the socio-economic drivers of antimicrobial use in different livestock systems [11]. Addressing these knowledge gaps is essential for designing effective interventions and for contextualising the impact of veterinary AMR on public and ecosystem health.

Projects analysed under this thematic area were selected based on their relevance to understanding AMR mechanisms, dynamics, and drivers in the veterinary domain. This encompasses epidemiological modelling, resistance gene transmission, surveillance harmonisation, and host-microbiome interactions.

Overall, the projects reviewed demonstrate a maturing portfolio of science-led efforts that inform the epidemiology, surveillance, and transmission dynamics of AMR in animal production systems. Many contribute robustly to the EU One Health Action Plan, the CAP's objectives on sustainable livestock production, and the Farm to Fork Strategy**,** especially in laying the foundation for more effective AMR surveillance and risk modelling.

As the portfolio projects contribute to understanding AMR in diverse ways, for the purposes of this analysis, we grouped the highly relevant and relevant projects into five thematic clusters. Each reflects a distinct yet complementary dimension of AMR understanding within the veterinary domain:

- Source attribution and risk modelling: Projects in this cluster enhance the ability to identify where resistance originates, how it is transmitted across One Health domains (animals, humans, environment), and what burden it creates. This knowledge is essential for designing evidence-based interventions and quantifying the impact of veterinary AMR on public health and the food chain.
- Surveillance integration and genomic data harmonisation: These projects address methodological fragmentation in AMR surveillance by developing harmonised genomic tools and cross-sectoral data standards. Understanding AMR in this context means building a consistent and interoperable evidence base for resistance patterns, gene flow, and prevalence trends across regions and species.
- Environmental and ecological AMR pathways: This cluster deepens the understanding of how resistance emerges, persists, and spreads through soil, water, wildlife, and farm environments, factors often overlooked in veterinary AMR mitigation. These ecological insights are crucial to developing a full-system view of AMR risk drivers and potential intervention points.
- Resistance in host-microbiome systems: Projects here focus on the internal biological mechanisms that influence AMR development, including microbial ecology, horizontal gene transfer, immune response, and the

9 A one health priority research agenda for antimicrobial resistance. Geneva: World Health Organization, Food and Agriculture Organization of the United Nations, United Nations Environment Programme and World Organisation for Animal Health; 2023. Licence: CC BY-NC-SA 3.0 IGO. Available online at: https://www.woah.org/app/uploads/2023/06/one-health-amr-research-prioritisation-launch-v7-2.pdf

10 Lyimo, B. & Sonola, V. (2025) 'Antimicrobial Resistance Gene Distribution and Population Structure of Escherichia coli isolated from Humans, Livestock, and the Environment: Insights from a One Health Approach', medRxiv [preprint]. Available at: https://doi.org/10.1101/2025.04.07.25325408

11 Velazquez-Meza ME, Galarde-López M, Carrillo-Quiróz B, Alpuche-Aranda CM (2022) Antimicrobial resistance: One Health approach, Veterinary World, 15(3): 743-749.

effects of nutrition or stress. This knowledge supports a mechanistic understanding of resistance evolution at the individual and population levels.

- Operational, social and systemic drivers: This cluster explores the behavioural, institutional, and economic conditions that influence antimicrobial use (AMU) in livestock production. Understanding AMR from this angle means identifying why excessive AMU persists despite available alternatives, and how system-level change (e.g., training, incentives, decision-making support) can reduce AMR risk in practice.

4.1.1. Source attribution and risk modelling

Projects in this cluster advance the EU's ability to identify and quantify where AMR originates and how it spreads across animal, human, and environmental sectors. This work is foundational for understanding AMR dynamics and for enabling targeted mitigation strategies that are both scientifically sound and operationally feasible. The relevance of these efforts lies in their capacity to move AMR action from generic responses toward source-specific, risk-based policymaking.

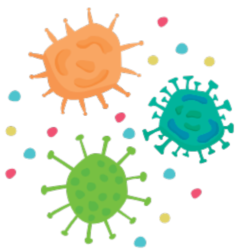
The **RADAR** project represents a cornerstone contribution in this area. It developed one of the most advanced One Health attribution models currently available in the EU, quantifying the proportion of the AMR burden in humans that can be traced back to food, animals, and the environment.

Case example of RADAR

Focusing on ESBL-producing E. coli, RADAR adapted pathogen source attribution techniques for the specific needs of AMR, integrating data across sectors and applying Bayesian evidence synthesis frameworks. In doing so, it significantly enhanced methodological robustness for AMR risk modelling.

In parallel, RADAR produced several highly practical tools and datasets for future scientific and regulatory use. These include the COMPASS plasmid database, which aggregates curated AMR plasmid data across bacterial species and compartments, and the FSK file format for standardised exchange of risk assessment models. Both outputs are openly accessible and support interoperability across modelling platforms used by EFSA and national authorities.

RADAR also demonstrated the feasibility of metagenomics-based surveillance and machine learning for AMR risk prediction. While these contributions are highly policy-relevant, their uptake into EU surveillance and decision frameworks remains under development.



In a way, complementing this work, the **DECIDE** project tackled the question of how endemic disease surveillance and control systems can be optimised to reduce AMU without compromising animal health. Although not directly focused on resistance mechanisms, DECIDE contributed to AMR mitigation by creating multivariate tools that link disease occurrence patterns with AMU pressure. Its burden of disease prioritisation models help veterinary authorities identify which diseases are most associated with high antibiotic use and design targeted, data-driven interventions accordingly. By enabling earlier and more strategic disease control, DECIDE's outputs offer indirect yet substantial contributions to reducing the need for antimicrobials at the farm level.

The **ICONIC** project addressed a specific but highly under-explored risk: the co-selection of AMR due to the use of ionophore coccidiostats in poultry. These compounds, currently classified as feed additives rather than veterinary medicines, are assumed to pose minimal risk due to their lack of human medical use. However, ICONIC's molecular epidemiology studies revealed that ionophores may co-select for resistance to medically important antibiotics, such as vancomycin, through genetic linkage of resistance determinants. By analysing isolates from poultry, meat, environmental samples, and hospital settings, the project provided evidence of shared resistance genes and transmission routes between animal and human populations. This challenges long-standing assumptions in EU risk assessment frameworks and offers concrete evidence to inform ongoing regulatory debates over the classification and monitoring of ionophores under the EU Chemicals Strategy for Sustainability and the One Health Action Plan against AMR.

SEFASI contributed to this cluster by modelling the systemic impact of AMR interventions across sectors. Although it did not generate biological data, SEFASI developed a suite of dynamic models that simulate the effects of different intervention strategies on AMR transmission. These tools help policy planners evaluate trade-offs and prioritise actions based on projected outcomes, taking into account cross-sector feedback loops and long-term scenarios. This systems perspective complements the more pathogen-specific approaches found in RADAR and ICONIC.

Overall, the projects grouped under this cluster provide both conceptual and operational tools to advance AMR control. Their combined outputs enhance the EU's capacity to pinpoint risk origins, inform proportionate regulation, and support science-based planning. However, further steps are needed to advocate that these innovations are embedded within EU surveillance systems and decision-making frameworks to realise their full potential.

4.1.2. Surveillance integration and genomic data harmonisation

Understanding AMR relies not only on identifying sources but also on accurately detecting resistance trends, mapping gene flow, and standardising data across surveillance systems. Projects grouped under this cluster contribute to filling critical gaps in AMR monitoring infrastructure, especially in integrating genomic data, harmonising antimicrobial susceptibility testing, and linking animal, environmental, and human datasets. These efforts support EU-level goals to enhance AMR surveillance under the One Health Action Plan and are directly relevant to upcoming EU policies such as the expansion of EARS-Vet and the implementation of integrated AMU/AMR databases.

The OneHealth EJP project, **ARDIG**, is among the most comprehensive One Health surveillance studies to date. It conducted genomic epidemiology of AMR in humans, animals, food, and the environment across six European countries (the UK, France, Germany, Spain, Norway, and the Netherlands), covering diverse production systems and resistance profiles.

The project aimed to harmonise AMU and AMR data for comparison, as well as study AMR persistence and transmission. It provided high-resolution insights into resistance gene flow using whole-genome sequencing (WGS) of over 3,000 isolates and comparative analyses between clinical and non-clinical samples. These analyses identified differences in AMR between clinical and non-clinical isolates for different animal populations and found that bacterial strains isolated from humans generally shared greater similarities with each other than with those from animals, and vice versa.

ARDIG also addressed a major bottleneck in AMR surveillance by harmonising in silico pipelines for AMR gene prediction. It compared tools such as ResFinder, PointFinder, and GeneFinder by running WGS data from approximately 450 isolates through five different AMR pipelines across partner labs. While ARDIG contributed significantly to these harmonisation efforts and a manuscript on this pipeline comparison was being prepared, the project indicated that a harmonised method for AMR genotyping could be "considered for future", rather than explicitly stating immediate adoption as reference methods for EU and national AMR monitoring systems.

Importantly, ARDIG confirmed the presence of cross-sector resistance pathways through phylogenetic analysis and AMR profiling, which helped identify possible transmission events or epidemiological links between different compartments and countries. The project's findings, including observations that decreasing resistance was found in animal isolates between 2014 and 2017 due to measures like reduced AMU, and the focus on AMR persistence, reinforce the need for fully integrated AMR surveillance. ARDIG's recommendations were also disseminated to experts from organisations like EFSA, EMA, and ECDC to improve "One Health" surveillance strategies.

The **FULL-FORCE** and **WORLDCOM** projects contributed to this effort by improving the tracking of mobile genetic elements (MGEs), particularly plasmids. FULL-FORCE deployed long-read sequencing to map full plasmid architectures, with a particular focus on IncZ plasmids that are linked to hospital infections. The project highlighted how conventional surveillance may miss plasmid-mediated resistance, thereby underestimating the true mobility and risk of certain resistance genes. WORLDCOM added to this by curating a database of over 600 sequenced isolates from animals, humans, and the environment, providing comparative genomics data on ESBLs, colistin resistance, and carbapenemases.

A significant challenge in AMR surveillance remains the lack of harmonisation in susceptibility testing and breakpoint interpretation. **The EUPAHW project SPAMR-VET (SoA8)** is tackling this by developing veterinary-specific clinical breakpoints and proposing new epidemiological cut-off values (ECOFFs) for food-producing terrestrial and aquatic animals. Its work supports the expansion of EARS-Vet by addressing methodological mismatches that currently hinder the comparability of AMR trends across countries and species. Similarly, the same EUPAHW partnership's project **KNOW-PATH (SoA11)** is contributing by identifying AMR markers in priority veterinary pathogens and improving pathogen-host detection methodologies, particularly for mixed infections.

Several other projects enhanced surveillance integration through specific technological or analytical advances. **IMPART** focused on bridging the phenotypic-genotypic detection gap by comparing genotypic resistance markers with observed phenotypes in *Enterobacterales* and *Pasteurella* species. This work is particularly relevant for ensuring reliability in genomic surveillance data interpretation. **FARMED** demonstrated the feasibility of long-read metagenomics (MinION) for real-time detection of AMR genes in complex samples. Although not implemented at scale, its findings support innovation in rapid, field-level AMR diagnostics. Similarly, **PIGSs** combined epidemiological risk assessment and WGS to profile *Streptococcus suis* strains, enabling improved risk prediction for resistant variants, though its focus was more pathogen-specific than surveillance-wide.

Taken together, projects in this cluster address a central weakness in the AMR response: fragmented and non-interoperable surveillance systems. They provide a set of harmonised tools, validated genomic pipelines, and data-sharing platforms that can enable more effective detection, comparison, and response to AMR trends across sectors.

The opportunity ahead lies in advocating for the use of these tools, especially through EARS-Vet, EFSA-supported systems, and national action plans, so they contribute to sustained AMR risk monitoring and mitigation.

4.1.3. Environmental and ecological AMR pathways

Projects grouped under this cluster focus on understanding how AMR develops, persists, and spreads through environmental reservoirs and ecological systems. This includes investigating resistance transmission via water, soil, wildlife, and non-target farm exposures, as well as the impact of co-selective pressures such as heavy metals, herbicides, or feed additives. These projects align strongly with the One Health Action Plan's commitment to environmental AMR integration.

The **FED-AMR** project offers arguably the most systematic assessment of how resistance genes circulate in the environment, particularly through free extracellular DNA (exDNA). Sampling 476 sites across six EU countries, the project provided robust evidence that exDNA, which can account for up to 60% of environmental DNA in soil, carries clinically relevant resistance genes, and that naturally competent bacteria capable of taking up this DNA are widespread in manured fields, drainage systems, and animal-adjacent habitats. FED-AMR also quantified the effects of environmental conditions on gene uptake, demonstrating, for example, that elevated soil temperatures can suppress bacterial competence for transformation. It further developed harmonised metagenomic and qPCR protocols, now shared openly, which will inform future EU guidance on environmental AMR surveillance. Perhaps most importantly, FED-AMR produced mathematical models that simulate how antimicrobial resistance genes (ARGs) spread via exDNA under different farm and climate conditions. These models provide a basis for long-term environmental AMR risk assessments and reinforce the urgency of including soil and water compartments in AMR policy frameworks.

ICONIC, while also relevant to source attribution, made a unique contribution by exploring the environmental persistence of resistance arising from ionophore use in poultry systems. Its data showed that bacteria carrying linked resistance genes (e.g., *vanA*) remain viable in poultry litter and runoff, presenting a credible risk of environmental dissemination. These findings not only challenge assumptions around the AMR neutrality of feed additives but also highlight the need for environmental monitoring of veterinary substance residues and their microbial impacts.

PHAGOVET and **PHAGE STOP** (JPI-EC-AMR ERA-NET project) both addressed the environmental risks associated with antimicrobial use in poultry farming. PHAGOVET demonstrated that phage-based feed additives could reduce *Salmonella* colonisation by over 90% in broiler chickens, potentially limiting the need for antibiotic interventions. While primarily an intervention project, PHAGOVET's results contribute to environmental AMR reduction by limiting faecal shedding of resistant bacteria into the farm environment. PHAGE STOP tackled resistance from a more mechanistic perspective, exploring how bacteriophage-derived proteins can inhibit plasmid conjugation in *E. coli*. It is important to note that, though early-stage, the project adds to the understanding of how resistance gene spread might be curtailed at the environmental interface between animals and pathogens.

TechPEPcon contributed to this area by developing early-warning systems using rapid nanopore-based detection tools, which can be applied to environmental matrices such as water and dust. While its primary contribution lies in biosecurity innovation, the ability to detect resistance determinants in real time at environmental checkpoints opens opportunities for preventive interventions that reduce ecosystem-level exposure to resistant bacteria.

Projects such as **FARMCARE, EUPAHW SoA19, and HARTEMIS** further illustrate the environmental complexity of AMR transmission. FARMCARE provided data on how improved pig welfare, stress reduction, and environmental hygiene reduce the prevalence of resistance genes in animal and environmental samples. SoA19 contributed by investigating antimicrobial and antiparasitic compounds and their environmental breakdown profiles. HARTEMIS explored how parasitic resistance in ruminants evolves and spreads in pasture systems, drawing attention to anthelmintic resistance (AR) as an emerging challenge closely linked to AMR ecology, particularly in outdoor grazing systems where drug exposure is diffuse.

In summary, these projects contribute to understanding that AMR in the environment is not incidental but systemic, shaped by microbial ecology, farm practices, and environmental co-selective forces. They collectively provide evidence to support the inclusion of environmental pathways in EU surveillance, highlight the importance of non-traditional vectors such as *exDNA*, and support the design of future soil and water monitoring protocols under a One Health framework. However, gaps remain in linking environmental resistance data to clinical risks and integrating findings into cross-sector decision-making, an area requiring continued investment.

4.1.4. Resistance in host-microbiome systems

Projects in this cluster focus on how AMR develops and circulates within the complex microbial ecosystems of the animal host. Understanding these dynamics is critical for identifying both risks and opportunities for intervention, particularly in reducing AMU by targeting the microbiome or modulating host-pathogen interactions. These projects contribute directly to the understanding of resistance gene acquisition, horizontal transmission, and the potential for microbiome-informed AMR mitigation.

The EUPAHW SoA18 project is providing a comprehensive systems-level investigation of resistance emergence within polymicrobial communities in terrestrial livestock and aquaculture species. Its research links gut microbiota composition and mucosal immune responses with infection risk, showing that dietary components such as prebiotics can promote short-chain fatty acid production, enhance immune function, and reduce AMU. Mechanistically, SoA18 aims to demonstrate how resistance traits (e.g. *blaCTX-M*) can transfer from commensal to pathogenic bacteria, underlining the gut as both a reservoir and amplifier of AMR. Additional work on biofilm formation and efflux pump expression in aquatic pathogens further expanded the project's contribution to understanding resistance resilience within host-associated microbial communities.

CARTNET added value by training early-career researchers to investigate AMR from a microbiome perspective, focusing on transferable resistance elements, RNA-targeted therapies, phage-bacteria co-evolution, and virulence inhibition strategies. Although the project did not deliver field-level trials, it built cross-sectoral expertise in advanced AMR research approaches highly relevant to microbiome-pathogen interactions.

AVANT directly tested microbiota-modulating strategies, namely faecal microbiota transplantation (FMT) and symbiotic, in real-world pig farming systems to reduce post-weaning diarrhoea and associated AMU. Field trials conducted in the Netherlands, France, and Denmark demonstrated that FMT reduced diarrhoea prevalence by 40% and increased the abundance of beneficial lactic acid bacteria. However, FMT did not entirely eliminate the need for antimicrobials, especially in high-stress weaning conditions. AVANT also revealed production barriers-some promising strains used in symbiosis were not scalable due to slow bacterial growth-and identified key societal and cost-effectiveness challenges. Surveys conducted by the project highlighted low consumer awareness and mixed acceptability, especially regarding FMT, and emphasised the need for clearer communication about alternatives to antibiotics.

> Our interview with the Project Coordinator found that the Netherlands trial was the first of its kind in pigs destined for slaughter and provided new safety and feasibility data, paving the way for regulatory engagement. Nevertheless, national regulatory inconsistencies across the EU remain a major bottleneck for uptake.

MOMIR-PPC focused on identifying microbiome and immune markers associated with "super-shedders" of zoonotic pathogens in pigs. The project found that a small subset of animals contributes disproportionately to pathogen and possibly AMR gene transmission. Although MOMIR-PPC did not track resistance genes directly, it provided methodological tools for stratifying animals by transmission risk, potentially useful for targeted AMU reduction strategies.

FARMCARE bridged host-microbiome understanding and environmental AMR risk by examining how improved animal welfare and reduced stress affect gut microbiota and ARG abundance. Using DNA sequencing of faecal and environmental samples, the project found preliminary evidence that less stressful housing and better hygiene correlated with reduced AMR gene prevalence. Although these results remain under analysis, they suggest that animal management practices can shape microbial dynamics in ways that support AMR mitigation.

Table 3. Key contributions to resistance in host-microbiome systems

Project	Key Contribution	Specific Outputs	AMR Relevance	Impact Type
SoA18	Microbiome-pathogen-immune interactions in livestock and aquaculture	Demonstrated diet-immunity-microbiome linkages; tracked HGT of *blaCTX-M*; aquatic biofilm resilience	Direct	Scientific and applied
CARTNET	Training on AMR evolution and microbiome-pathogen dynamics	Trained researchers on gene transfer, RNA therapies, phage biology, and anti-virulence strategies	Direct	Strategic and enabling
AVANT	Field trials of microbiota-based AMU alternatives in pigs	Demonstrated efficacy of FMT (40% diarrhoea reduction); identified regulatory and production bottlenecks; societal acceptability surveys conducted	Indirect	Applied with regulatory insight
MOMIR-PPC	Identifying super-shedders using microbiome and immune markers	Proposed biomarker panels for stratified AMU risk; did not measure resistance genes directly	Indirect	Surveillance insight

FARMCARE	Animal welfare and AMR gene prevalence in pig systems	Preliminary data show a correlation between reduced stress and lower ARG abundance in pig and environmental samples	Indirect	Operational

Source: Compiled by PPMI.

Overall, these projects show that interventions targeting microbial community structure, animal resilience, and host-pathogen ecology can have meaningful (even if sometimes indirect) effects on AMU and resistance evolution. They also highlight important gaps (or rather challenges)-particularly around scalability, regulatory frameworks, and long-term impact measurement- that must be addressed to fully integrate microbiome insights into AMR prevention policy.

4.1.5. Operational, social and systemic drivers

Projects in this cluster explore how AMR risk in the veterinary domain is shaped by decision-making dynamics, behavioural norms, economic incentives, and broader farm management systems. While these projects may not always focus directly on resistance genes or mechanisms, they play a vital role in understanding and addressing the root causes of AMU and identifying leverage points for more sustainable practices. Their relevance to understanding AMR lies in their contribution to systemic mapping of behaviours, implementation barriers, and context-sensitive interventions that reduce AMU across diverse livestock systems.

ROADMAP stands out for its systems-based approach to AMU behaviour. Through 12 Living Labs in 10 countries, the project mapped 73 structural "lock-ins" and 93 behavioural "hindrances" that limit reduction in the use of antimicrobials on farms. These ranged from economic dependencies on veterinary sales to social norms among peer farmers and inconsistent advisory systems. ROADMAP also demonstrated that interventions co-designed by farmers and veterinarians, and tailored to local production and policy contexts, are more likely to be adopted.

Although ROADMAP did not directly quantify resistance prevalence or isolate the effects of specific interventions such as hygiene or biosecurity, its Living Lab pilots demonstrated that participatory, systems-based approaches-combining improved farm management, advisory support, and behavioural change-can achieve measurable reductions in AMU across sectors. This offers indirect but evidence-backed contributions to AMR mitigation.

DISARM, in contrast, focused on community building and dissemination of AMR-reducing practices. It catalogued 137 on-farm innovations, hosted 80 dissemination events, and engaged over 600 stakeholders through a Community of Practice. Its flagship output, the Farm Health Team Toolbox, was piloted on 30 farms and provided qualitative evidence that cross-disciplinary collaboration (e.g. between farmers, vets, feed advisors) is key to reducing AMU without compromising animal health. Although DISARM did not deliver new experimental data, it filled a critical operational gap by making existing knowledge accessible and applicable. Its insights have informed EU FarmBook recommendations and several national advisory programmes.

SEFASI contributed with a systems modelling approach. It developed simulation tools to evaluate the transmission of AMR and the effect of control interventions at sectoral and policy levels. While its primary focus was not generating new biological data, SEFASI's work supports scenario planning, particularly around how behavioural interventions and regulatory shifts could influence resistance outcomes across animal and environmental compartments.

The portfolio also addresses the systemic drivers of anthelmintic resistance (AR), a challenge that parallels bacterial AMR. Projects like **COMBAR** (COST Action) and **SPARC TN** explored the intersection of technical, behavioural, and economic factors that drive the overuse of antiparasitic drugs. COMBAR's white paper, for instance, explicitly identified systemic gaps by calling for the integration of socio-economic research with biological innovation, a key operational driver for sustainable practice. Similarly, SPARC TN's work in promoting targeted treatments based on diagnostics addresses the systemic reliance on blanket drug use. These projects contribute to this cluster by providing strategic insights into the non-biological drivers of resistance, informing a more holistic and systems-aware approach to drug stewardship.

Together, these projects show that the path to reducing AMR is not solely technical but deeply embedded in economic, behavioural, and institutional structures. Interventions that ignore these realities may be poorly adopted or fail to scale. Understanding AMR thus requires not only identifying biological mechanisms but also addressing the systems within which antimicrobial decisions are made.

Table 4. Key contributions to understanding operational and systemic AMR drivers

Project	Key Contributions	Specific Outputs	AMR Relevance	Potential Impact
ROADMAP	Socio-economic and behavioural drivers of AMU	12 Living Labs; mapped 166 AMU barriers	Indirect	Applied and systemic
DISARM	Dissemination of good practices and multi-actor coordination	137 practices shared; Farm Health Toolbox piloted on 30 farms; ~600 stakeholders engaged	Indirect	Operational
SEFASI	Modelling AMR intervention scenarios	Developed One Health AMR transmission models; supported strategic policy planning	Indirect	Strategic
COMBAR	Policy and research coordination on anthelmintic resistance (AR)	White paper; integration of socio-economic and veterinary research agendas	Indirect	Policy enabling
SPARC TN	Targeted anthelmintic control in ruminants	Field evidence of 48-86% AR prevalence; promoted targeted grazing management and use of bioactive forages	Direct	Field operational

Source: Compiled by PPMI.

4.2. AMR/AMU surveillance & diagnostics

Surveillance and diagnostic capacity are central pillars in the fight against AMR and AMU stewardship. Projects under this theme span a wide spectrum of innovations, from molecular diagnostics and high-throughput field tools to genomic surveillance harmonisation and stewardship-enabling decision systems.

4.2.1. Molecular and genomic diagnostics

Projects in this cluster advanced the development of tools for detecting AMR at the genetic and physiological level, targeting resistance genes, mobile genetic elements, or specific pathogens across veterinary, environmental, and zoonotic interfaces. Their contributions span high-throughput sequencing, portable molecular assays, and early-stage biosensors, collectively enhancing Europe's capability for rapid, specific, and field-deployable diagnostics. These innovations are foundational to enabling earlier, more targeted antimicrobial use and improving stewardship outcomes, in alignment with One Health principles.

ANTHELMOGRAM contributed by developing a high-throughput larval motility assay for anthelmintic resistance screening. With a capacity for over 4,000 phenotyped samples per week, it allows robust phenotypic surveillance of helminth resistance and provides a gateway to future molecular diagnostics through marker identification. Field validation is ongoing, but foundational laboratory infrastructure is already in place. **WORLDCOM** produced highly practical outputs through LAMP-based diagnostics capable of detecting key resistance genes (e.g. *CTX-M*, *OXA*, *MCR*) in animal and environmental samples in under 20 minutes. Its smartphone-connected, field-applicable format enables on-site decision-making without the need for culture, particularly in low-infrastructure settings. Field trials on pig farms and in wastewater confirmed feasibility, though broader environmental validation is ongoing.

PHAGE STOP and **HARTEMIS** further advanced real-time molecular diagnostics. PHAGE STOP introduced CRISPR-Cas assays for plasmid-mediated AMR detection, while HARTEMIS developed CRISPR-Cas12a field kits to identify resistance-conferring mutations (e.g. *F200Y, Q134H*) in helminths with up to 98% specificity. These tools enable on-farm diagnostics that can guide treatment decisions and reduce unnecessary antimicrobial use. **FARMED** contributed at the diagnostic development level by demonstrating the feasibility of long-read metagenomic sequencing (e.g. using Nanopore platforms) to detect AMR genes in complex samples such as faeces and slurry. It addressed the challenge of interpreting genomic data in field conditions and developed harmonised workflows for accurate resistance gene detection. While not yet scaled for widespread application, these tools lay the groundwork for integrating genomics into field diagnostics. (FARMED's role in system-wide surveillance integration is discussed in Section 4.2.2.)

BM-FARM, while not a DNA-based diagnostic initiative, explored microbiome and salivary biomarkers as early-warning indicators of AMU-linked stressors. This indirect approach to diagnostics strengthens pre-emptive surveillance by flagging animal health risks before antimicrobial use rises. These tools require further validation but may complement conventional diagnostics in AMU monitoring systems. **METABOLAR** developed a prototype metabolite-based assay to detect benzimidazole resistance in gastrointestinal nematodes. The assay was tested across different European climates to assess environmental performance, but its diagnostic accuracy and field applicability remain to be confirmed through additional trials.

Finally, **Biosens4PrecisionMastitis** is advancing the frontier of on-farm diagnostics by developing innovative channel-based biosensors for the early and accurate detection of bovine mastitis. This project's core contribution lies in identifying and targeting specific biomarkers of the cow's early immune response, such as *miRNAs*, *cytokines*, and antimicrobial peptides, enabling detection before widespread infection. It has made significant progress in developing label-free electrochemical detection methods, including a new porous silicon (*pSi*) nanostructured transducer that outperforms commercial electrodes, with 35% detection achieved in buffer and plans for milk sample testing.

Table 5. Key contributions to molecular and genomic AMR diagnostics

Project	Key Contributions	Est. TRL	AMR Relevance	Potential Impact
FULL-FORCE	FFPA-pipeline for plasmid sequencing and cross-sector harmonisation	TRL 6–7	Direct	Enables intersectoral AMR tracking; pending broader regulatory uptake
WORLDCOM	Portable LAMP assay detecting AMR genes with 20-min turnaround	TRL 7–8	Direct	Improves field diagnostics in low-infrastructure settings
PHAGE STOP	CRISPR diagnostics for plasmid-mediated AMR-monitoring	TRL 5–6	Direct	Potential for real-time resistance gene mapping at the farm level
HARTEMIS	CRISPR-Cas12a for SNP detection; miRNA biomarkers as resistance proxies	TRL 6–7	Direct	Enables early intervention in helminth control
FARMED	Long-read metagenomics for AMR gene detection and field data interpretation	TRL 5	Direct	Supports genomic detection in complex samples; basis for future field diagnostics
ANTHELMOGRAM	High-throughput larval phenotyping supports marker identification	TRL 5–6	Indirect	Provides a foundation for molecular diagnostic development for helminth resistance
BM-FARM	Biomarker-based early warning indicators for AMU-linked stressors	TRL 4–5	Indirect	May support AMU monitoring through animal health indicators; requires broader testing
METABOLAR	Metabolomic test prototype for benzimidazole resistance	TRL 4	Indirect	Concept-stage innovation with potential for climate-adapted field diagnostics
Biosens4Precision Mastitis	Channel-based biosensors for early mastitis detection via immune biomarkers.	TRL 4-5	Direct	Enables precision treatment, significantly reducing unnecessary AMU in dairy farming; supports animal welfare.

Source: Compiled by PPMI.

Looking forward → Emerging technologies such as those explored in TechPEPCon, which investigated peptide-based biosensor platforms, may offer future potential for rapid AMR detection, though their readiness for field application remains low.

These diagnostic innovations form a critical pipeline of tools that can support more precise, responsive antimicrobial use across animal health systems. While many of the technologies remain under validation, they represent an important shift toward on-farm, field-ready, and genomically informed diagnostics. These tools are not intended to replace system-wide surveillance frameworks but to complement them by making resistance detection more immediate and actionable at the point of care

4.2.2. Harmonisation and integration of AMR surveillance systems

Effective AMR surveillance requires not only advanced diagnostic tools but also an integrated and harmonised infrastructure that ensures data is comparable, shareable, and policy-relevant across Europe. The projects in this cluster provide the essential infrastructural backbone: from laboratory protocols to computational pipelines, for a modern, One Health AMR surveillance system.

A key challenge is harmonising laboratory methods. **IMPART**, part of the One Health EJP, played a foundational role by establishing validated antimicrobial susceptibility testing (AST) protocols for veterinary pathogens like *Clostridium difficile*. By contributing to the development of veterinary ECOFFs, its tools directly feed into national and EU-level surveillance efforts, making data generation more standardised.

Beyond standardising lab tests, a robust digital and genomic infrastructure is needed to track resistance genes across sectors. **SPAMR-VET (SoA8)** addresses this by creating genomic monitoring hubs that integrate whole-genome sequencing (WGS) data from over 12 EU countries to track AMR gene transmission. Its pilot metagenomic analyses also reveal resistome-microbiome associations, enabling wildlife to be used as sentinels for environmental AMR spread.

To translate this vast amount of data into actionable policy, **ARDIG** and **RADAR** developed computational frameworks to integrate veterinary and environmental surveillance datasets. RADAR's Food Safety Knowledge/FAIR Scientific Knowledge eXchange model and COMPASS plasmid database are now used by agencies like EFSA to improve the reproducibility of risk-based modelling. Finally, to enable more decentralised surveillance, **FULL-FORCE** and **FED-AMR** developed advanced sequencing protocols and pipelines for tracking mobile genetic elements. The FULL-FORCE Plasmid Assembler Pipeline (FFPA), for instance, equips laboratories to track plasmid-level AMR. Complementing this, the **FARMED** project piloted the use of field-deployable MinION metagenomic workflows, representing a significant technical step toward integrated, real-time AMR surveillance outside of traditional laboratories.

Case example of FULL-FORCE

The FULL-FORCE project developed the FFPA (Full Force Plasmid Analysis) pipeline, an open-source bioinformatics workflow designed to enhance plasmid sequencing and AMR gene tracking across human, animal, and environmental compartments. This tool enables h**armonised analysis of plasmid-mediated resistance**, which is particularly relevant for One Health surveillance, given the mobility of resistance genes across species and sectors.
FFPA supports standardisation in the detection and classification of resistance plasmids and has been tested in inter-laboratory settings, demonstrating strong reproducibility and utility for regulatory science.
Although still awaiting formal integration into EU surveillance infrastructures, the FFPA pipeline **offers a practical platform for cross-sector genomic data exchange** and could play a pivotal role in the development of EU-wide monitoring protocols for mobile AMR determinants.

Together, these projects mark a substantial leap toward coordinated, interoperable AMR/AMU surveillance across Europe. However, a number of barriers remain, such as sensitivity limitations in field-ready genomics tools, uneven diagnostic capacity across Member States, and underrepresentation of minor species and extensive systems in harmonised protocols.

Table 6. Key contributions to harmonisation and integration of AMR surveillance systems

Project	Key Contributions	Est. TRL	AMR Relevance	Potential Impact
IMPART	Harmonised AST protocols; validated disk diffusion methods; veterinary ECOFFs	Protocols validated, VetCAST adoption (TRL 7–8)	Direct	Improves cross-sector comparability of resistance data; supports integrated surveillance.
SPAMR-VET (SoA8)	Genomic monitoring hubs using WGS data; metagenomic surveillance protocols	Protocols deployed in 12 EU countries (TRL 5-7)	Direct	Fosters inter-compartment AMR tracking and provides early warnings of environmental AMR spread.
ARDIG	Computational integration of veterinary and environmental surveillance datasets	Models developed; policy integration ongoing (TRL 6–7)	Direct	Improves One Health surveillance data synthesis; informs evidence-based policy.
RADAR	FSK model exchange standard; COMPASS plasmid database; One Health attribution models	Models and databases operational; EFSA alignment (TRL 7–8)	Direct	Enhances transparency and regulatory uptake of AMR risk models.
FULL-FORCE	Plasmid assembler pipeline (FFPA); harmonised sequencing protocols	Protocols operational; data-sharing in place (TRL 7–8)	Direct	Strengthens mobile genetic element surveillance; improves cross-border AMR tracking.
FED-AMR	Sequencing pipelines for mobile resistance elements; environmental AMR surveillance strategies	Research outputs; pilot data available (TRL 5–6)	Direct	Builds capacity for environmental integration into AMR surveillance; supports cross-reservoir analysis.
FARMED	Field-deployable MinION metagenomic workflows	Piloted on farms; refinement needed (TRL 5–6)	Direct	Enables real-time, on-site AMR/pathogen surveillance; complements lab-based systems.

Source: Compiled by PPMI.

4.2.3. Phenotypic testing, interpretation, and cut-offs

This cluster includes projects that address fundamental gaps in the consistency, comparability, and accuracy of antimicrobial susceptibility testing (AST) for veterinary pathogens. These efforts are crucial for interpreting resistance trends, guiding treatment decisions, and informing policy responses. Unlike purely genomic diagnostics, phenotypic methods remain the regulatory standard for AMR confirmation and therefore require harmonisation across countries and sectors.

IMPART made one of the most substantial contributions to this domain by harmonising phenotypic AST methods across veterinary and public health laboratories in Europe. It addressed methodological inconsistencies through:

- Development of ECOFFs for *Pasteurella multocida* and *Mannheimia haemolytica*, now adopted by VetCAST, providing clear breakpoints for interpretation across labs.
- Validated detection protocols for colistin-resistant *E. coli* and *Salmonella spp.*, achieving ~90% accuracy across a European multi-lab study.
- Improved phenotypic detection of carbapenem-resistant *Enterobacterales* (CPE), though the project noted limitations for low-level producers in their final report.
- Harmonised *Clostridium difficile* disk diffusion protocols, which were validated across human, animal, and environmental isolates.

These outputs advance not only methodological clarity but also ensure surveillance data from diverse settings is comparable. The projects are being integrated into surveillance platforms.

EUPAHW BETO (SoA12) is focussing heavily on diagnostic platform harmonisation and quality assurance. While broader in scope than AMR alone, it included AMR-specific deliverables, such as:

- Validation of broth microdilution assays for *Campylobacter* spp., ensuring EU-wide comparability in resistance monitoring.
- Standardised multiplex qPCRs for co-detection of respiratory pathogens in pigs, intended to reduce empirical antimicrobial prescribing due to misdiagnosis.
- Collaborative development of FAIR-compliant (Findable, Accessible, Interoperable, Reusable) AMR diagnostics across 30 institutes in 16 countries.

Its coordinated inter-lab trials and protocol dissemination strongly support EU ambitions to align veterinary AMR diagnostics with EARS-Vet and EU-JAMRAI standards.

ENOVAT, a COST Action, supported this cluster by generating shared interpretive criteria:

- Defined new clinical breakpoints (CBPs) and ECOFFs for under-monitored pathogens through consensus.
- Facilitated the development of the CAMiProt strain repository and diagnostic harmonisation across member labs.
- Supported training workshops on harmonised AST methods, embedding harmonisation into veterinary education and practice.

While it does not directly implement diagnostics, ENOVAT is a key enabler of quality control and convergence in AMR detection across EU states.

These projects collectively strengthen the foundations of AMR surveillance in Europe by ensuring that laboratories across countries test for antimicrobial resistance in the same way and interpret the results using common standards. By agreeing on which resistance levels matter (through ECOFFs and clinical breakpoints), and by using consistent testing protocols, we can make resistance data more reliable and comparable. This is essential for tracking AMR trends, informing treatment guidelines, and guiding EU policy.

The next step would be to advocate that these tools and standards are adopted widely, especially in countries with fewer resources or infrastructure, and fully integrated into EU-wide surveillance systems.

4.2.4. On-farm and field-ready surveillance tools

This cluster includes projects that bring AMR surveillance directly to the point of need: farms, veterinary practices, and field settings with limited laboratory access. These initiatives aim to reduce diagnostic delays, support real-time treatment decisions, and enable earlier identification of resistance trends in agricultural environments. By making surveillance more accessible and faster, these tools help reduce the need for prophylactic antimicrobial use and improve antimicrobial stewardship in practice.

WORLDCOM made a major contribution to portable AMR diagnostics by developing a field-ready loop-mediated isothermal amplification (LAMP) assay capable of detecting critical resistance genes, such as *blaCTX-M*, *mcr*, and *OXA variants* within 20 minutes. This test requires no prior culture and can be performed directly on faecal or water samples. A mobile phone app was developed to read and transmit results, enabling real-time data integration. While pilot testing on pig farms and in environmental samples showed high promise, further evaluation is needed in more complex matrices to confirm sensitivity under diverse field conditions.

PHAGE STOP and HARTEMIS advanced the use of CRISPR-based diagnostics for detecting antimicrobial and anthelmintic resistance, respectively. PHAGE STOP PHAGE STOP designed CRISPR-Cas assays for detecting *blaCTX-M* and *tetA* genes on-farm, enabling real-time tracking of plasmid-borne resistance. These tools are at the proof-of-concept stage, with field validation pending. HARTEMIS aims to develop sustainable strategies to monitor and control *Haemonchus contortus* resistance to macrocyclic lactones in sheep and goats. The project focuses on understanding resistance mechanisms, especially in the context of climate change, and on generating predictive models and farm-level interventions. It collects resistant and susceptible parasite strains from across Europe and develops experimental tools for resistance tracking and drug efficacy prediction. While field-deployable diagnostics are not yet part of the project's deliverables, its foundational work supports future development of on-farm tools to detect and prevent anthelmintic resistance.

FARMED piloted the use of portable metagenomic sequencing (MinION devices) for on-site AMR gene detection. The project established field-ready workflows from DNA extraction to analysis for pig farms and clinical environments. Although the method holds great potential to identify resistance directly from mixed microbial communities, the project identified important limitations, including detection sensitivity in low-abundance pathogens and the need for high-quality reference databases. Nonetheless, FARMED demonstrated that real-time sequencing could feasibly support future AMR surveillance outside of traditional laboratories, especially if further validated.

Table 7. Key Contributions to On-Farm and Field-Ready AMR Surveillance Tools

Project	Key Contributions	Use Context	Est. TRL	AMR Relevance	Validation Status / Potential Impact
WORLDCOM	LAMP-based assay for AMR genes; smartphone app	Pig farms, water, soil	TRL 7–8	Direct	Validated in pilot farms; potential for low-infrastructure deployment
PHAGE STOP	CRISPR-Cas assay for *blaCTX-M*, *tetA*	On-farm AMR detection	TRL 5–6	Direct	Proof-of-concept stage; pending field validation
HARTEMIS	Resistance monitoring and predictive modelling for *H. contortus* in sheep/goats	Sheep farms (Spain, France, Poland)	TRL 3–4	Indirect	Tools under development; predictive models and farm strategies proposed; field diagnostics not yet validated
FARMED	Portable metagenomics (MinION); real-time bioinformatics for AMR detection	Pig farms, clinical settings	TRL 5	Direct	Piloted with limitations noted (e.g., low-abundance gene sensitivity, database quality)

Source: Compiled by PPMI.

Collectively, these projects demonstrate that field-ready diagnostics, from simple visual assays to advanced genetic tests, are moving closer to operational deployment. They offer new avenues for integrating surveillance into daily animal health practices, improving antimicrobial decision-making at its source. However, further steps are needed to ensure validation across diverse production systems, regulatory acceptance, and affordability for end users.

4.2.5. Stewardship support and risk-based targeting

Projects in this cluster underpin AMR mitigation by supporting smarter, evidence-based AMU decisions, not through new molecular tools, but by improving how data, diagnostics, and risk profiles are used to guide interventions. Their common thread is the development of frameworks, guidance, and systems that enable more targeted treatments, reduce metaphylactic use, and promote responsible AMU at farm and veterinary practice levels. These efforts are central to strengthening antimicrobial stewardship across Europe and building institutional capacity for One Health risk management.

DECIDE is particularly notable for integrating disease prioritisation with AMU impact modelling. The project developed a multi-criteria decision analysis (MCDA) framework to rank endemic livestock diseases by their potential for AMU reduction if better managed. This allowed the design of tailored control strategies for cattle, poultry, and pigs. While the focus was not AMR surveillance per se, DECIDE contributes to upstream AMR mitigation by targeting disease drivers of antimicrobial use, including metrics for socio-economic trade-offs. The tool has been piloted across several EU countries and is undergoing further adaptation for national animal health planning.

Case example of DECIDE

The DECIDE project introduces **an innovative framework that directly underpins AMR mitigation by developing data-driven decision support tools**. This framework uniquely enables authorities to identify which animal diseases are most critical to control based on a multidimensional burden of disease metric, specifically factoring in their contribution to AMU, economic burden, and animal welfare implications. DECIDE directly supports AMR strategies by linking disease surveillance data to AMU patterns, which in turn helps governments and veterinary authorities tailor national disease control programmes under the Animal Health Law. This systematic prioritisation **allows for more targeted interventions and promotes responsible AMU at farm and veterinary levels** across Europe.

The benefits are manifold:

- It helps governments and veterinary authorities target surveillance and resources where they matter most.
- Significantly reduces unnecessary use of antibiotics by controlling key diseases earlier.
- Provides ready-to-use models that can be applied across different livestock sectors, including pigs, poultry, cattle, and salmonids.
- Ultimately, this contributes to a more sustainable animal production system and builds institutional capacity for One Health risk management.

ENOVAT, while also classified under diagnostics, directly supports stewardship by establishing evidence-based antimicrobial treatment guidelines for veterinary use across Europe. Using the GRADE methodology, the project produced harmonised treatment recommendations and has promoted uptake through workshops and publications targeting veterinary professionals. This is a major step toward aligning clinical practice with surveillance evidence, which is a gap long identified in European AMR policy discussions. ENOVAT also mapped diagnostic capacity and treatment variability across countries, revealing critical inconsistencies that hinder rational AMU.

SPARC TN complements this by embedding diagnostics within decision-support platforms. It promotes the use of targeted anthelmintic treatment (e.g., FEC tests), contributing to reduced blanket AMU and more precise drug use. SPARC's advisory modules and risk maps are being integrated into digital farm management tools, enabling real-time feedback to veterinarians and farmers. The project's emphasis on translating resistance data into practical action is a key value-added.

IMPART and **EUPAHW** BETO (SoA12) also indirectly support stewardship by improving the accuracy and interpretability of AST results. IMPART developed new interpretative criteria (e.g., ECOFFs, disk diffusion protocols) for veterinary pathogens like *Clostridium difficile* and *Pasteurella multocida*, while **BETO** is advancing FAIR-compliant diagnostic platforms, linking test results to clinical action thresholds. While these outputs are largely laboratory-based, their downstream impact lies in enabling trustworthy treatment decisions aligned with resistance risks.

BM-FARM, though focused on pig production, supports stewardship by identifying early warning signs of disease risk before AMU is needed. It combines stress biomarkers and microbiome data to predict when animal health is deteriorating. This allows farmers to intervene with management changes rather than prophylactic antimicrobials.

Though still under validation, this approach points toward the use of preventive, data-driven interventions as a pillar of responsible AMU.

COMBAT and **COMBAR**, both operating at the livestock–vector interface, contribute to risk-based targeting through updated maps of resistance (e.g., tsetse distribution in Africa; helminth resistance across Europe) and field-deployable diagnostic guides. While not centred on bacteria, they reinforce the broader AMR logic by reducing reliance on antiparasitic (another class of resistance-prone drugs) and promoting strategic treatment based on infection pressure.

Overall, projects under this cluster reflect a policy-relevant shift from AMU reduction through restriction alone, to smarter use informed by diagnostics, risk assessments, and stewardship tools. Many of these projects are operationally mature and ready for broader integration into veterinary training, advisory systems, and national action plans.

4.3. Disease surveillance & diagnostics

Effective monitoring of infectious diseases is an important pillar of AMR mitigation. By enabling early detection, accurate diagnosis, and strategic interventions, advanced surveillance systems can reduce the overall disease burden in livestock, thereby decreasing the pressure for antimicrobial use. The projects in this portfolio contribute to a multi-layered and modernised European surveillance ecosystem, spanning from harmonising laboratory standards to developing predictive, data-driven tools for proactive disease control.

4.3.1. Foundational capacity and harmonisation

An essential for effective European-wide disease surveillance is the standardisation of diagnostic methods and data. Several projects within the analysed portfolio focused on building this foundational capacity, creating the frameworks and infrastructure necessary for coherent, cross-border monitoring.

The **ENOVAT** COST Action played a critical role by harmonising the entire diagnostic workflow across nearly 300 veterinary laboratories. This included developing standardised protocols for bacterial identification and AST, creating shared reference strain libraries, and establishing interpretive criteria like epidemiological cut-off values (ECOFFs). By connecting these harmonised diagnostics to clinical practice through its GRADE-based treatment guidelines, ENOVAT ensures that data generated across different Member States are consistent, comparable, and can inform rational antimicrobial use.

Similarly, **the EUPAHW project BETO (SoA12)** pioneered the harmonisation of diagnostic workflows for major infectious diseases in pigs. A box below presents the case example of **BETO** in this domain.

Case example of
Beto better tools for diagnosis of infectious diseases BETO (SoA12)

One of the most impactful initiatives is the BETO (SoA12) project, which has pioneered the harmonisation of diagnostic workflows for major infectious diseases in pigs. It validated multiplex qPCR panels with over 95% sensitivity for simultaneous detection of key respiratory pathogens, enabling earlier and more targeted interventions.
This not only improves clinical outcomes but also reduces empirical use of broad-spectrum antibiotics. Additionally, BETO developed FAIR-compliant diagnostic protocols that were co-developed and tested across 30 laboratories in 16 countries, laying the foundation for future Europe-wide surveillance networks.
These contributions are particularly relevant for improving standardisation in veterinary diagnostics-a known gap in transnational disease monitoring.

In parallel, the **VETBIONET** project strengthened the EU's physical infrastructure for surveillance. As a network of high-containment (*BSL-3*) facilities, it enhances the capacity to study epizootic and zoonotic pathogens. By developing shared infection models and harmonised biosafety protocols for high-impact diseases, VETBIONET provides the essential infrastructure needed to develop and validate the next generation of surveillance tools safely. Together, these projects build the bedrock of a modernised European surveillance system, enabling other initiatives to focus on technological innovation and predictive analytics, which are discussed in the following sections.

The table below summarises some of the most notable diagnostic innovations and harmonisation achievements emerging from this project cluster. These examples showcase how EU-funded research has advanced not only technical detection tools but also the interoperability of diagnostic data across countries, laboratories, and production sectors. These examples collectively illustrate the breadth of progress achieved across the cluster.

Table 8. Key contributions to harmonisation and innovation in veterinary disease diagnostics

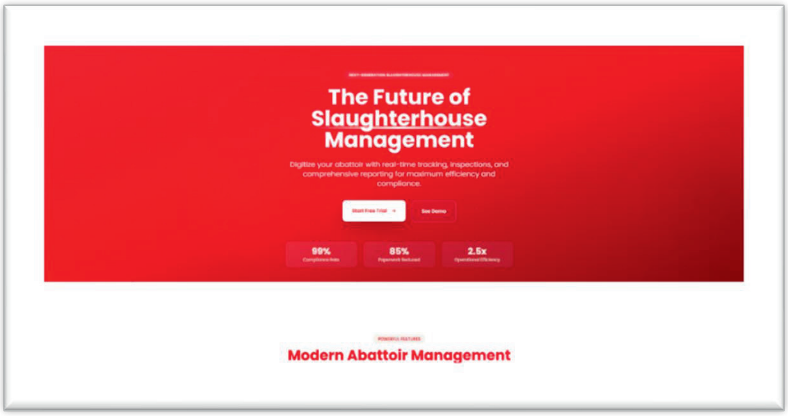
Project	Key contributions	Est. TRL	AMR Relevance	Potential Impact
BETO (SoA12)	Multiplex qPCR panels for pig respiratory diseases; FAIR-compliant diagnostic workflows	Validated across 30 labs in 16 countries (TRL 7-8)	Indirect	Enables earlier, targeted interventions; supports Europe-wide standardisation
ENOVAT	Harmonisation of AMR diagnostics (ECOFFs, CBPs); Europe-wide treatment guidelines (GRADE)	Guidelines adopted by 290 labs; protocols in use (TRL 8)	Direct	Ensures cross-border diagnostic comparability; informs rational AMU decisions
VETBIONET	Network of BSL-3 facilities; harmonised biosafety protocols; shared infection models	Operational; protocols in use (TRL 8–9)	Indirect	Enhances EU capacity for zoonotic disease research; strengthens outbreak preparedness

Source: Compiled by PPMI.

4.3.2. Predictive surveillance and risk-based disease monitoring

A notable strategic shift in the portfolio is the move from reactive, symptom-driven surveillance to predictive, risk-based models that identify threats before outbreaks occur. These efforts are crucial for enabling more targeted disease control and reducing blanket antimicrobial use.

The **DECIDE** project is one of the most advanced in this area. It developed a data-driven decision support dashboard, Abattoir Inspect, which uses anomaly detection algorithms on slaughterhouse data to flag emerging disease risks early.



Its predictive models for major diseases like bovine respiratory disease integrate weather, management, and biological data to simulate outcomes and compare control strategies, transforming how authorities can plan disease control. This approach is complemented by the SAPHIR project, which used mathematical models to predict vaccine effectiveness under different outbreak scenarios for PRRSV and Eimeria, helping farmers and veterinarians make more informed, proactive decisions on vaccination.

According to the interview with the Project Coordinator, DECIDE's experience shows that farmers prefer simple dashboards over complex early warning systems, and that data-sharing and privacy concerns limit the integration of slaughterhouse data across countries. Policymakers show limited interest in endemic disease tools unless AMU/AMR is directly addressed, underscoring the importance of aligning digital innovations with stakeholder needs and regulatory frameworks.

This predictive capability is broadened by projects that expand surveillance beyond the individual farm. **The EUPAHW project SPAMR-VET (SoA8)** expands its epidemiological scope by monitoring the presence of pathogens across healthy animals, wildlife, and environmental reservoirs. Its use of metagenomic techniques provides systemic early warnings for pathogen emergence, helping to shift veterinary surveillance from a reactive to a more predictive, systems-based approach. The **COMBAT** project adds further value through detailed risk mapping of vector-borne diseases like *African Animal Trypanosomosis*, using advanced genomic profiling to identify disease hotspots and prioritise resources.

Other projects focus on identifying animal-level risk factors and biomarkers. For instance, **PIGSs** advanced risk-based surveillance by identifying specific farm conditions and co-infections (e.g., *PRRSV*) that trigger outbreaks of *Streptococcus suis*, enabling more targeted monitoring. Similarly, **MoMIR-PPC** introduced a novel approach of identifying potential "super-shedders"- animals likely to spread infection widely using gut microbiota and immune markers (also mentioned under the 4.1. Understanding AMR section). This allows for selective, targeted interventions instead of whole-herd treatments. Finally, **TechPEPCon** links environmental monitoring to disease surveillance by combining real-time detection of respiratory pathogens with environmental sensor data, allowing producers to adjust farm management proactively before disease spreads.

Collectively, these initiatives demonstrate a clear evolution toward integrated, data-driven surveillance systems that anticipate rather than react to disease threats. By combining predictive modelling, environmental monitoring, and targeted risk assessment, they offer a pathway to more sustainable disease control, reducing antimicrobial use while aligning interventions with real-world farming and policy contexts.

Table 9. Key contributions to predictive surveillance and risk-based disease monitoring

Project	Key contributions	Est. TRL	AMR Relevance	Potential Impact
DECIDE	Abattoir Inspect dashboard using slaughterhouse data; predictive disease models	The dashboard has moved beyond laboratory validation and is functioning as a demonstration tool with stakeholders, allowing real-world scenario testing and user interaction via https://abattoir.app/. (TRL 6–7)	Indirect	Provides early warning on herd health trends; supports targeted interventions and reduces prophylactic AMU
SPAMR-VET (SoA8)	Harmonised metagenomic surveillance protocols across wildlife, livestock, and environment	Protocols deployed in 12 EU countries (TRL 5-7)	Direct	Provides predictive early warning of pathogen emergence and AMR spread
SAPHIR	Mathematical models predicting vaccine effectiveness under different outbreak scenarios	Modelled; applied to PRRSV, Eimeria (TRL 5–6)	Indirect	Informs vaccination strategies; reduces reliance on antibiotics by enhancing *immunoprophylaxis*
COMBAT	Pan-African tsetse distribution atlas; vector competence modelling	Completed; (TRL 7–8)	Indirect	Supports targeted vector control; avoids unnecessary drug use; model transferable to EU vector threats
PIGSs	Global GWAS database of S. suis; identification of co-infection risk amplifiers (e.g., PRRSV)	Database established; co-infection dynamics analysed (TRL 6–7)	Indirect	Enables risk-based S. suis surveillance; informs selective treatment strategies
MoMIR-PPC	Biomarkers for predicting "super-shedder" status using gut microbiota and immune profiles	Early validation; candidate markers identified (TRL 4–5)	Indirect	Supports stratified monitoring and selective interventions; reduces broad antimicrobial application
TechPEPCon	Real-time integration of environmental sensor data with pathogen detection in pigs	Proof of concept demonstrated (TRL 4–5)	Indirect	Enables proactive environmental management to reduce disease pressure; lowers need for reactive AMU

Source: Compiled by PPMI.

4.3.3. Pathogen-specific surveillance and zoonotic threat monitoring

This thematic cluster focuses on projects that enhance the surveillance of priority pathogens with zoonotic potential, improving early detection and risk assessment. Their combined results provide essential tools for managing infectious threats at the animal-human interface. This is a critical component of AMR mitigation, as zoonotic pathogens often drive high antimicrobial use.

REPRODIVAC exemplifies high-level innovation in this area by targeting major reproductive diseases. The project developed DIVA (Differentiating Infected from Vaccinated Animals) diagnostic tools for pathogens such as *Brucella suis, Coxiella burnetii*, and *Chlamydia abortus*. This specificity is critical in outbreak scenarios, as it allows for accurate identification of infected animals, thereby preventing the misclassification that could otherwise lead to mass antimicrobial administration.

Similarly, **PIGSs** tackled *Streptococcus suis*, a leading cause of sepsis in piglets and a major reason for metaphylactic AMU in European pig farms. The project developed rapid, PCR-based diagnostics for virulent strains and created a global genomic database of over 3,000 isolates. These tools enhance our understanding of disease risk dynamics and support more targeted interventions, reducing both infection rates and reliance on antibiotics.

For zoonotic threats at the food chain level, **VIVALDI** focused on validating the VETPOD point-of-care system, capable of detecting *Salmonella*, *Campylobacter*, and Avian Influenza Virus. By enabling rapid, on-site detection, VIVALDI facilitates faster decision-making in outbreak settings, which can reduce empirical antibiotic use and improve response times. Finally, **the EUPAHW project KNOW-PATH (SoA11)** delivers important diagnostic innovations by identifying novel host biomarkers through RNA sequencing. These tools help assess host-pathogen interaction dynamics across multiple production sectors, strengthening disease risk modelling and early detection efforts for a range of priority pathogens. Collectively, these projects reinforce Europe's ability to monitor zoonotic disease threats with greater accuracy and speed. Their tools support earlier detection, more tailored interventions, and ultimately reduce AMU through more precise management of emerging and endemic pathogens.

Table 10. Key contributions to pathogen-specific surveillance and zoonotic threat monitoring

Project	Key contributions	Est. TRL	AMR Relevance	Potential Impact
REPRODIVAC	DIVA-compatible and point-of-care diagnostics for reproductive diseases (*Brucella, PRRSV, etc.*)	Early validation (TRL 5-6)	Indirect	Reduces unnecessary antibiotic use in outbreak settings by accurately identifying infected animals.
PIGSs	Strain-specific PCR diagnostics for *Streptococcus suis*; global GWAS database (3,000+ isolates)	Validated in 30 farms; global database operational (TRL 7)	Indirect	Supports precision treatment; reduces metaphylactic antibiotic use for a major pig pathogen.
VIVALDI	VETPOD point-of-care system for detecting *Salmonella*, *Campylobacter*, and Avian Influenza Virus	Validated and certified for *Salmonella* (TRL 7-8)	Indirect	Enables faster, on-site outbreak confirmation for key zoonotic threats, reducing empirical AMU.
KNOW-PATH (SoA11)	Identification of novel host biomarkers (via RNA sequencing) to assess host-pathogen interactions	Ongoing (TRL 4-5)	Indirect	Strengthens disease risk modelling and early detection for priority pathogens across multiple species.

Source: Compiled by PPMI.

4.3.4. Disease surveillance infrastructure and capacity building

Effective disease surveillance relies on robust infrastructure, from high-containment laboratories to coordinated networks and harmonised diagnostic platforms. The projects in this cluster provide the foundational capacity that underpins Europe's ability to monitor and respond to animal health threats, which indirectly supports AMR mitigation by reducing overall disease pressure.

VETBIONET is central to this effort. As a network of high-containment (BSL-3) facilities, it strengthens the EU's physical infrastructure for studying epizootic and zoonotic pathogens. By developing shared infection models and harmonised biosafety protocols, VETBIONET provides the essential capacity needed to safely develop and validate the next generation of surveillance tools.

This physical infrastructure is complemented by projects that build coordinated diagnostic and monitoring networks. The EUPAHW project **BETO (SoA12)** made a strong contribution by coordinating 30 institutions across 16 countries to co-develop FAIR-compliant diagnostic workflows. The **ENOVAT COST Action** created an extensive network of nearly 300 veterinary laboratories, building shared strain collections and harmonising diagnostic criteria. Together, these initiatives strengthen Europe's core capacity to detect and respond to animal health threats. By building connected networks and harmonised platforms, they provide a resilient foundation for future surveillance and AMR mitigation.

Table 11. Key contributions to disease surveillance infrastructure and capacity building

Project	Key Contributions	Est. TRL	AMR Relevance	Potential Impact
VETBIONET	Network of BSL-3 facilities; harmonised biosafety protocols; shared infection models	Operational; protocols in use (TRL 8–9)	Indirect	Enhances EU capacity for zoonotic disease research; strengthens outbreak preparedness.
BETO (SoA12)	FAIR-compliant diagnostic workflows; multiplex qPCR panels validated across 30 labs in 16 countries	Multiplex panels validated; network established (TRL 7–8)	Indirect	Enables standardised diagnostics across Europe; underpins harmonised animal disease monitoring.
ENOVAT	Harmonised diagnostic criteria (ECOFFs, SOPs); EU-wide survey of 290 labs; shared strain collections	Guidelines and SOPs produced; online (TRL 7–8)	Indirect	Strengthens diagnostic comparability and stewardship infrastructure; supports EU-wide coordination.

Source: Compiled by PPMI.

4.3.5. Disease risk profiling and syndromic surveillance

This cluster comprises projects that move beyond traditional pathogen detection to predict disease risks and enable earlier, more targeted interventions**.** These initiatives often combine diverse data sources, such as abattoir records, environmental factors, or animal-level biomarkers, with modelling and decision-support tools to enhance strategic disease prevention.

DECIDE is a key project in this area. As detailed in the previous section on predictive surveillance, its *Abattoir Inspect* dashboard repurposes existing slaughterhouse data to provide early warnings of health problems at a regional level. This syndromic approach, specifically by monitoring for signs of disease rather than specific pathogens, allows authorities to detect subclinical outbreaks and emerging threats before they escalate, offering a powerful tool for strategic, large-scale disease management.

At the farm level, other projects have developed innovative risk-profiling tools. **BM-FARM** took a novel approach by integrating biomarker and microbiome data from saliva and faecal samples to detect subclinical health disturbances likely to lead to increased antimicrobial use. Its machine-learning models identify early warning signs, enabling a shift from reactive to preventive health management.

For parasite control, **SPARC TN** developed a decision-support tool for evidence-based anthelmintic use. By incorporating epidemiological data (e.g., faecal egg counts) and farm records into treatment algorithms, it helps farmers move away from routine blanket treatments, a major driver of resistance. While less technologically complex than other projects, its practical, user-friendly tools have strong relevance for reducing drug reliance in grazing systems.

In sum, these projects signal a shift in EU disease surveillance towards predictive, risk-based systems that:

- Use routine or passive data (e.g., abattoir records, biomarkers) to detect anomalies before full-blown outbreaks occur.
- Support farm-level decision-making with user-facing tools (e.g., SPARC TN, BM-FARM).
- Enable more strategic, resource-efficient deployment of surveillance and disease control interventions.

Their outputs, while sometimes still in validation, represent a tangible upgrade to Europe's disease preparedness toolkit, particularly in the context of resource constraints and increasing pathogen complexity. These examples collectively illustrate the breadth of progress achieved across the cluster.

Table 12. Key contributions to Disease Risk Profiling and Syndromic Surveillance

Project	Key Contributions	Est. TRL	AMR Relevance	Potential Impact
DECIDE	*Abattoir Inspect* dashboard for syndromic surveillance using slaughterhouse data	(TRL 6–7)	Indirect	Uses passive data to detect emerging disease risks at a regional level, enabling early intervention.
BM-FARM	Biomarker and microbiome-based health risk profiling for AMU early warning	Implementation ongoing on 60 farms (TRL 6)	Indirect	Enables farm-level preventive health management by detecting subclinical disease risk.
SPARC TN	Decision-support tool for evidence-based anthelmintic use using epidemiological data	Dissemination phase; tools in use (TRL 7)	Direct	Promotes targeted treatment and reduces blanket drug use, a major driver of anthelmintic resistance.

Source: Compiled by PPMI.

4.4. AMU Stewardship

Antimicrobial stewardship ensures that antimicrobials are used only when necessary and in the most appropriate way to preserve their effectiveness. This requires moving from routine treatments toward evidence-based approaches that protect both animal and public health. The projects in this cluster contribute by creating the essential diagnostic, policy, and economic frameworks that enable smarter stewardship.

A cornerstone of stewardship is having clear, evidence-based guidelines for treatment. **ENOVAT** is a major force in this area, having harmonised veterinary treatment guidelines across Europe using the rigorous GRADE methodology.

According to ENOVAT's coordinator, while evidence-based treatment guidelines and harmonised diagnostics have been developed, real-world adoption is still in early stages. ENOVAT has established a veterinary subgroup in the GRADE network and is planning a guidelines centre, indicating ongoing capacity-building. A key gap identified is the lack of clinical studies to underpin guideline development, highlighting the need for more solution-oriented research funding.

While guidelines provide the "what," **ROADMAP** explored the "why" behind stewardship decisions on the ground (as also discussed in the "Understanding AMR" chapter. ROADMAP's Living Labs revealed that farmers' AMU choices are shaped by economic pressures and social dynamics, emphasising the need for participatory strategies. This is complemented by **the EUPAHW projects SoA15 and SoA20**, which are refining AMU benchmarking indicators and developing farm- and vet-level decision trees to translate policy into practice.

The portfolio also contains a smaller but strategically important focus on anthelmintic stewardship. **SPARC TN** and **COMBAR** addressed this by promoting diagnostics-based, selective deworming, providing tools to reduce the overuse of antiparasitic drugs.

To make stewardship more strategic, **SEFASI** built economic models to evaluate the cost-benefit of different interventions, providing policymakers with evidence to prioritise investments.

A prominent example of how these stewardship principles can be put into action through social innovation and peer-to-peer learning is the **DISARM** project, which successfully translated knowledge into on-farm change.

DISARM (Disseminating Innovative Solutions for Antibiotic Resistance Management)

DISARM (H2020, 2019–2022, €2 million) built a unique multi-country, multi-actor platform to combat antimicrobial resistance (AMR) in livestock farming. Instead of focusing solely on new **technologies, DISARM prioritised behavioural change, peer learning, and practical collaboration.**

Key achievements

- Developed **42 multi-actor farm case studies** across pigs, dairy cows, broilers, and dairy sheep in 9 countries, creating SMART farm action plans that improved biosecurity, animal health, and reduced antimicrobial use (AMU).
- Created a **629-member Community of Practice (CoP)**, an online knowledge-sharing hub connecting farmers, veterinarians, advisors, industry, and researchers to exchange best practices and innovations.
- Built an open-**access database with over 500 entries**, including research papers, innovations, tools, and checklists, to serve as a long-term knowledge repository for the livestock sector.
- **Ran 78 workshops and events** and contributed to **97 external events** across Europe, ensuring wide dissemination and stakeholder engagement despite the challenges of COVID-19.

Why it stands out?

DISARM is a standout success because it went beyond research and **translated knowledge into action**. By combining social and technical solutions, it demonstrated that networking, peer-to-peer learning, and collaborative farm health planning can drive sustainable AMU reductions.
Importantly, it directly tackled the often-overlooked behavioural and social drivers behind AMU, complementing technical innovations with long-lasting, community-driven change.

Long-term impact

DISARM's tools, action plans, and CoP continue beyond the project's funding, with ongoing stewardship by related initiatives like ROADMAP. Its approach offers a replicable model for embedding behavioural change in AMR efforts across the EU and globally.

These projects collectively build a comprehensive ecosystem for AMU stewardship, with key contributions summarised in the table below.

Table 13. Key contributions to AMU stewardship

Project	Key Contribution	Est. TRL	AMR Relevance	Potential Impact
DISARM	Community of Practice, peer-to-peer learning, farm health plans.	Operational (TRL 8–9)	Direct	Shows real-world AMU reductions are achievable through social innovation and better farm-vet collaboration.
ENOVAT	Evidence-based veterinary AMU guidelines (GRADE); diagnostic harmonisation.	Guidelines published (TRL 8)	Direct	Critical for ensuring vets apply consistent, science-backed treatments, reducing unnecessary AMU.
ROADMAP	Systemic analysis of AMU drivers; participatory stewardship frameworks.	Completed (knowledge outputs)	Direct	Reveals socio-economic factors shaping AMU decisions, promoting "bottom-up" stewardship approaches.
SPARC TN	Evidence-based selective deworming strategies, advisory tools for anthelmintic stewardship.	Dissemination phase (TRL 7)	Direct	Provides actionable tools to reduce anthelmintic overuse, helping preserve drug efficacy and farm productivity.
COMBAR	Multi-disciplinary platform and socio-economic analysis of helminth control.	COST Action network (knowledge sharing)	Direct	Advances behavioural change and knowledge transfer for sustainable parasite control.
SoA15 & SoA20	Harmonised AMU benchmarking indicators; farm- and vet-level decision-support tools.	Ongoing (TRL 6)	Direct	Lays groundwork for better monitoring and provides tailored, risk-based treatment guidance.
SEFASI	Economic models to optimise AMU interventions across countries.	Policy tools under development (TRL 5–6)	Direct	Provides evidence-based decision tools for policymakers to balance AMU reduction with economic sustainability.

Source: Compiled by PPMI.

Overall, these projects reflect a broader shift in Europe's AMU stewardship, from a narrow focus on restriction to one driven by better information, more effective tools, and smarter, preventive practices. This means moving away from blanket antimicrobial use toward targeted, evidence-based strategies that align diagnostics, treatment guidelines, and farm management with real-world conditions. It also underscores that social, economic, and behavioural factors are as critical as technical innovations in reducing antimicrobial use. Yet, important gaps remain: many tools are still in early implementation, antiparasitic stewardship continues to lag behind antibiotic stewardship, integration into routine veterinary practice is incomplete, and stronger cross-sectoral coordination is needed to sustain gains across the value chain.

4.5. Practices to reduce AMU (including biosecurity)

While the previous chapter focused on the principles of antimicrobial stewardship, this chapter addresses its most fundamental component: preventing the need for antimicrobials in the first place. This is achieved through practical, on-farm interventions that enhance biosecurity, reduce animal stress, and improve overall farm management. The projects in this cluster are dedicated to developing and promoting these proactive, preventive solutions.

At the heart of this is changing on-farm behaviour. The **DISARM** project tackled this head-on, working directly with farmers and veterinarians through a large Community of Practice to co-develop farm health plans. Similarly, the **NETPOULSAFE TN** took a behavioural approach in the poultry sector, working to strengthen compliance with existing biosecurity rules. These initiatives are complemented by the **BETTER** COST Action, a network focused on enhancing biosecurity through training, evaluation, and raising awareness, tackling the crucial human factors that influence the success of any on-farm practice.

Interview evidence from BETTER highlights that biosecurity improvement programmes must be tailored to farm type and socio-economic context. The network identified a significant need for training in communication and behavioural change for veterinarians and advisors, as changing farmer behaviour is critical but often overlooked. BETTER also developed practical assessment tools and fostered synergies with international bodies like FAO, underlining the value of large, motivated networks for scaling best practices.

Technological tools are crucial for supporting these improved practices. **HealthyLivestock** developed Biosecurity Risk Analysis Tools (BEATs), tested on over 100 farms, and used sensor-assisted detection to promote precision medication. **FARM-CARE** also explored digital tools that detect stress in piglets to identify health risks early, while **BIOPIGEE** developed practical biosecurity checklists and manuals for pig farmers.

A central challenge, highlighted in an interview for this study, is that biosecurity measures are often not sufficiently science-based, and advice can be too generic to be effective across the vast diversity of European livestock systems. There is a critical need for quantifiable data to understand what works where and why. The **BIOSECURE** project was designed specifically to fill this gap by providing an evidence base for biosecurity.

The projects in this cluster provide a range of practical, on-farm solutions, with key contributions summarised in the table below.

EUPAHW's SoA15 blends mechanistic disease models with environmental monitoring tools, showing how combining farm-entry hygiene and all-in/all-out pig flows can cut transmission risks by over 70%. While these findings are still under validation, they point toward a future where biosecurity is not just about barriers but about smart, data-driven interventions.

Finally, the **HE-FARM** project is an initiative focused on enhancing biosecurity and environmental control in livestock farming, targeting pigs, poultry, cattle, and sheep, with the overarching goal of reducing AMU. Its contributions are rooted in developing advanced technologies that enable proactive disease management. This includes the creation of integrated smart fast detectors for airborne pathogens like PRRS and Avian flu, providing rapid, 10-minute results that allow for timely interventions. HE-FARM also innovates in biosecurity methodology and technology by developing a "Biosecurity Channel-resolved Assessment and Monitoring Technology," which supports comprehensive disease prevention. Furthermore, the project addresses environmental hygiene through the development of low-toxicity biocides, green insecticides, and cold plasma water sanitisation. By providing farmers and veterinarians with tools and validated procedures to maintain healthier animal environments and enable early disease recognition, **HE-FARM** directly supports a precision farming approach that reduces disease pressure and, consequently, the need for prophylactic and therapeutic antimicrobials.

Table 14. Key contributions to practices to reduce AMU (including biosecurity)

Project	Key Contribution	Est. TRL	AMR Relevance	Potential Impact
DISARM	Community of Practice, peer-to-peer learning, farm health plans.	Operational (TRL 8–9)	Direct	Shows real-world AMU reductions are achievable through social innovation and better farm-vet collaboration.
BIOSECURE	Biosecurity benchmarking tools; farm-to-farm disease transmission models; new Biocheck.UGent surveys.	Models under development; new tools deployed (TRL 5-7)	Indirect	Identifies priority gaps and provides evidence-based tools for data-driven risk management.
HealthyLivestock	Biosecurity Risk Analysis Tools (BEATs); sensor-assisted disease detection.	Tools validated on 100+ farms (TRL 7-8)	Direct	Provides practical tools and evidence for farm-level biosecurity and precision medication.
FARM-CARE	Stress detection, machine learning-based health monitoring, and hygiene upgrades.	Pilot stage (TRL 5–6)	Direct	Demonstrates potential to cut prophylactic antibiotic use by using digital and practical tools.
NETPOULSAFE TN	Tools for improving biosecurity compliance in poultry.	Deployed on farms (TRL 7–8)	Indirect	Translates recommendations into on-farm behavioural change.
BIOPIGEE	Practical biosecurity manuals and checklists for pig farmers.	Training materials deployed (TRL 7-8)	Indirect	Helps farmers implement science-based hygiene measures through practical, co-developed tools.
BETTER	COST Action network for training, evaluation, and raising awareness in biosecurity.	Network operational (knowledge sharing)	Indirect	Strengthens the human and social dimensions of biosecurity implementation across Europe.
EUPAHW SoA15	Mechanistic disease models for biosecurity and disease spread.	Ongoing (TRL 5-6)	Indirect	Enables proactive disease prevention by quantifying biosecurity efficacy.
HE-FARM	Smart fast detectors for airborne pathogens; Biosecurity channel assessment; Environmental control technologies.	TRL 5-6	Indirect	Enables proactive disease management and improved farm hygiene; reduces disease prevalence and subsequent need for AMU.

Source: Compiled by PPMI.

Overall, the projects in this category show that reducing AMU through improved farm practices is a multi-dimensional challenge. It requires technical innovations: from data-driven biosecurity models to rapid on-farm diagnostics, alongside behavioural change supported by clear, actionable advice and trusted networks. It also depends on system-level enablers such as advisory services, regulatory alignment, and economic incentives. While many tools and strategies are now available, scaling success across Europe remains difficult due to fragmented veterinary services, uneven infrastructure, and regulatory bottlenecks. Achieving meaningful EU-wide AMU reductions will require integrating the best of these technical and social innovations, ensuring farmers have both the means and the motivation to implement lasting change.

4.6. Vaccines

Vaccination is a critical preventive strategy in the fight against AMR. By protecting animals against infectious diseases, effective vaccines reduce the need for antimicrobial treatments, directly supporting the EU's One Health and Farm-to-Fork objectives. The projects in this portfolio vary widely in their stage of development, from early experimental research to commercially advanced candidates, and they contribute both directly and indirectly to reducing AMU in livestock systems.

Several projects are at the forefront of innovating vaccines that could significantly reduce antimicrobial use. The **PARAGONE** project, for example, advanced the development of sub-unit vaccines targeting multicellular parasites, a major driver of anthelmintic use. This initiative is a standout success because it provided one of the first clear proofs that vaccination can effectively substitute for chemical dewormers, as detailed in the infographic below.

Similarly, the **NEOVACC** project is tackling a critical challenge: protecting newborn animals despite the presence of maternal antibodies. By developing novel immunogens and DNA vaccines designed to overcome this barrier, NEOVACC's work is highly relevant for preventing early-life infections that often necessitate heavy antibiotic use.

The **SAPHIR** project designed six vaccine candidates for key livestock diseases (including PRRSV and *Eimeria*), demonstrating that they can be effective even in young animals with maternal antibodies. This is considered a critical limitation of many existing vaccines. The **REPRODIVAC** project adds important advances by developing vaccines for reproductive diseases like *Brucella suis*, aiming to reduce the need for metaphylactic antibiotic use. While these candidates remain in the preclinical phase, they represent an important pipeline of future solutions.

Complementing this work, **the EUPAHW project SoA21** is focused on developing next-generation immunological tools and vaccine platforms. By advancing nano- and micro-particle vaccines, nucleic acid platforms, and novel immune monitoring assays, SoA21 equips researchers with the means to build more robust and durable preventive measures against a wide array of livestock diseases, strengthening the EU's overall non-antimicrobial disease control capacity.

ENVIRE also delivered a significant contribution to the vaccine portfolio by demonstrating the effectiveness of *E. coli* vaccination in reducing antimicrobial resistance in poultry. Through a large-scale field trial involving two broiler flocks of approximately 20,000 broilers each under normal industrial conditions, ENVIRE investigated the effectiveness of *E. coli* vaccination in reducing the prevalence of fluoroquinolone-resistant, colistin-resistant, and ESBL- and pAmpC-producing *E. coli*. The project's findings highlighted a significant difference in ESBL *E. coli* prevalence between vaccinated and

PARAGONE: vaccines for animal parasites

PARAGONE (H2020, 2015–2019) advanced the development of sub-unit vaccines targeting multicellular parasites, particularly Teladorsagia circumcincta in sheep, a key driver of anthelmintic drug use and resistance in European livestock.

Key achievements

- Demonstrated over **50% reduction in parasite burden in field trials using native antigen formulations.**
- Provided **one of the first clear proofs that vaccination can effectively substitute for chemical dewormers**, a major driver of anthelmintic resistance.
- **Established a scalable, sub-unit vaccine platform** adaptable to other major livestock parasites like Haemonchus contortus.
- **Engaged with industry and EU networks** like GLOWORM to amplify knowledge and explore commercialisation pathways.

Why it stands out?

- PARAGONE is a standout success because it **tackled a parallel AMR challenge: rising anthelmintic resistance.**
- By proving that an immunological **alternative to chemical dewormers is feasible**, the project offers a sustainable solution that aligns with EU Farm-to-Fork goals.
- It represents a **blueprint for transitioning livestock systems away from chemical dependency** toward precision, immunology-driven health management.

Long-term impact

- By testing and refining new vaccine formulations, PARAGONE **generated crucial data on protective immune responses, identified promising antigen targets, and created technical roadmaps** for vaccine development and commercialisation.
- These efforts **laid vital groundwork for future parasite vaccines,** supporting sustainable livestock health and reducing reliance on antiparasitic drugs, a cornerstone in combatting anthelmintic resistance and improving animal welfare across Europe.

non-vaccinated flocks. This direct link between vaccination and reduced prevalence of critically resistant bacteria emphasises the potential of preventive measures to decrease the need for antibiotic use in poultry farming, aligning strongly with the EU's Farm-to-Fork and One Health objectives for AMR mitigation.

Finally, the **PIGIE** project contributes to the strategic use of vaccines in animal health by providing crucial knowledge on swine influenza virus (swIAV) dynamics. By actively gathering insights into how vaccination programs influence virus spread in pig herds, PIGIE's research directly informs optimal vaccine deployment strategies. This understanding is vital for preventing swIAV outbreaks and the associated secondary bacterial infections that often necessitate antimicrobial use in pig farming. Therefore, PIGIE's focus on informing effective vaccine interventions indirectly supports the reduction of AMU and contributes to broader AMR mitigation efforts in livestock.

Table 15.Key Contributions to Vaccine Development

Project	Key Contribution	Est. TRL	AMR Relevance	Potential Impact
PARAGONE	Sub-unit parasite vaccines reducing anthelmintic use.	Field tested; production scale-up needed (TRL 6–7)	Direct	Provides one of the first proven alternatives to chemical dewormers, addressing anthelmintic resistance.
NEOVACC	Neonatal vaccines overcoming maternal antibody interference.	Novel immunogens, DNA vaccines; field trials pending (TRL 4–5)	Indirect	Could transform neonatal livestock health, significantly reducing the need for early-life antibiotics.
SAPHIR	Multi-pronged vaccines, DIVA tools, and socio-economic models.	Six candidates; advanced validation; farm relevance shown (TRL 6–7)	Indirect	Lays a strong scientific foundation for reducing antibiotic reliance through improved vaccination strategies.
REPRODIVAC	Vaccines and DIVA diagnostics for reproductive diseases.	Preclinical (TRL 4–5)	Indirect	Aims to reduce metaphylactic antimicrobial use for major reproductive pathogens.
EUPAHW SoA21	Development of next-generation vaccine platforms and immunological tools.	Early stage (TRL 4-5)	Indirect	Strengthens the EU's overall non-antimicrobial disease control capacity through preventive approaches.
ENVIRE	Demonstrated effectiveness of *E. coli* vaccination in reducing the prevalence of ESBL *E. coli* in broiler flocks.	Field-tested (TRL 6-7)	Direct	Provides evidence for effective non-antibiotic intervention; supports reduction of AMR in poultry.
PIGIE	Understanding swIAV dynamics to inform vaccine deployment strategies.	TRL 5	Indirect	Informs optimal swine influenza vaccine use; indirectly reduces AMU by preventing secondary infections.

Source: Compiled by PPMI.

Overall, the vaccine portfolio shows strong alignment with EU One Health and AMR-reduction goals, but it also reveals key challenges:

- Direct AMR impact remains limited: While scientific advances are evident, most projects have yet to demonstrate large-scale, field-level reductions in antimicrobial use.
- Translational bottlenecks: Moving from laboratory success to market-ready, scalable vaccines involves production challenges (especially for recombinant antigens), complex regulatory approval processes, and the need for farmer and veterinarian buy-in.

- Need for integrated strategies: Vaccines are a crucial tool, but they work best as part of a holistic disease management approach that also includes biosecurity, diagnostics, and farm management improvements.
- Policy implications: Continued investment is needed to bridge the gap between promising vaccine innovations and measurable AMU reduction. Regulatory frameworks and financial incentives could play a pivotal role in accelerating deployment.

In summary, while vaccines hold substantial promise for reducing antimicrobial use in European livestock systems, their impact on AMR will depend on scaling scientific breakthroughs into widely adopted, affordable, and integrated solutions.

4.7. Antimicrobials & alternatives to antibiotics

Developing and promoting alternatives to antimicrobials is critical for reducing AMU without compromising animal health, a cornerstone of the EU's One Health Action Plan. The projects in this portfolio explore several distinct innovation pathways, including bacteriophages, plant-derived natural compounds, and novel molecules. While rich in scientific advances, all share a common challenge: translating promising lab-stage results into validated, field-ready solutions that can achieve measurable AMU reductions.

4.7.1. Bacteriophages and biological agents

Several projects have explored bacteriophage-based therapies as a direct replacement for antibiotics. **AVANT**, a Horizon 2020 flagship, piloted phage cocktails, antimicrobial polymers, and immunostimulants, showing strong in vitro pathogen control. However, as noted in interviews with the coordinator, these innovations did not progress to regulatory approval within the project timeline, reflecting a systemic bottleneck in Europe's framework for approving such novel biologicals.

AVANT's coordinator emphasised regulatory gaps, particularly for faecal microbiota transplantation, and noted that alternatives reduce but do not eliminate the need for antibiotics. The root cause of many diseases is animal stress, suggesting that welfare improvements are central to sustainable AMR reduction. Legislative change and consumer education are also needed to support the adoption of alternative interventions.

Similarly, **PHAGOVET, PHAGE-STOP**, and **PHAGE-EX** demonstrated strong proof-of-concept efficacy, achieving up to a 90% reduction in *Salmonella* shedding in controlled trials. Yet, scaling these advances requires clearer regulatory pathways and economic incentives for farmers.

4.7.2. Plant-derived and natural antimicrobials

NeoGIANT stands out as a success story in this area.

The project's approach directly confronts the recognised scarcity of viable, affordable, and farmer-accepted alternatives to traditional antibiotics, advancing its prototypes to TRL 7. NeoGiANT demonstrates a strong commitment to market viability, navigating the complex and often fragmented regulatory landscape that new feed additives and animal health solutions face.

Moreover, the project uniquely embodies circular economy principles by valorising agricultural waste, transforming a significant by-product of winemaking into high-value functional ingredients. NeoGiANT's contributions extend beyond product development; it actively informs the dialogue around evolving animal health and nutrition standards, strategically leveraging intellectual property protection and open-access principles to foster wider adoption and impact within the agri-food and animal healthcare sectors.

NeoGIANT – The Power of Grape Extracts as Antimicrobial and Antioxidant Agents

NeoGIANT (Horizon 2020, 2020–2025) is developing innovative antimicrobial solutions based on grape-derived polyphenols, offering a natural, plant-based alternative to antibiotics for use in pigs, poultry, and cattle.

Key achievements

- **Developed and validated five grape extract-based antimicrobial candidates**, advancing them beyond lab-scale prototypes.
- Demonstrated that these polyphenol-based feed additives and topical formulations could **reduce pathogen loads and improve animal performance parameters** in early trials.
- Proactively delivered regulatory recommendations to the European Commission, **advocating for clearer approval pathways for plant-based antimicrobials.**
- Engaged industrial partners to initiate early-stage commercialisation discussions, **bridging the gap between research and market readiness.**

Why it stands out?

- NeoGIANT stands out because it **addresses a fundamental bottleneck in antibiotic reduction**: the lack of viable, affordable, and farmer-accepted alternatives.
- By showing that natural, plant-based products can offer a promising route to replace or reduce antibiotic use, its **work directly supports the EU's Farm-to-Fork and Green Deal ambitions.**
- The project's active policy engagement and industrial collaboration make it, arguably, **one of the more commercially advanced and policy-relevant initiatives** in Europe's antimicrobial alternatives portfolio.

Long-term impact

- NeoGIANT is **developing natural, effective antimicrobial solution**s from white grape marc by-products.
- The project aims to **bring these advanced prototypes to market** (TRL 7), fostering a significant reduction in conventional antimicrobial use.
- It is **expanding scientific knowledg**e on how host-microbiomes and immune systems interact, leading to breakthrough products such as natural antimastitis syringes and enhanced semen extenders for livestock and fish.

The **PIGSs** project takes a complementary approach by focusing on "next generation probiotics" derived directly from the pig's own microbiota.

This initiative seeks to provide intrinsic solutions for animal health, designed to confer colonisation resistance against specific pathogens like *Streptococcus suis* and support the healthy development and microbiota restoration of piglets, both pre- and post-weaning. It is reported that PIGSs achieved a 40% reduction in *Streptococcus suis* colonisation in piglets using Lactobacillus strains, offering a viable substitute for preventive antibiotics, though large-scale trials and commercial pathways remain to be developed.

4.7.3. Novel Molecules, adjuvants, and drug alternatives

Projects like **CARTNET** and **EUPAHW's SoA19** focus on developing entirely new antimicrobial or antiparasitic compounds. CARTNET's innovation pipeline includes synthetic and natural antimicrobial leads, phage applications, and adjuvants designed to potentiate existing antibiotics. Although these outputs are primarily at early discovery stages, they diversify the European R&I portfolio and lay the groundwork for longer-term AMU reduction. EUPAHW SoA19 is integrating in vitro, in vivo, and in silico approaches to identify promising candidates against resistant veterinary pathogens. However, like CARTNET, most outputs remain in precommercial phases, facing the dual hurdles of regulatory clearance and market cost-effectiveness before they can significantly impact farm-level AMU.

4.7.4. From scientific promise to farm-level impact

Across the portfolio, a consistent theme emerges: while EU research has delivered rich scientific advances, measurable reductions in antibiotic use at the farm level remain rare. Interviews and project reports highlight several systemic barriers, including:

- Regulatory bottlenecks: There is a need for clearer, faster pathways for approving novel antimicrobials, including phages, plant extracts, and microbiota-based interventions
- Integrated farm solutions: Experts call for alternatives being embedded within whole-farm health management strategies, not positioned as stand-alone fixes.
- Economic incentives: Consultations with farmers show that for farmers to adopt alternatives, solutions must be cost-effective, practical, and aligned with value chain incentives or certification schemes.
- Monitoring and evidence generation: Future projects should include field-scale trials capable of generating robust AMU reduction data, critical for scaling impact.

In line with stakeholder interviews conducted as part of this portfolio analysis, it is increasingly clear that the narrative must shift, there is no such thing as *"less antibiotics"* without viable alternatives. While EU R&I frameworks have made important strides in developing these innovations, the next critical phase must focus on translational support, regulatory innovation, and practical incentives to drive real-world adoption. Only then can alternatives meaningfully displace antibiotics in veterinary medicine.

5. Contribution to EU policy objectives

This analysis assesses how 52 EU-funded R&I projects in the veterinary AMR domain contribute to three key European Commission policy frameworks:

- the Common Agricultural Policy (CAP) 2023–2027,
- the Farm-to-Fork Strategy, and
- the European One Health Action Plan Against Antimicrobial Resistance (AMR).

The full mapping is presented in the Annex, cross-referencing each project's outputs to specific policy objectives.

5.1. One Health Action Plan

The portfolio shows a strong alignment with the European One Health AMR Action Plan, particularly the first pillar: making the EU a best-practice region through improved evidence, coordination, surveillance, and control measures. Many projects, notably DISARM, BIOSECURE, ENOVAT, the EUPAHW cluster, and One Health EJP, directly contribute to these objectives by enhancing AMR surveillance systems, developing harmonised diagnostic tools, and strengthening data integration across sectors. Importantly, these efforts not only advance scientific understanding but also generate practical outputs that can inform veterinary guidelines, national monitoring programs, and EU-level coordination frameworks, reinforcing the systemic capacity to manage AMR risks.

A smaller but strategically important subset of projects, including NEOVACC, SAPHIR, REPRODIVAC, AVANT, and NeoGIANT, contributes to the second pillar of the Action Plan: boosting research and innovation. These projects address critical knowledge gaps by developing new vaccines, novel antimicrobial alternatives, and emerging therapies like phage-based treatments. Their work is vital for diversifying the toolbox available to reduce AMU in livestock, supporting long-term solutions that move beyond reliance on traditional antibiotics.

However, there is relatively limited portfolio engagement with the third pillar: intensifying EU efforts to shape the global AMR agenda and mitigate international risks. Few projects focus explicitly on outward-facing objectives, such as global surveillance harmonisation, cross-regional policy coordination, or Europe's role in international AMR governance. This gap suggests that while the current portfolio is strong in supporting Europe's internal capacity, it leaves room for future R&I activities to better position the EU as a global leader on AMR - an area of increasing importance given the transboundary nature of antimicrobial resistance.

5.2. Farm-to-Fork Strategy

The portfolio aligns strongly with the Farm-to-Fork Strategy, particularly through its direct contributions to achieving the 50% reduction target in sales of antimicrobials for farmed animals and in aquaculture by 2030. This is primarily driven by projects focusing on upstream interventions at the farm level, which ultimately reduce the need for AMU. Projects such as HealthyLivestock, BETTER, BIOSECURE, DISARM, and SPARC TN develop tools, technologies, and practices that improve animal health, enhance biosecurity, and provide alternatives to antimicrobials. These interventions are critical because they directly support the Farm-to-Fork Strategy's goal of building more resilient and sustainable production systems, with tangible benefits for both animal and public health by reducing antimicrobial dependency.

The portfolio's contributions are largely concentrated at the primary production stage, aligning with its core mandate to reduce AMU, which is predominantly addressed at the farm level. While the Farm-to-Fork Strategy encompasses the entire food chain, this AMR R&I portfolio presents a potential opportunity for future integrated research that could explore how animal health innovations can synergise with broader food system objectives, fostering value-chain-wide approaches to sustainability beyond direct AMU reduction. This approach opens the door to engaging more with downstream aspects such as sustainable processing, distribution, or consumption patterns, or broader challenges like food loss and waste.

5.3. Common Agricultural Policy (CAP)

The portfolio's alignment with the Common Agricultural Policy (CAP) 2023–2027 relates mainly to CAP objective 9, which aims to improve the response of EU agriculture to societal demands on food and health, with a focus on combating antimicrobial resistance. Projects such as DISARM, BETTER, and COMBAR play a clear role in generating knowledge, developing innovative practices, and facilitating knowledge exchange between researchers, farmers, and advisors. Others, like FARM-CARE and FED-AMR, also contribute indirectly to environmental objectives by addressing the ecological dimensions of antimicrobial resistance and promoting sustainable farming practices that reduce environmental contamination.

The portfolio primarily focuses on addressing AMR in the veterinary domain, while other projects outside of this portfolio work towards the CAP's broader socio-economic goals, such as ensuring a fair income for farmers, increasing competitiveness, strengthening farmers' positions in the food chain, or supporting generational renewal and vibrant rural areas. Most projects in this portfolio are designed as technical or biological R&I initiatives, focusing on improving animal health, reducing AMU, or advancing diagnostics and surveillance, rather than addressing market, policy, or socio-economic drivers, in a more holistic approach. Moreover, the issue of translating research outputs into tangible economic benefits for farmers or rural communities was rarely emphasised in final reports or interviews, suggesting that this dimension remains underexplored.

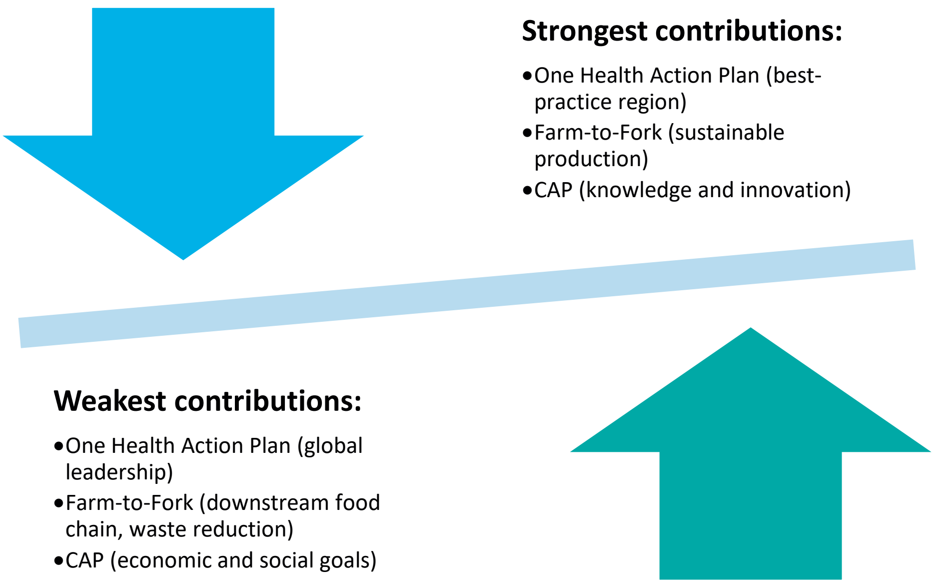
Looking ahead, there is an opportunity to expand future research efforts on AMR to address CAP priorities beyond knowledge generation. For example, by integrating socio-economic research, strengthening the co-design of solutions with farmers to improve competitiveness, or exploring how AMR-focused innovations can support rural vitality and resilience. Strengthening these links would help ensure that veterinary AMR research not only delivers technical solutions but also contributes meaningfully to the broader sustainability and economic goals set out under the CAP.

5.4. Potential gaps and unexplored opportunities

Several cross-cutting gaps emerged from the analysis:

- Behavioural change integration: While many projects develop technical tools, fewer robustly address the behavioural or social uptake of AMU reduction strategies, an issue raised in interviews (e.g., DISARM, HealthyLivestock).
- Scalability and translation: Some promising innovations still face regulatory or market barriers, limiting their farm-level impact (e.g., AVANT, NeoGIANT).
- Socio-economic and rural impacts: while socio-economic and rural development aspects are already addressed in other EU-funded projects, there remains scope for AMR-focused initiatives to engage more systematically with these dimensions. Incorporating more interdisciplinary research that integrates social sciences could strengthen the contribution of AMR projects to wider CAP themes, such as rural vitality, generational renewal, and competitiveness, while maintaining their core focus on animal health and antimicrobial use.

This visual below highlights the differences in distribution of portfolio contributions across EU policy objectives, with clear strengths in building Europe's best-practice capacity for AMR surveillance and promoting sustainable farm-level production, but notable weaknesses in areas like global leadership, downstream food system innovation, and the economic and social goals of the CAP. While the portfolio offers a robust technical foundation, the imbalance suggests potential untapped opportunities to broaden future research agendas. This could include integrating socio-economic dimensions, post-farm value chain actions, and international coordination to fully support Europe's comprehensive AMR and agri-food strategies.



This assessment provides an evidence-based foundation for the European Commission to inform future research planning, shape upcoming European Partnerships, and respond to policy and parliamentary needs regarding the impact of veterinary AMR research.

6. Conclusions

This case study delivers the first comprehensive analysis of 52 EU-funded R&I projects focused on AMR in the veterinary domain, addressing an urgent One Health challenge with far-reaching public and animal health, environmental, and economic implications. Drawing on desk research, portfolio categorisation, project document review, and ten targeted interviews, the analysis assessed the outcomes, potential impacts, and gaps across projects, situating them within the broader objectives of key EU policy frameworks and recent political priorities, including the Farm-to-Fork Strategy (part of the Green Deal), the CAP, the EU One Health AMR Action Plan, and the 2023 Council Recommendation on AMR.

The analysis shows that the portfolio is technically diverse and policy relevant. Projects are spread across eight thematic focus areas, from surveillance and diagnostics to vaccines, biosecurity, stewardship, and the development of alternatives to antimicrobials, addressing directly or indirectly AMU/AMR. Together, they offer a robust contribution to reducing AMU in livestock, advancing technical solutions, and supporting evidence-based policy and regulatory frameworks. Notable success stories mentioned in the analysis under chapter 4 demonstrate how combining technical innovation with behavioural change and peer learning can achieve measurable impact on AMU reduction at the farm level.

Contributions to the Farm-to-Fork Strategy are strongly concentrated on upstream, farm-level production, which directly supports the target to reduce by 50% the sales of antimicrobials for farmed animals. However**,** the portfolio shows comparatively less engagement with other Farm-to-Fork dimensions, such as sustainable processing, distribution, or broader circular economy principles**.** This targeted focus, while effective for direct AMR impact, also highlights areas where future R&I initiatives could explore greater cross-policy coherence and integration to avoid fragmentation or duplication of effort with broader food system sustainability objectives.

Under the CAP, the portfolio contributed directly to CAP specific objective 9, which aims to improve the response of EU agriculture to societal demands on food and health, with a focus on combatting antimicrobial resistance. However, it rarely tackles CAP's broader socio-economic objectives, such as improving farm competitiveness, income, or rural vitality. R&I play a vital role in strengthening the knowledge base and developing innovations that better connect technical advancements to socio-economic uptake, behavioural change, and market integration that work hand in hand with CAP instruments, such as AKIS to link R&I with potential users. Strengthening both R&I and CAP relevant tools would help maximising the added value of R&I investments in addressing AMR challenges under a One Health approach.

The interviews added crucial insight, highlighting challenges in translating research into practice, regulatory barriers to innovation scaling, and gaps in behavioural integration and stakeholder engagement. Moreover, several underexplored areas emerged, including environmental AMR transmission, parasite resistance, and market mechanisms for incentivising AMR-related innovations.

Overall, this case study shows that veterinary AMR research in the EU is making substantial contributions to scientific progress and policy goals, but also points to potential opportunities for future improvement. Strengthening interdisciplinary collaboration, embedding socio-economic dimensions, expanding food system integration, and reinforcing Europe's outward-facing leadership will be essential for maximising the long-term policy impact of future R&I investments. These findings will inform the European Commission's planning for upcoming initiatives, including the European Partnership on Animal Health and Welfare and the planned European Partnership on One Health AMR, as well as contribute to broader EU efforts to tackle AMR as part of the One Health agenda.

7. Annex: Detailed mapping of portfolio's contributions to EU policy objectives

The mapping of project contributions was conducted against the specific objectives outlined in three key European Commission policy frameworks:

1. Common Agricultural Policy (CAP) 2023-2027

The CAP aims to support sustainable agriculture and rural development through the following objectives:

- To ensure a fair income for farmers.
- To increase competitiveness.
- To improve the position of farmers in the food chain.
- To take action on climate change.
- To promote environmental care.
- To preserve landscapes and biodiversity.
- To support generational renewal.
- To foster vibrant rural areas.
- To protect food and health quality.
- To foster knowledge and innovation.

2. Farm-to-Fork Strategy

The Farm-to-Fork Strategy provides a comprehensive approach to sustainable food systems with the following objectives:

- Sustainable food production.
- Sustainable food processing and distribution.
- Sustainable food consumption.
- Prevention of food loss and food waste.

3. European One Health Action Plan Against Antimicrobial Resistance (AMR)

This plan emphasises a collaborative approach to combat AMR with three core pillars:

- Making the EU a best-practice region by improving evidence, coordination, surveillance, and control measures.
- Boosting research, development, and innovation to address knowledge gaps and develop novel solutions and tools.
- Intensifying EU efforts to shape the global agenda on AMR and mitigate related risks.

These objectives serve as the foundation for evaluating the contributions of the project portfolio, ensuring alignment with EU policy priorities and strategic goals.

Project Name	Concrete Contributions/Examples	One Health Action Plan Objectives	Farm-to-Fork Objectives	CAP Objectives
1. DISARM	Community of Practice, 42 farm case studies, peer learning for AMU reduction	Best-practice region (evidence, coordination)	Sustainable food production (on-farm practices)	Foster knowledge and innovation (farmer networks)
2. NETPOULSAFE TN	Poultry-specific biosecurity compliance tools, farm advisory	Best-practice region	Sustainable food	Foster knowledge and

		(biosecurity improvements)	production (biosecurity)	innovation (advisory services)
3. HE-Farm	Biosecurity innovations, farm management strategies to reduce AMU	Best-practice region (improved biosecurity)	Sustainable food production (better farm practices)	Promote environmental care (sustainable farm management)
4. SPARC TN	Tools for targeted anthelmintic use, AR surveillance in grazing systems	Best-practice region (surveillance, control)	Sustainable food production (parasite management)	Promote environmental care (reduced drug impact on ecosystems)
5. AVANT	Alternative therapies: FMT, phage, symbiotic products for pigs	Boost R&I (novel solutions)	Sustainable food production (reduce antibiotic reliance)	n/a
6. NeoGIANT	Natural compound alternatives, grape marc feed additives	Boost R&I (alternative antimicrobials)	Sustainable food production (reduce AMU)	n/a
7. VIVALDI	Rapid diagnostics (VETPOD), zoonotic pathogen tools	Boost R&I (rapid diagnostics)	Sustainable food production (food safety)	n/a
8. PHAGOVET	Phage-based *Salmonella* reduction, feed additives for poultry	Boost R&I (phage innovation)	Sustainable food production (reduce AMU)	n/a
9. REPRODIVAC	Vaccines and diagnostics for reproductive diseases, DIVA tests	Boost R&I (vaccine innovation)	n/a	n/a
10. HealthyLivestock	Sensor technologies, stress reduction to reduce AMU in pigs, poultry	Best-practice region (improved AMU practices)	Sustainable food production (animal health)	n/a
11. Paragone	Anti-parasite vaccines for helminth control	Boost R&I (vaccine innovation)	Sustainable food production (parasite control)	Promote environmental care (pasture management)
12. SAPHIR	Multi-pathogen vaccines, AMU reduction	Boost R&I (vaccine development)	n/a	n/a
13. PIGSs	Probiotics, diagnostics for *Streptococcus suis*, piglet interventions	Boost R&I (probiotic innovation)	Sustainable food production (reduce AMU)	n/a
14. COMBAT	Integrated vector control, trypanosomiasis risk mapping	Best-practice region (vector-borne disease control)	n/a	Promote environmental care (ecosystem management)
15. DECIDE	Decision-support dashboards using slaughterhouse data for AMU tracking	Best-practice region (surveillance,	Prevention of food loss	n/a

			decision support)	(disease prioritization)	
16.	VETBIONET	BSL-3 infrastructure, harmonised diagnostics	Best-practice region (diagnostic capacity)	n/a	n/a
17.	BIOSECURE	Biosecurity cost-benefit tools, benchmarking models	Best-practice region (biosecurity practices)	Sustainable food production (farm risk assessment)	n/a
18.	HE-Farm	Farm hygiene, welfare, AMU reduction	Best-practice region (biosecurity practices)	Sustainable food production (improved hygiene)	n/a
19.	IMPART	Harmonised AST, ECOFFs, diagnostics	Best-practice region (diagnostic standards)	n/a	n/a
20.	ARDIG	Harmonised genomic surveillance, cross-sectoral data pipelines	Best-practice region (genomic surveillance)	n/a	n/a
21.	RADAR	Source attribution, risk modelling	Best-practice region (risk assessment)	n/a	n/a
22.	FARMED	Field-ready metagenomics, rapid diagnostics	Boost R&I (diagnostic innovation)	n/a	n/a
23.	FULL-FORCE	Plasmid mobility mapping, surveillance tools	Boost R&I (genetic mobility research)	n/a	n/a
24.	WORLDCOM	Comparative genomics, LAMP-based diagnostics	Boost R&I (genomic tools)	n/a	n/a
25.	FED-AMR	Environmental AMR pathways, exDNA models	Best-practice region (environmental monitoring)	n/a	Promote environmental care (environmental AMR tracking)
26.	BIOPIGIE	Pre-/probiotics for piglets, AMU reduction strategies	Boost R&I (probiotic innovation)	Sustainable food production (reduce AMU)	n/a
27.	MoMIR-PPC	Microbiome markers, "super-shedder" profiling	Best-practice region (microbiome research)	n/a	n/a
28.	SoA8 (EUPAHW)	Veterinary breakpoints, harmonised AST	Best-practice region (harmonised testing)	n/a	n/a
29.	SoA11 (EUPAHW)	Pathogen-host detection, AMR markers	Best-practice region (improved detection)	n/a	n/a

30. SoA12 (EUPAHW)	Harmonised diagnostics for respiratory diseases	Boost R&I (respiratory diagnostics)	n/a	n/a
31. SoA15 (EUPAHW)	Disease models, environmental monitoring	Boost R&I (disease modelling)	n/a	n/a
32. SoA18 (EUPAHW)	Host-microbiome AMR mechanisms, immune response	Boost R&I (host-microbiome research)	n/a	n/a
33. SoA19 (EUPAHW)	Novel antimicrobials, environmental profiles	Boost R&I (drug discovery)	n/a	n/a
34. SoA21 (EUPAHW)	Vaccine platforms, immunological surveillance	Boost R&I (vaccine innovation)	n/a	n/a
35. ENVIRE	Integrated AMR/AMU surveillance, *E. coli* vaccines	Best-practice region (environmental AMR control)	n/a	Promote environmental care (environmental protection)
36. SEFASI	Systems modelling, scenario planning for AMR interventions	Best-practice region (policy modelling)	n/a	n/a
37. Phage-Stop AMR	Phage proteins for AMR gene containment	Boost R&I (phage protein tools)	n/a	n/a
38. Phage-EX	Phage therapy for MRSA/*E. coli*	Boost R&I (phage therapy)	n/a	n/a
39. ICONIC	Ionophore-linked resistance, risk assessment, EU Chemicals Strategy	Boost R&I (chemical resistance research)	n/a	n/a
40. FARM-CARE (JPI-EC-AMR)	Farm hygiene, AMR gene prevalence, stress reduction	Best-practice region (farm-level AMR reduction)	n/a	Promote environmental care (farm practices)
41. NEOVACC	Vaccine platforms for neonates	Boost R&I (vaccine platform innovation)	n/a	n/a
42. PIGIE	Swine influenza vaccine platform	Boost R&I (swine vaccines)	n/a	n/a
43. TechPEPcon	Environmental/clinical diagnostics, Healthy Climate Monitor	Boost R&I (diagnostic tech)	n/a	n/a
44. METABOL-AR	Metabolite-based diagnostics, field validation	Boost R&I (anthelmintic diagnostics)	n/a	n/a
45. HARTEMIS	Anthelmintic resistance diagnostics, CRISPR tools	Boost R&I (genetic tools for resistance)	n/a	n/a
46. ANTHELMOGRAM	High-throughput AR phenotyping, marker discovery	Boost R&I (anthelmintic phenotyping)	n/a	n/a
47. BM-Farm	Biomarker/microbiome risk profiling, AMU early warning	Best-practice region (risk profiling)	n/a	n/a

48. Biosens4PrecisionMastitis	Biosensor diagnostics for mastitis, precision AMU	Boost R&I (biosensors for AMU)	n/a	n/a
49. COMBAR	Socio-economic analysis of helminth control, farmer tools, white paper	Best-practice region (parasite control)	n/a	Promote environmental care (pasture management)
50. BETTER	Biosecurity network, training toolkit, tailored improvement	Best-practice region (biosecurity systems)	Sustainable food production (improved practices)	Foster knowledge and innovation (biosecurity training)
51. ENOVAT	Harmonised diagnostics, GRADE-based veterinary guidelines	Best-practice region (veterinary guidelines)	n/a	n/a
52. CARTNET	Microbiome research training, novel antimicrobials	Boost R&I (microbiome research)	n/a	n/a

Source: Compiled by PPMI.

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